COGNITIVE ASPECTS OF SEMANTIC DESKTOP TO SUPPORT PERSONAL INFORMATION MANAGEMENT

by

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DECLARATION

I declare that the Master Thesis entitled: *Cognitive Aspects of Semantic Desktop to Support Personal Information Management* is my own original work, and hereby certify that unless stated, all work contained within this thesis is my own independent research and has not been submitted for the award of any other degree at any institution, except where due acknowledgment is made in the text.

ERKLAERUNG

Mit der Abgabe die Diplomarbeit mit dem Thema: *Cognitive Aspects of Semantic Desktop to Support Personal Information Management*, versichere ich, dass ich selbststndig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe. Die Stellen, die anderen Werken dem Wortlaut oder dem Sinn nach entnommen wurden, habe ich durch die Angabe der Quelle, auch der benutzten Sekundrliteratur, als Entlehnung kenntlich gemacht.

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As the main supervisor of the candidate's graduate committee, at the University of Osnabrueck, I have read the dissertation of Danish Nadeem in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures and tables are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university record.

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As the close mentor of Danish Nadeem at German Research Center for Artificial Intelligence, I have closely monitored the thesis progress from time to time with feedback and suggestions.

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ABSTRACT

Better Knowledge Management enhances our efficiency of work and gives satisfaction. Personal Information Management (PIM) tools support augmented productivity of user in an organizational role. The research for developing standard metrics to capture, understand and model user requirements needs high attention, the thesis focuses on Cognitive considerations of Personal Information Management and evaluating the Semantic Desktop: Gnowsis , looking up for a standard "utility function" based on user's PIM behaviour and derive standard evaluation methods. A number of cognitively adequate design methodologies have been explored and suggested for developing user-centred Semantic Desktop.

The thesis critically views different Philosophical theories in order to realize their application in Semantic Desktop prototypes. The theory of Mental Models is explored and its characteristics are elicited as an analytic tool to understand peoples behaviour for organising their personal information. Mental Model has been revisited to understand how people represent their mental images, assumptions and real-world concepts. Moreover, its possible application is suggested for the Semantic Desktop. The current status of the Semantic Desktop evaluation for PIM support is still in its infancy, there are not many publications, which implies that the work in this direction demands high research attention to claim the usability of the Semantic Desktops. The thesis is an initiative to bring an attention on usability issues of the Semantic Desktop from Cognitive Science point of view. The research has been conducted within the Gnowsis prototype, being developed at DFKI. Several approaches are being taken to the date to study PIM. But study of PIM behaviour within the Semantic Desktop framework would be a novel approach. In this work we explore several evaluation criteria which are to be tested for the Semantic Desktop developments. The thesis concludes with suggestions on formalizing Mental Models and the evaluation scenarios of the Semantic Desktop prototypes.

ACKNOWLEDGMENTS

> *The proper and immediate object of science, is the acquirement, or communication, of truth[...]* - Samuel Taylor Coleridge, Definitions of Poetry, 1811

This research is done in requirements for the partial fulfillment of the Masters in Cognitive Science, It begun while I started working with the Semantic Desktop group at the Knowledge Management Lab of German Research Center for Artificial Intelligence (Deutsches Forschungszentrum fuer Kuenstliche Intelligenz GmbH, DFKI), within the context of NEPOMUK Social Semantic Desktop project.
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Chapter 1

An Introduction

"I know it's here somewhere,' was lame enough when "here" is a PC with an 80 GB or 120 GB hard disk hiding dozens of folders, thousands of files and tens of thousands of e-mail messages and attachments, it's an admission of defeat." [66]

-Eric Grevstad (Win Planet) in a review of 'Scopeware Vision'.

Knowledge is inextricably bound up with human cognition. The way people behave at work are central to organizational effectiveness. Therefore, it is important to fully understand the cognitive aspects of how knowledge is acquired and shared at work before deciding how to conduct Knowledge Management [21].
After the inception of Computer technology, its usability has been a constant issue of research investigation within various disciplines. Many fields have thus gradually originated from the branches of computer science and created its own independent field of study. Human-Computer Interaction (HCI) being one of them has formed the integration of other closely related disciplines such as human factors, ergonomics, multimedia and cognitive psychology. There have been some major paradigms that had discriminated in its evolvement:

1. personal computing
2. cooperative computing
3. social computing.

The first paradigm is the Personal Computing with its user-system relations. With the implementation of the networked (connected) computers, the second paradigm is realized as cooperative computing via rich interactive multimedia. This advances into the third paradigm, social computing paradigm with community mediated interaction, with applications for Computer Supported Cooperative Work (CSCW) (see Section 1.8) and the Internet with its communities. Since the last decade Internet and computing technologies have taken a new vision to revolutionize mobile, nomadic and ubiquitous technology with focus on personalized and intimate interaction.

Within the scope of the current thesis we limit our discussion to the single-user interaction with a computer. Now, from a single user perspective the term Personal Information Management (PIM) is a day to day task that a PC user performs. PIM is a user behaviour towards acquiring information (see Section 1.5). Moreover PIM behaviour is highly decentralized, the point of interests would be to know how such a decentralized knowledge management is supported by existing tools. PIM as a field is maturing in growing research interests. It is reported that PIM as a field of study, provides a good meeting ground and area of application for the work of several different disciplines including information retrieval, database management, artificial intelligence, human-computer interaction and cognitive science [57]. This chapter gives an overview of the thesis structure. This chapter provides broader overview of current research efforts in personal and social computing within the realm of Semantic Web technologies. A formal definition of PIM is given, and the overall context in which the thesis is written would be the major issue addressed in general.

1.1 Research Motivation

One of the characteristic features of human nature is to accumulate and collect information. With the advent of computer systems such behaviour could be realized with the support of tools like file managers, email clients and (Web) browsers. Although current technology has been able in providing tools for organizing user's resources but they are rather distinct to support distributed nature of users PIM activity. Overheads of PIM adversely affect both productivity and user satisfaction in their digital ambience.

With the plethora of tools available to organise the users personal resources (email, files, bookmarks etc.), what is still missing is a user-centered software, which takes care of users' distributed PIM activity and support flexible personalization according to her Mental Model[1].

To realize this technically we have a vision from Tim Berners-Lee, who invented the Semantic Web, formed a non-profit consortium called the World Wide Web Consortium (W3C) that by promoting interoperability and encouraging an open forum for discussion that ultimately lead to the technical evolution of the Web by its three design principles of interoperability, evolution, and decentralization (W3C, 1999). The Semantic Web technology [10] provides standards for the definition and exchange of metadata and ontologies. RDF[2]) framework identifies relations between data and different types of data. The Semantic Desktop [104] technology allows users to organize, manage and present their information in a customized flexible environment. This personalization is possible in Semantic Desktop environment as users can gain direct access to the different types of underlying information and control how it is presented for themselves [30].

[1]Mental Model is discussed in Section 3.4

[2]http://www.w3.org/RDF/

The following discussion identifies the motivation for this thesis more precisely. In our literature search we have found that the usability of the Semantic Desktop has not been extensively reported. In this respect, we don't know how a user (knowledge worker) could benefit from the Semantic Desktop's interesting claims. We also don't know which task could be performed by a user to exploit the features provided by the Semantic Desktop tools in order to organise her personal information. Finally and most importantly, how could a user's world-view reflected in the Semantic Desktop: *Mental Model*.
Thus the thesis is an initiative to address the usability issues of the Semantic Desktop prototypes. In this respect, we sketch the following list of questions which should be able to serve as the litmus test to understand the usability issues of the Semantic Desktop.
Some of the important cognitive considerations which should be identified with the Semantic Desktop are as follows:

- Does the Semantic Desktop minimize information overload by providing enhanced support to perform daily tasks of a knowledge worker?
- Does it help in organising (personal)information, the way we think with respect to our working context?
- Is it able to formalize our Mental Models?
- Can we query our personal information resources with the help of the Semantic Desktop prototypes to know our meetings, schedules and tasks?

Based on the above questions the work in this thesis has made an overview of current state of literature, addressing the issues of similar interests.

1.2 Pre-requisite literature

It is recommended to the readers to review the following literature in order to follow the ideas described in this thesis.

1. Boardman Phd Thesis *Improving Tool Support for Personal Information Management* [11]. The work has been an excellent effort till date to address the current issues and challenges of PIM.
2. Relevant Philosophical topics like Computational thinking, Classical theories of Artificial Intelligence are taken from the Encyclopaedia of Cognitive Science [34].
3. RDF Primer [3].

[3]http://www.w3.org/TR/rdf-primer/

4. Technical report of Personal Information Model (PIMO-draft) by Leo Sauermann [103].

5. Report on the NSF PIM Workshop, January 27-29, 2005, Seattle [56]. This report is based on the workshop to bring together 30 acknowledged leaders from various disciplines (e.g. information retrieval, database management, information science, human-computer interaction, cognitive psychology and artificial intelligence) involved in PIM-related research as a step towards building a more integrated community of PIM research.

1.3 Structure of thesis

An overview of thesis structure is shown in the Figure 1.1. The thesis starts with the

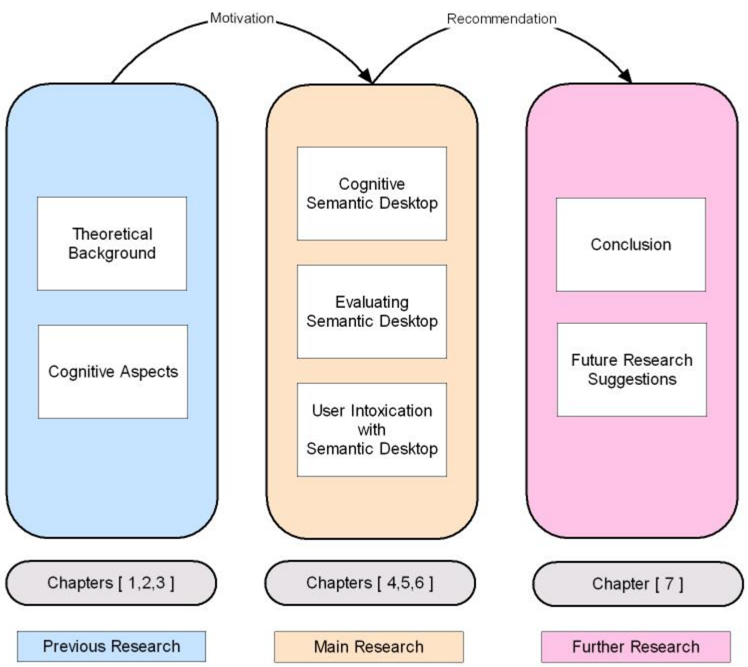

Figure 1.1 Overview of Thesis Structure

background research and studies of earlier work, as described in Chapter 1, Chapter 2 and Chapter 3. The main research and the contributions of this thesis is to bring the ideas relevant to the Semantic Desktop development, this is described in Chapter 4, Chapter 5 and Chapter 6, finally in Chapter 7 a conclusion is derived with further recommendations and guidelines for the Semantic Desktop development. The work in this thesis proposes a need to further explore the usability of the Semantic Desktop, the research in this direction is currently in its infancy and needs high attention.
It has been discussed with my research advisor during the initial stage of the thesis to

provide a kind of scale that defines the thesis content clearly. This idea is realized in the Figure 1.2. It is also considered as a good idea for the readers to get a snapshot of the contents. In the given thesis the degree of technicality varies with respect

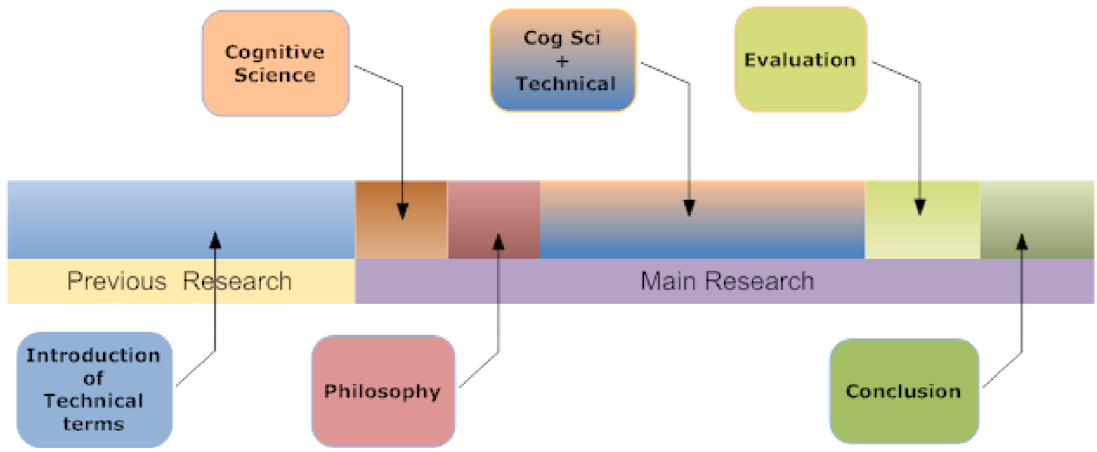

Figure 1.2 Contents of thesis represented over scale

to chapters, in the beginning some technical terms are introduced, which are re-iterated in the scope of thesis. Later, Cognitive Science and Philosophy comes into discussion. As the main research direction of the thesis, an attempt is made to merge the theories of Cognitive Science to the current technical efforts of the Semantic Desktop community. Further, the work focusses on the Semantic Desktop evaluation and finally conclusions are derived with remarks on future research.

1.4 Personal Semantic Web

Called the Semantic Web, this new technology is designed to improve communications between people using differing terminologies, to extend the interoperability of databases, to provide tools for interacting with multimedia collections, and to provide new mechanisms for the support of science. With the involvement of scientists in its design, application, and dissemination, the Semantic Web will be able to provide infrastructural support for a revolution in interdisciplinary "e-science." [...] However, to realize this potential, scientists and information technologists must forge new models of cooperation, and new thinking must go into the funding and dissemination of this next generation of scientific tools on the Web.

- James Hendler, Science and The Semantic Web, Science, Jan 24, 2003 [46].

One of the main themes of this thesis is to highlight the benefits of Semantic Web for Personal Information Management. Personal information like Agendas, Address books, Bibliographies has several advantages with regards to the semantic web, this was highlighted in the Bristol meeting debate[4] on Personal Information Management and the Semantic Web:

- it can be found in great quantities over the web;
- it is structured (and relatively standardized);
- people are not shy at inputting it;
- it is yet difficult to search on the web.

Semantic Web should provide technical means in dealing with personal information (PIM).

1.5 PIM Definition

Personal Information Management (PIM) refers to both the practice and the study of the activities people perform in order to acquire, organize, maintain and retrieve information for everyday use [56]. One ideal of PIM is that we always have the right information in the right place, in the right form, and of sufficient completeness and quality to meet our current need. Tools and technologies help us spend less time with time-consuming and error-prone actions of information management (such as filing). We then have more time to make creative, intelligent use of the information at hand in order to get things done.

This ideal is far from the reality for most people. A wide range of tools and technologies are now available for the management of personal information. But this diversity has become part of the problem leading to information fragmentation. A person may maintain several separate, roughly comparable but inevitably inconsistent, organizational schemes for electronic documents, paper documents, email messages and web references. The number of organizational schemes may increase if a person has several email accounts, uses separate computers for home and work, uses a PDA or a smart phone, or uses any of a bewildering number of special-purpose PIM tools [57].

There could be many interpretations of Personal Information, in order to have a proper definition of PIM which is discussed in this thesis, we studied Richard Boardman approach in his dissertation [11] to understand the conceptual background of the theme Personal Information Management. A formal, step-by-step and elaborated definition of PIM is given in Boardman's thesis. Based on the definition of his thesis context, this thesis also derives the following definition excluding all other possible ambiguous interpretations.

- Thus we first define *Personal Information*: The information that a person acquires, owns, stores on his or her personal computer. This implies organization of digital personal information collected by the user, which includes, for example

[4] http://www.w3.org/2001/sw/Europe/200210/calendar/SyncLink.html

e-mails, music files, pictures, videos, contacts, and web bookmarks etc, which are owned by a person and are personal to her. The information is directly under user's control and management. This may or may not include information about user itself, like curriculum vitae, personal-webpage, weblogs etc. It is the user who decides what she considers her personal information on a computer.

- Further, we define *Personal Information Management*: Personal Information Management (PIM) is management of personal information which is performed by the owning individual. PIM describes the procedure, how every single person deals with her everyday information: how it is collected, stored, organized and retrieved [45, 11]. People manage their information not only to make it more easily to be found later, but also to remind themselves of their tasks. The methods and tools for doing PIM may be of a user's own devising, or they may be standard tools such as email clients, operating systems, or paper calendars and organizers. The tools and methods are that support computer based PIM activities are the main concern of the thesis. One ideal of PIM is that we always have the right information in the right place, in the right form, and of sufficient completeness and quality to meet our current needs. Tools and technologies help us spend less time with time-consuming and error-prone actions of information management. We then have more time to make creative and intelligent use of the information at hand in order to get things done [71]. We have to see how far the Semantic Desktop supports PIM activities, this we will learn from evaluation.

Dominik Heim in his thesis *Semantic Wikis in knowledge management - Evaluating the Gnowsis approach* [45] has identified some of the important questions. These questions are of vital importance with respect to types of (personal) information that a user interact in her daily life.

1. Which information should be gained? : A User could have many interests which increases her daily information experience. It is yet to be known which information are worth to be filed or thrown away immediately. Off course disk-memory are getting cheaper with time and user has no tendency to delete information, this has a side effect in piling up information and losing the valuable information when needed.

2. How should the information at hand be organized? : People file information according to their context and own personal requirements, roles, urgency etc. we need to know how information is organised, Is "'semantic-way"' is an ideal solution.

3. Is a piece of information worth to be organized? : Decision about information's worth or value is crucial, if we don't make the organising decision when encountering information we may pay the cost in re-finding [54, 32]

4. Which piece of information is no longer needed and can be thrown away?

5. How to retrieve a certain piece of information within the existing one?

The questions come in many forms towards addressing PIM activities. In this context, Indratmo et.al [50] proposed some of the important requirements for Personal Information Management as follows:

- support information organization
- support for maintaining context and retrieval cues
- tackling information overload
- support for interoperability between individuals and organizations

This should also include the point that context and semantic should be preserved in current approaches to PIM based prototypes developments. At present PIM research has gained increased attention, according to the NSF Report on PIM workshop 2005 [57] the latest issues of research in PIM are highlighted as follows:

1. Examining what PIM is as a field of inquiry. What should it encompass?

2. Determining what good and better PIM looks like. How do we measure?

3. Establishing key problems and challenges that must be met if we are to make progress in PIM.

4. Identifying promising approaches to PIM (that may meet these challenges).

5. Fostering a research community for the field of PIM inquiry.

The next section introduces the Semantic Desktop as a framework to support PIM, while keeping in considerations the challenges we discussed in the previous sections.

1.6 Semantic Desktop

> *A Semantic Desktop is a device in which an individual stores all her digital information like documents, multimedia and messages. These are interpreted as Semantic Web resources, each is identified by a Uniform Resource Identifier (URI) and all data is accessible and query able as Resource Description Framework (RDF) graph. Resources from the web can be stored and authored content can be shared with others. Ontologies allow the user to express personal Mental Models and form the semantic glue interconnecting information and systems. Applications respect this store, read and communicate via ontologies and Semantic Web protocols. The Semantic Desktop is an enlarged supplement to the user's memory* [104].

The Semantic Desktop is the paradigm for desktop computing [24]. Data stored on the Desktop are considered as the Semantic Web resources, they are represented in the form of Resource Description Framework (RDF) graph, which are then used for browsing and searching by the Semantic Desktop applications. The initial idea for the Semantic Desktop was to bring Semantic Web technologies to desktop computers. The need for developing Semantic Web applications for end users has been analyzed in the early years of 21st century. It is found that major projects are aimed at distributed organizations. This led to several discussions on developing end user applications some of them includes the talks given by Tim Berners-Lee himself addressing the issues of building useful applications for end users. Semantic Web could provide several advantages with respect to the personal information of a user (emails, contacts, bookmarks, bibliographies etc.). Some of the points that support the vision of using Semantic Web for personal information management as identified by Jerome Euzenat[5] report on Personal information management and the semantic web in bristol meeting:

- personal information is found over the web in distributed fashion.
- personal information are rather structured and relatively standardized.
- people are willing to provide more personal information (specially their experiences, expertise and interests).
- there are still several difficulties in searching personal information over the web.

Semantic Web could be useful right away considering these facts mentioned above. It could also produce standardized data formats that could be used for other applications. Considering the existence of various such initiatives to support end users like Haystack [30] and Protege[6]. One such vision was proposed by Stefan Decker called *Semantic Desktop*, which was preceded by Leo Sauermann to develop a prototype called *Gnowsis* in his Masters thesis [72].

1.7 Social Semantic Desktop

In 2004, Stefan Decker and Martin Frank [23] recognized the impact of novel technologies on how people organize, interact and collaborate. They envisioned the Social Semantic Desktop as a result of combining the ideas of Semantic Web, Peer-to-Peer computing and Social networking. The solution is called the *Social Semantic Desktop* [23]. This enhanced personal workspace (the Desktop) will be *semantic* since it will give information a well defined meaning, making it processable by the computer. It will be Social since it will support the interconnection and exchange with other desktops and their users. The roadmap to the Social Semantic Desktop according to the [23] has been defined in three phases :

[5] http://www.w3.org/2001/sw/Europe/200210/calendar/SyncLink.html
[6] http://www.protege.org

1. In the first phase, Semantic Web, P2P, Social networking technologies are developed and deployed broadly.

2. In the second phase, a convergence between the existing technologies brings Semantic Web technology on the desktop leading to the Semantic Desktop. In parallel, Semantic Web and P2P are incorporated and lead to Semantic P2P. Social networking and Semantic Web to ontology driven social networking.

3. In the third phase, the social, desktop and P2P technology fully merge to a Social Semantic Desktop.

In the following section we give an introduction of the well developed practise in information management at work places termed as Computer Supported Collaborative Work (CSCW). The discussion is given to understand the research efforts in Social Semantic Desktop in the light of CSCW.

1.8 CSCW (Computer Supported Collaborative Work)

In this section an overview is given on how information management tasks and technology affect group and organization. Computer Supported Collaborative Work (CSCW) is the study of how people work together using computer and communication technologies [85]. The term itself was first unfurled by Paul Cashman and Irene Greif in 1984, the research insights were on how people work in groups and how technology could support them. The research in this direction is particularly interesting to understand the people behavior in collaborative works, how technology specially computing affects groups, organizations and society. The same technology can have a remarkably different effect on groups that have different compositions, relationships, organizations and contexts of time and location. A group that has members with similar and appropriate task skills will function differently than one that is heterogeneous. Collaborative computing is not only a field but it is an arena, in which people from many fields gather to demonstrate their work and learn from others [40, 64].

In real world interaction we hardly face difficulties in recognition of objects, or understanding someone's speech, yet unexpected difficulties have been encountered in the development of machine vision and speech recognition systems. Our effortless interaction with others make it easy to overlook the complexity of workplaces and poorly understood nature of collaboration in general. To design systems that support collaboration and to predict the impact of technologies on groups and organizations will require an expansion of our understanding [40]. Therefore, the fundamental element of CSCW is to research into the individual and group behaviour and into the nature of workplaces and organizations.

Social Semantic Desktop [23] as a CSCW can help us chart our future course of experience with these new technologies. Collaborative computing could be revolutionized providing an unending stream of surprises and challenges.

Knowledge Management(KM) in an organizational settings has followed two streams of research according to Abecker and Elst [5]. Figure 1.3 depicts the dimensions of basic research in Knowledge Management. According to [5], these are *Process-centered* and *Product-centered* view on KM as follows:

- *Process-centered*: The process-centered view mainly understands KM as a social communication process. It is based on the observations that the most important knowledge source in an organization are its employees. Hence knowledge exists, is created, and is further developed in the interaction among people and tasks such that the focus of IT should be to enable, facilitate, and support communication and collaboration.
  Technical solutions in this area comprise, for example, yellow page and expert finder systems for finding the right communication partner, Computer Supported Collaborative Work 1.8 systems for effective collaboration between geographically separated people, Skill Management systems for the systematic and planned acquisition and development of human skills and competencies, etc. In this view, organizational measures such as installation of expert networks, training courses, virtual teams, and all kinds of cultural KM support play a particularly important role.

- *Product-centered*: The product-centered view focuses on knowledge documents, their creation, storage, and reuse in computer-based corporate memories. It is based on the idea of explicating, documenting, and formalizing knowledge to have it as a tangible resource, and on the idea of supporting the user's individual knowledge development and usage by presenting the right information sources at the appropriate time. Hence the main assumption is that knowledge can exist outside of people and can be treated as an object dealt with in IT systems.
  Of course, the transition from intangible (implicit and tacit) to tangible (explicit) knowledge in the form of standardized processes and templates, FAQs, lessons learned and best practices, etc., allows a company to enhance its structural capital, maybe at the price of loosing creativity and flexibility. Basic techniques for this approach come from Document Management Systems, Knowledge-Based Systems and Information Systems. In this view, organizational measures aim at fostering the use and improving the value of information systems by bonus systems, or by installing organizational roles and editing processes for high-quality knowledge content management.

According to [118] these dimensions of KM research are identified as *Organic* and the *Mechanistic* form of managing knowledge in software development. The organic form is fitting when the primary intention of knowledge transfer is achieving innovation effects. The mechanistic form is suitable for companies mainly aiming at leveraging existing knowledge. According to [44] these streams are identified as *Personalization strategy* versus *Codification strategy*.

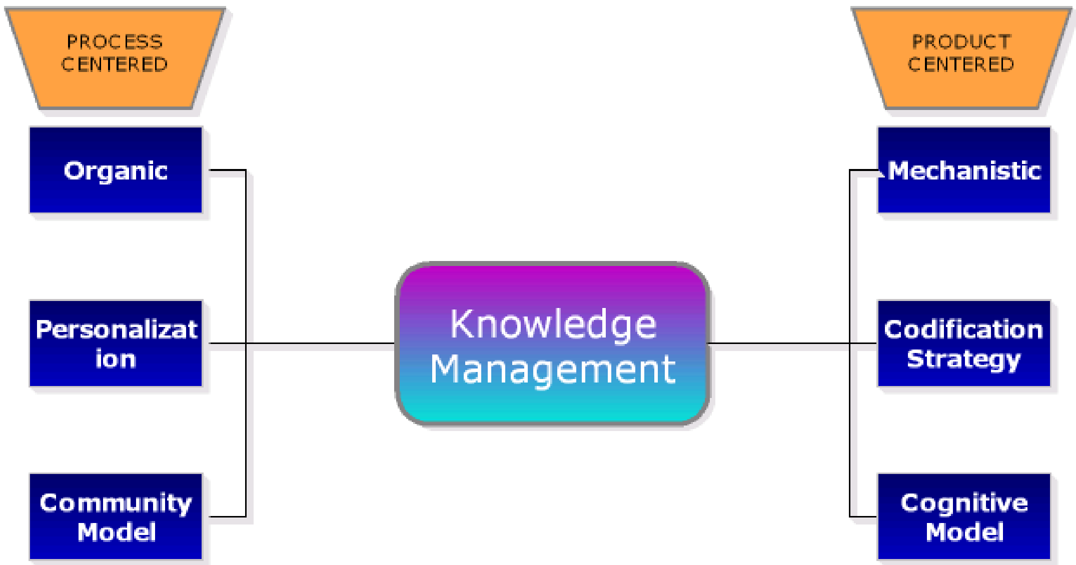

Figure 1.3 Two Basic dimensions of Knowledge Management activities in consulting practices

- *Personalization strategy*: In companies that provide highly customized solutions to unique problems, knowledge is shared mainly through person-to-person contacts, the chief purpose of computers is to help people communicate.
- *Codification strategy*: In companies that sell relatively standardized products that fill common needs, knowledge is carefully codified and stored in databases, where it can be accessed and used-over and over-again by anyone in the organization.

According to [113] *Community Model* and the *Cognitive Model* is contrasted, that argues for a community-based model of knowledge management for interactive innovation and the cognitive-based view that underpins many IT-led knowledge management initiatives. Community Model focused almost entirely on using IT (intranet) for knowledge sharing, while in the Cognitive Model, there was also recognition of the importance of face-to-face interaction for sharing tacit knowledge. The emphasis was on encouraging active networking among dispersed communities, rather than relying on IT networks.

1.9 NEPOMUK Project

In relevance to this thesis it is thought to give an overview of the NEPOMUK [7] Social Semantic Desktop project in which context the thesis is written, although the thesis carefully addresses the needs of a single user's personal information management, a general overview is necessary to understand how Personal Information Management would ultimately lead to Group Information Management(GIM). As defined in NSF report [56, 116], GIM refers to PIM as it functions in more public spheres. In the report GIM is defined as :

> *GIM has to do with how personal information is shared amongst a group, with an emphasis on the norms that underlie that sharing, and the ways in which participants negotiate those norms in response to a variety of tensions.*

The report highlights the issues and opportunities in GIM. Since GIM has to do with how information is shared amongst a group, it is not surprising that a wide array of applications can be used to support GIM, including email, web pages, wikis, and several traditionally produced web documents. Many other emerging GIM examples highlighted in the reports are:

- *Shared Calenders*: The idea is to make a person's calendar available to others could facilitate the sometimes onerous task of scheduling a meeting.
- *Blogs*: Portal to express views, which has more dynamic and growing information written by a person. A diary-like document which could be read and commented by readers.
- *Social Networking Services*: Portals facilitating social collaboration, sharing informations and making personal and social connections.

Many other GIM-centered application areas include peer to peer(P2P) file sharing, information sharing and tagging systems such as del.ici.ous and flickr, online reviewing and rating systems, and event organizing applications such as eVite® and MeetUp™. GIM currently does not exist as a distinct field but it raises a number of interesting issues, and has considerable potential as a focus for research [116].
One such vision of information management for distributed scenarios is being realised in European project NEPOMUK. The European project NEPOMUK was initiated by a consortium lead by the DFKI. Involving researchers from NUI Galway, EFPL Lausanne, DFKI Kaiserslautern, FZI Karlsruhe, L3S Hannover and ICCS-NTUA Athens with practitioners from companies like HP, IBM, SAP, Mandriva, Thales, PRC Group. NEPOMUK brings together the efforts from academic, industrial and open-source community to realize a methodological and technical framework. This would enable users to build, maintain and employ inter-workspace relations in large

[7] http://nepomuk.semanticdesktop.org

scale distributed scenarios. It is expected that the deliverables of NEPOMUK could support semantic structures for knowledge management to support connection with information items on local and remote desktops. An open-source integration framework with the a set of standardized interfaces, ontologies and applications could be developed which would provide support for sharing knowledge, information items and their metadata without central infrastructure. The Semantic Desktop itself plays a pivotal role within this project. The overview and the first hand information that could be known about the NEPOMUK projects on its website are briefly illustrated as follows:

1.9.1 Main goals

NEPOMUK intends to realize and deploy a comprehensive solution methods, data structures, and a set of tools for extending the personal computer into a collaborative environment, which improves the state of art in online collaboration and personal data management and augments the intellect of people by providing and organizing information created by single or group efforts.

1.9.2 Desktop Aspect

To build the Semantic Desktop, NEPOMUK's objectives are to develop the methods, data structures and services necessary

- to annotate and link arbitrary information on the local desktop, across different media types, file formats, and applications. Semantic web data structures and techniques will be applied and adapted to achieve this goal.
- to articulate and visualize the user's ideas and transform them into semantic information. We will extend easy-to-use wiki technology and integrate it with annotation mechanisms.
- to integrate content creation and processing with the users' way of structuring their work. Key approach will be the integration of agile process modelling concepts with the information generation and structuring.

1.9.3 Social Aspect

To cope with the interconnection and exchange with other desk-tops and their users, NEPOMUK's objectives are to develop

- tools for social relation building and knowledge exchange which support knowledge sharing within social communities. These tools will provide semantically rich recommendations, which allow members of a community not only to exchange documents and other isolated information chunks, but all relevant information about their context and the participating community as well.

- techniques for distributed search and storage of information, based on scalable extensions of the distributed hash table technology and p-grid infrastructures, which allow efficient search over distributed information resources and provide a shared knowledge pool within a community.

1.9.4 Community Uptake

The idea of the Social Semantic Desktop will reach its full potential only if it is adopted and applied by a large and active community of people. The build-up of this community is a central objective of the project which will be pursued right from the beginning. In detail, our objectives towards sufficient community uptake are

- to realize the Social Semantic Desktop as an open framework architecture with clearly defined interfaces which are published and possibly submitted for standardization; this will allow external adopters to integrate their proprietary desktop tools into the comprehensive framework and offers ways for commercial support and extension activities;

- to reach early dissemination of project results and to interact with the open-source developer community; this will allow for the gathering and inclusion of feedback and development contributions form interested third parties; and finally

- to prove the benefits of the Social Semantic Desktop in representative application areas which will stipulate the interest of possible industrial users and service providers in uptaking the project results.

1.9.5 Nepomuk Scenario

A ***scenario*** is a story which shows one or more types of behaviour observed during a case study.

- System : A system is an intellectual construction composed of a set of elements and the interactions between them.

- Abstractions: A set of elements together with a written description resulting from the understanding of the project as a whole.

- Functionalities: A functionality is a generalization from behaviour appearing in the scenarios.

- Scenarios: A scenario is a story which shows one or more behaviors observed during a case study.
- Specifications: A Specification is a written description of what a system is supposed to do.
- Architecture: The architecture is a set of representations explaining the organization of the implementation.
- Usages: Real world observations or experiments. Experiments can be seen as the implementation.

The chapter has provided a broader view of Knowledge Management in organizational settings and its various aspects. It gave an overview of the practices involved in Social Semantic Desktop and the NEPOMUK project initiative to realize the idea. The following chapter addresses the issues related to Cognitive Science and Semantic Web. It is an effort to contrast and view Semantic Web from scientific aspect as reported in [46].

Chapter 2

Theoretical Background

This chapter intends to give a theoretical idea of the subject, with overview and definitions. The authors intention is to introduce the readers briefly to the subject, the overall theme, motivation and importance of this research. As the thesis addresses the cognitive aspects of Knowledge Management, it is necessary to give readers a big picture of Cognitive Science as a scientific field, its application and importance to technology which are being developed to be used by human. Nowadays we are realizing that every technology is valuable, if it is useful for humans in general. I would say cognitive aspects behind a technology address the issues of philosophy in general, usability evaluation and user-oriented design suggestions. Although the field of Cognitive Science deals with many hard problems of understanding human brain and mind. Cognition in itself has become a word of scientific standards to prove the applications of science that supports human in an intelligent way. In the following sections a definition is given and a historical account the Cognitive Science development.

2.1 What is Cognitive Science

> *If the human brain were so simple that we could understand it, we would be so simple that we couldn't* Emerson M. Pugh

Cognitive Science is defined as the scientific study of mind, brain and intelligence be they real, artificial, human or even animals. The field of cognitive science overlaps Artificial Intelligence (AI). Cognitive scientists study the nature of intelligence from a psychological point of view, mostly building models that help elucidate what happens in our brains during problem solving, remembering, perceiving, and other psychological processes. One major contribution of AI and Cognitive Science has been to provide an information processing model of human thinking in which the metaphor of brain-as-computer is taken quite literally. Although Cognitive Science itself is considered as a novel field of development to understand human mind from different perspectives, nevertheless interest in mind and brain is as old as recorded history from ancient philosophy. Many fundamental questions about cognition and its physical bases have existed, long before the term *Cognitive Science* was coined. The field of Cognitive Science has evolved as an independent discipline based on interrelated subjects. Some of the well said comments about Cognitive Science are quoted below:

> AI can have two purposes. One is to use the power of computers to augment human thinking, just as we use motors to augment human or horse power. Robotics and expert systems are major branches of that. The other is to use a computer's artificial intelligence to understand how humans think. In a humanoid way. If you test your programs not merely by what they can accomplish, but how they accomplish it, then you are really doing cognitive science; you are using AI to understand the human mind.

Herbert Simon

> Back in the Winter of 1982, Inspired by having just read Douglas Hofstadter's book Gödel, Escher, Bach at the impressionable age of 18, I decided that my undergraduate college's "prefabricated" majors were not what I had in mind, and that I would create my own independent major in the little understood and littler known field called Cognitive Science.

Dr. Robert Goldstone, Indiana University

Nadel and Piatelli in their paper published in the Encyclopedia of Cognitive Science [34], address that in practice Cognitive Science has been more limited, largely restricting itself to domains in which there is reasonable hope of attaining real understanding. The richness and diversity of the contributions to these volumes show that there are now many such domains [78, 34]. It is no longer surprising when a cognitive system is shown to work in highly unexpected ways. One of the insights of modern cognitive science is that the mind often works in counter-intuitive ways [34]. Mature sciences owe much of their initial progress to the pursuit of phenomena and hypotheses within a few *windows of opportunity*, often opened by chance. Many of these seem, at their inception, to be quite far from the daily concerns of ordinary people, but they come to have great impact.

2.1.1 Historic behaviourism perspectives

The behaviorist revolution in North America, by John B.Watson (Watson, 1924), can be viewed in retrospect as a reaction against the overly ambitious reach of early cognitive scientists. Behaviorists rightly pointed out that not enough was known about what goes on inside the organism to ground any sort of meaningful theory. This judgment combined with an infectious enthusiasm for spreading *rigorous* scientific methodology to all fields of inquiry, effectively banishing all appeals to internal states and representations (concepts, ideas, meanings, percepts, computations etc). Better to focus on what could be observed and measured if one wants to create a science as mentioned in [78].

2.1.2 Cognitive Science modern views

According to Nadel [78] the modern era in Cognitive Science started in late the 1930s after the Turing's revolutionary publication in 1936 on computability by Turing machine, he proposed that any calculation that is possible, can be performed by an algorithm running on a computer, provided that sufficient time and storage space are available. The way Humans solve calculations with a pencil and paper following a set of rules. Later the contribution by Kenneth Craik(1943), entitled *The Nature of Explanation* [20] connected ways to connect mental and mechanical operations, and settled on the notion of internal models that he expected would become central to the Cognitive Science in future. He claimed:

> *[...]thought is a term for the conscious working of a highly complex machine, built of parts having dimensions where the classical laws of mechanics are still very nearly true, and having dimensions where space is, to all intents and purposes, Euclidean. This mechanism, I have argued, has the power to represent, or parallel, certain phenomena in the external world as a calculating machine can parallel the development of strains in a bridge[...](p.85)*

Craik views on thoughts involved three critical steps as claimed in [78]

1. First, external processes were translated into words, numbers or symbols
2. Second, these *representations* were manipulated by processes such as reasoning to yield transformed symbols
3. Third, these transformed symbols were re-translated into external processes to yield a product, such as behavior.

The essential assumptions made in Craik's idea are that minds create *internal models*, and then use these models to think about the future. Such a thought process allowed an organism the luxury of trying out possible futures before settling on the one that would be most adaptive. According to Craik beliefs, thoughts could not be separated from feelings, a perspective that early cognitive science ignored to its detriment.

2.1.3 Ideas development timeline

The development timeline of Cognitive Science is shown in paper by Nadel [78]. It is also cross-referenced in the Encyclopedia of Cognitive Science [34], describing the empirical findings of the overall contribution to the field of Cognitive Science. Starting

later half of 20th century there has been an impressive growth in empirical results, in all the domains of cognitive science. Chomsky revolutionized the study of language, Broadbent (1958) and others focused on attention, Bruner and his colleagues (1956) looked at thinking, Newell, Shaw and Simon in 1958 produced the General Problem Solver (GPS), Hochberg (1956) studied the role of memory and other internal factors on perception, Sperling's (1960) work on brief visual presentations and partial report methods led to the notion of an iconic memory store (Sperling, 1960), and there were various thrusts in artificial intelligence (e.g. Samuel's checkers program 1959), including interesting work on mathematical neural networks (Rosenblatt, 1958; Selfridge, 1958 (November)). But, there were problems. In many cases the successes were garnered in severely restricted systems, with no certainty that they would scale up or generalize. Some domains were simply not part of the mix – the study of emotion, or consciousness, was ruled off limits. In these days only those phenomena of which humans were somehow at least partially conscious qualified as *cognitive* – implicit capacities did not make the grade, nor did any animals, which are now inclusive in the studies of Cognitive Science.
At that time Cognitive Science paid little heed to the brain, when neuroscience pushed ahead, making great strides in a number of areas. In the late 1940s the discovery of the *reticular activating system* (Moruzzi and Magoun, 1949) had a major impact. This landmark event shifted thinking about the brain in a fundamental way. It showed that, contrary to prior notions, the brain was not a passive organ waiting to respond to external stimulation. Instead, it was constantly active, and the critical question was no longer what brought it into activity but rather what kind of activity it engaged in. The selectivity of brain function was shown to reflect not just exogenous factors, but endogenous ones as well.

> [...]having grown into a rich and multi-faceted domain, it's normal that cognitive science has witnessed, is witnessing, and will continue to witness, disagreements, schisms, partial reconciliations and yet further splits in theories and methodological criteria[...] [78].

To characterize as *mainstream* or *classical* cognitive science the individualist, largely innatist, modular and representational-mentalist (RTM) conception of the mind that characterized much of the 80s and 90s, there are clear signs that we may be entering a post-classical cognitive science (Piattelli-Palmarini, 2001). The innovative turn introduced by connectionist models in the mid-80s revamped an anti-modular and general-purpose conception of the mind-brain, soon contested by *classic* cognitive scientists (Pinker and Mehler, 1988).

What do Cognitive Scientists do?

A good friend of mine and co-graduate from Osnabrueck nicely comments:

> Cognitive Scientists (Neuroscientists, psychologists, computer scientists, philosophers, linguists) are trying to find out how we connect what we do with what we perceive. By scrutinizing the black box called brain

from different perspectives, a wider area can be covered - there is a lot of unexplored paths and misleading cartographic information. Explorers are needed. Questions about the brain come in many forms and sorts. One can easily plug any of the interrogative pronouns, as most questions are far from answered. The level of generality of these questions ranges over the most abstract philosophical paradox to the most specific experimental hypothesis. Because of that, the answers can and will be scattered, it is a job of the cognitive science researcher to reintegrate them into the human's knowledge lattice about the brain. The vocabulary of the brain researchers will often include words as computations, inputs, stimulus, outputs, behavior, processing, representations, dynamics, oscillations, frequency, information and quite a vast range of others. It is no wonder that the vocabulary is so broad, to be explained is no less than the mind (whatever you might name it).

Dip.Ing. Mario Negrello, University of Osnabrueck

After giving the brief overview of the field of Cognitive Science, the next section identifies the technnical aspects of Semantic Web. The bridge between Cognitive Science theories and Semantic Web applications is a crucial step in realizing artificial intelligence.

2.2 Semantic Web vision of TimBL

The Semantic Web is an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation.

Tim Berners-Lee, J.Hendler,O Lassila, The Semantic Web.
Scientific American May 2001

The basic ideas of the Web is that an information space through which people can communicate, but communicate in a special way: communicate by sharing their knowledge in a pool. The idea was not just that it should be a big browsing medium. The idea was that everybody would be putting their ideas in, as well as taking them out.

Tim Berners Lee
LCS 35th Anniversary celebrations, Cambridge Massachusetts,
1999/April/14.

Essential ideas from Tim Berners Lee in his book Weaving the Web [9]:

- Importance is given on making web editing as simple as browsing the web. (Wiki is a step in this direction, although Berners-Lee considers it merely a shadow of the WYSIWYG functionality of his first browser.)
- Computers can be used for background tasks that enable humans to work better in groups.
- Every aspect of the Internet should function as a Web, rather than a hierarchy.
- Computer scientists have a moral responsibility as well as a technical responsibility.

The Semantic Web vision [10] is aimed to improve various limitations of current Web data model. By using URI [1], the Semantic Web proposes a unified naming scheme capable of referring to objects at any level of granularity, with or without digital content, and independent of their physical storage locations and binary representations. The main purpose is the encoding and publication of data schemas through the Resource Description Framework (RDF)[2]. RDF allows semantics of relationships to be specified and relationships to be encoded. The benefit is that several schemas can be applied on the same object given its URI, and different aspects of the same object can be managed by the different software systems. For instance, an *email* schema and a *photography* schema can both be applied on a single *person* object to manage his or her e-mail communications and photographic creations[49].
RDF data models are much simpler than the Web's hypertext model in which data is expressed as human-readable textual contents in HTML. RDF data models can be easily stored, for instance RDF/XML or N3[3]

2.3 Cognitive Science vs Semantic Web

As a Thesis entitled: ***"Cognitive aspects of Semantic Desktop to support Personal Information Management"*** which is among the initial attempts to write about Cognitive aspects of Semantic web technology, needs a clarification of the each word components that describe the title, the authors' goal in mind and the audience it is addressing.
Currently, we are entering the process of transforming the 'first generation web', that is characterized by hyperlinked HTML pages of the Web contents, to the 'second generation web', or the 'Semantic Web' that aims at machine-process-able information. This would enable each individual to take part by publishing, learning and forming a social network -*Social Web*. To achieve that next level one needs means and standards

[1]http://www.w3.org/Addressing/
[2]http://www.w3.org/TR/rdf-primer/
[3]http://www.w3.org/DesignIssues/Notation3

not only for describing the syntactic structure of Web documents as offered by XML, but also means and standards for specifying the semantic content of Web sources. RDF and RDF-schema offers a first step in this direction.
First, the thesis is intended to attract more Cognitive Scientists, Semantic Web researchers and open minds to find the cognitive flavour in the Semantic Web vision [10]. I have highlighted some aspects with respect to the Semantic Desktop framework: A way to realise Semantic Web on personal computers [102] there are ample of open cognitive aspects for future research. Secondly, it is very important to say that the study is not intended to confuse the reader in analogizing Brain of interconnected neurons with the network of connected servers in Semantic Web, therefore it is important to keep in mind the point is not to look for "How" Cognitive Science views Semantic Web which would mean trying to make the analogy and understanding the Brain as if how semantics are stored or processed in it. Instead the research motive is to ask

*"Why"*Cognitive Science should view Semantic Web vision.

When we talk of the philosophy behind a technology, obviously Cognitive Science comes into play starting from the initial ideas till the user-based application support. The pace of scientific progress in the era of advanced technology, what is now more became a hype to talk about is cognitive adequacy and ergonomic design of tools, devices, instruments and software. The issues are not only limited to such tools or device development but how the technology in itself should affect and pass through the rigorous cognitive tests to meet the human needs. Of course the reason is "*Usability*" and "*Usefulness*" of existing technology and the novel ones.

- *Computer science* provides the tools needed to build the information systems that are often required to make certain aspects of knowledge management solution work.

- *Cognitive science* helps to design knowledge management solutions in line with the cognitive capabilities of the people involved and optimally embedded in their work context.

I feel that to improve the quality of useful technology we need to look into the strong theoretical foundation and principles governing the system. As once Prof. Ben Shneiderman in a talk at DFKI in Kaiserslautern said:

Good practise leads to good theory and vice-versa.

A key concern in the field of Human-Computer Interaction (HCI) is the so called theory-practice gap [112, 94], whereby the products of much HCI research can be irrelevant to the designers' needs in the real-world [11].

The theoretical research would not only lead to implement a supportive research design but also a reliable and more user-centered, personalised development of semantic web technology support to the people. Semantic Web technologies will be more quickly proliferated if they can prove to be directly useful to end users. The Haystack project [30, 25] brings the Semantic Web to end users by leveraging key Semantic Web technologies that allow users to easily manage their documents, e-mail messages, appointments, tasks, etc Today's end users benefit from the large scale in which the industry applies Web technologies. The key challenge for the Semantic Web community is to push technology in a similar direction. To gain momentum, technologies for building private Semantic Webs or parts of the World Wide Semantic Web must become a commodity and easy to integrate [111].
It is important to keep in mind, that in Semantic Web hype, What is meant by *"semantic"* is not that computers are going to understand the meaning of anything, but that the logical pieces of meaning can be mechanically manipulated by a machine to useful human ends [114].
Tim Berners-Lee's creation of the World Wide Web has forever changed the shape of modern life, altering the way people do business, entertain and inform themselves, build communities, and exchange ideas. If the vision gets truly successful, it would completely revolutionize, the way people behave in information age, the way they want to express themselves, and the way they want to be addressed. It would affect cultural exchange and more informed society, as I would say information is a valuable resource for today's civilization.

2.4 Human-Computer Interaction (HCI)

HCI is a multidisciplinary discipline with a relatively short history [101]. Its main goal is provide knowledge and methods for the design of usable computer systems. Now, computers have become integral part of peoples personal usage, work, entertainment, and social collaborations. Many organisations are adopting computerised systems to effectively manage information in order to enhance productivity, to minimize redundancy and to increase employee satisfaction. However, the effective use of such systems and their promised goals are still a challenge to scientific studies, specially their cognitive design and user-oriented support. *User-friendliness*, *user-adaptiveness* and similar terms have become business words, without any scientific claim, the usability of a system is still a question. Even in organisations which plan the introduction of their systems carefully, many users of the new technology encounter problems. Whilst technology suppliers initially attributed many of these problems to techno-phobia or resistance to change, user organisations often discovered that employees had been left to struggle with systems which were difficult to learn, difficult to use, and did not provide appropriate support for their tasks. The relatively new field of Human-Computer Interaction (HCI) has adopted these concepts to study the usability issues [22].

The Semantic Desktop is an idea to personalize a computer system and support Personal Information Management. This implies the system should ideally meet the user's needs to customize information resources according to user preferences and way of thinking. To understand this we need to focus on individual and understand user behaviour. The theories from Human-computer interaction (HCI) are important step towards this direction. Even though our brains are quite dedicated to preserve the memories of our valuable information, knowledge and experiences of daily life. There exists a fundamental limitation in our ability to attend to things, filing information and keeping records, in the time we have. Information overload is a common problem and has been addressed in many literature [55, 11, 63]. Computers plays an important role in representing artefacts of our real world experiences, which should be evaluated on the principles of HCI theories. Interested readers may refer to Martina Sasse Phd thesis for further discussion of the subject [22].

> HCI is a discipline concerned with the design, evaluation and implementation of interactive computer systems for human use and with the study of major phenomena surrounding them. - Gary Perlman

If viewed historically, HCI research has focused on meeting mainly three types of user needs, this could be categorized as follows:

1. Design of GUI to support high level user-interaction with computers.
2. Analyze how interfaces and system components are used to meet the specific task scenario.
3. To improve the way people use computers in order to work, communicate and collaborate.

With respect to this thesis on addressing the issues of the Semantic Desktop, the third stage of HCI research needs more attention, specifically the cognitive aspects of information categorization, finding and reminding in order to give the users benefit in Personal Information Management.

2.5 Information Types

According to Nardi [79] information types were classified as follows.

- **Ephemeral**: short shelf life. Users prefer to keep this in a visible place. They usually don't have a good solution for the problem of dealing with large quantities of this. He claimed that the most problematic issue was to deal with a large amount of ephemeral documents.
- **Working**: frequently used information relevant to the user's current work. Usually organized in folders. Usually user do not have problems to find this info. They know where the files are spatially.

- **Archived**: life shelf of years, indirectly relevant to current projects. Usually completed projects. Efforts to elaborate scheme failed because it takes more time and effort that what the information is worth.

Each knowledge worker keeps information organised differently. According to [13] one such possible ways, depending on the information needs, could be mainly classified in three categories: See Table 2.1. Each piece of information has a cost associated with finding and accessing it.

Table 2.1 Table (Information Storage Types)

Storage Type	**Frequency**
Primary Storage	Frequently used low cost of access
Secondary Storage	Less frequently used high cost of access
Tertiary Storage	Rarely accessed and rather stored in Library or Archive

2.6 How do people organize

We cannot possibly hypothesize a generic model of user organization, as people vary, and they have different world-views so would be their organizing strategies. Some of the theories and evaluations say we organize according to the following criteria:

- Spatial: The strategy which is extensively supported in the article: The intelligent use of space by Kirsh [62], In my literature search I found it as a detailed illustration of Spatial organisation. He claims "Spatial arrangements of items around us is an integral part of the way we think, plan and behave". Spatial organisation is particularly suitable for effectively exploiting our visual cognition, they are well suited for visual resources such as pictures.

- Temporal: Based on time events, the strategies may involve filing information with respect to date (like photos, events)

- Topical: The strategy based on topics of interests of user (science, technology, politics etc.).

- Hierarchical: The most common strategy employed in windows file system. Which has several limitations, one such limitations are strict hierarchy that restricts users to file information in only one category thus loosing semantic which a user would like to preserve.

The different working styles of people pose difficulties to hypothesize about the correct PIM behaviour. *We still have to evaluate if a hybrid of all such models is more efficient for PIM.* We know from previous studies that classification of information is

difficult [68]. A report on the virtual desktop users' studies [92] suggests that skilled users apply flatter file system structure. Although there is further claim that this tendency do not apply to emails or bookmarks filing. We also knew from the report that system usability depends on user's knowledge about the system [92]. Thus "Experts and novices have different preferences with respect to visual and structural organisation of information" [92]. The report recommended simple-to-use search facility, supporting content based search independent of the file types or formats. In general context supportive, semantic based, and easy-to-work with characteristics (like in adding notes and remarks to documents) were demanded. These features are obvious considerations in the Semantic Desktop approach.
According to Professor Paul A. Dorsey personal knowledge management, which is synonym to PIM terminology claims [4](PIM) as skills and defines the following seven criteria:

1. retrieving information;
2. evaluating/assessing information;
3. organizing information;
4. analyzing information;
5. presenting information;
6. securing information;
7. collaborating around information

From the discussion above it is clear that people have different organising strategies. The strategies might not be unique and vary according to the factors described above. In Section 4.5 we illustrate the information types for the Semantic Desktop with which a typical knowledge worker is associated in her day to day activities (see Figure 4.2).

2.7 Boardman cross-tool thesis

Boardman [11] came up with a comprehensive doctoral Thesis on theoretical, methodological and empirical issues of Personal Information Management (PIM), he advocated that many challenges of PIM could be solved from cross-tool perspectives. Since the distributed nature of PIM has not been dealt fully in literature, his thesis addresses the distribution of PIM across a range of distinct but inter-related tools as *File managers, email clients* and *Web browsers*. His research is quite significant to give an understanding of the incremental nature of changes in organizing strategy and highlights the supporting nature of PIM.

[4]http://www.millikin.edu/webmaster/seminar/pkm.html

He highlighted the lack of systematic investigation of data relating to PIM activities and cross-tool understanding of PIM. He argued that the design work has been based on designer intuition rather than empirical data of user evaluation. The main focus of his research was to explore the PIM behaviour by collecting data across three PIM tools viz: email messages, document files and web bookmarks. He argued that cross-tools approach is different from already existing studies on specific PIM-tools. It gave a better understanding of users long-term PIM activities.
In the present information age there are many good reasons to encourage the development of tools for PIM support, this could be broadly highlighted as:

- Success of email and the Web that provides vast amount of useful and personally relevant information.
- Huge capacity of storage leads to carefree collection of information by an average person.
- Success of the Semantic Web vision which promises to facilitate a better infrastructure for knowledge management.

With these motivations, the research attention has to be made for user oriented tools development. The current technology provides easy modelling of knowledge using data models RDF or OWL, but a research in PIM has to be founded on empirical user requirements. The advent of highly innovative technology has to be used to develop user-centric design, otherwise many existing tools would be a failure to meet the user needs, and thus would remain unsuccessful.

2.8 Challenges in PIM development

The research approach to address the issues of Personal Information Management has become frequent recently. Nevertheless, the difficulties of PIM still persist [11]. The information we need to complete a task is often scattered across locations and devices. Information is further fragmented across separate organizational schemes for paper, electronic documents, email, web references, etc. The opportunities to support PIM increase as increasing amounts of personal information are captured in digital form. But the capture of personal information raises important issues of security and privacy. The capture of personal information in the workplace raises additional issues of ownership [73]. Thus we can classify challenges as follows:

- *Information Overload*: User faces huge amount of data which is acquired through various media and sources like newspapers, web, emails, conversation forums, talks, adverts and digital documents etc.
- *Information Fragmentation*: User maintains several separate, roughly comparable but inevitably inconsistent, organizational schemes for electronic documents,

emails and references [55]. Resources are stored across different locations and information we need may be stored across different resources. Moreover, the number of organizational schemes may increase if for example, a person has several e-mail accounts, uses separate computers for home and work, PDAs, smart phone or any of number of special purpose PIM tools, any addition of new tool would introduce more schemes of organisation. In general user often expresses frustration that she needs to maintain so many different organizational schemes in parallel. A report on PIM [73] from the 2003 National Science Foundation (NSF) Information and Data Management (IDM) workshop identifies information fragmentation as one of the major challenges that must be met if PIM is to improve [55].

There are further set of problems with PIM which are mentioned in [50]. These problems are also identified and dealt in Man Lou thesis on Meeting Annotation [71], which provides features of meeting annotation on Gnowsis prototype.

- *Filing Information is a difficult task*: To make filing decisions about incoming documents is considered a difficult task. Very often people are not able to categorize information rather make some ad-hoc decisions such problems of cognitive overload is discussed by Kirsh [63] and also illustrated in Section 3.7. Some people make broad categorization as hot files, warm files and cold files according to their frequency of usage respectively. Other categorization approach are task based, grouping documents based on the task related to the documents. Additionally it is also considered, personality and job profiles affects people's filing behaviour. We don't know well about peoples organizing behaviour. Moreover, situation arises where we can have ambiguous filing category or synonymous category for example, if a user attends a Semantic Web conference in Japan, should the information and photos regarding it be filed according to location (Japan) he travelled or according to her professional interests in Semantic Web, how she differentiates between filing informations, the trip she made to Japan for a vacation or for a conference? Current provisions of strict hierarchical file systems are not semantically intuitive. Users finds limitations in classifying a document into multiple categories. So we conclude to look for a semantically rich file system to tackle this problem.

- *Limited Support for Maintaining Context and Retrieval Cues*: Maintaining context is a vital necessity in PIM activities of digital resources. Context act as a memory aid and is important to keep the user focussed in her work. Some of the attempts to maintain context could be filing information with dates as a tag could remind of deadlines, filing information with most common names may let the user remembering file for longer time, value and urgency of files may be improved by filing it in active folders or at desktop. Generally people maintain some cues to keep track of their information context. In case of physical paper documents there are many features associated with the documents which acts as cues and contexts to retrieve the information, like color, dimensions, time of access, situations etc. All these cues are necessary in digital resources of users. Current PIM tools either provide limited support maintain context or they are not they way people really want. User once loose the context, the cost of even finding the lost information overloads the user. Instead of maintaining visual retrieval cues, computer systems display details of files, such as their name, type, and size, which are less useful for retrieval cues [50]. According to [17], some specific characteristics owned by the personal desktop offers the context cues to the user, for example the documents in the same folder carry semantic relations to the user; one email might contain inner context connection with another email; one email usually include additional contextual information about its attachment. Unfortunately current desktop search applications fall short of utilizing these cues.

- *Information Overload*: Information overload is another challenging issue in PIM which should be handled by PIM prototypes. In typical users' computer there are many ephemeral documents, such as E-mail message, "to do" lists, notes and memos. These kind of documents usually serve as reminder and are placed at desktops. However, computer desktops are spatially limited that limits users filing flexibility [8]. Moreover, the lifetime of these documents sometimes depends on other factors, for instance, an inviting email is useful until a reply from other people, but not all people reply email timely. These situations lead to managing documents with difficultly. After a period of time the ephemeral documents accumulate increasingly in computer, but they might be omitted by users and cause information overload. Another reasons related to information overload, called premature filing, is observed by [125]. The premature classification that is currently appropriate may become unsuitable as user requirements or goals change over time, which is a very likely characteristics of PIM behaviour. However, according to Whittaker, once a document is filed, it seems to be difficult to discard it later. As a result, people continually keep these documents, even they are never used. These difficulties remain problematic till date. Therefore, all current efforts to for PIM supporting tools should take this issue with serious considerations.

A wide range of tools and technologies is now available for the management of personal information. *Browsing systems* like desktop metaphor, hierarchy structure, email folders are based on location based approach that exploits spatial memories. In such system a user needs to remember exact spatial location, It is more analogical to the physical world, user is more familiar with spatial organisation, but the real trouble occurs when the size and complexity increases. *Search systems* like Google, MSN desktop, Windows Find, the work on exploiting semantic memories. User needs to remember exact terms that feature in object.
NSF IDM Workshop Report on Personal Information Management had several recommendations [73]:

1. *Research into PIM should involve expertise from a variety of academic disciplines including cognitive psychology, sociology and social psychology, data management, information retrieval, and human-computer interaction.*

2. *Research into promising PIM tools and technologies should be balanced by empirically grounded studies aimed at acquiring a better understanding of underlying problems of PIM. Some of this research should focus deeply on the needs of selected professionals (doctors, for example). Though expensive to conduct, some research needs to extend over a period of time (weeks or even months) in order to better understand how PIM changes for an individual with time and to discern long-term patterns of use.*

3. *It is important to support the development of methodologies, frameworks and benchmarks for the evaluation of PIM tools and techniques.*

4. *It is important that at least some of the research take broader, integrative view of PIM that looks across and beyond existing applications and information forms (e.g., for email, e-documents, web references, "notes", etc.) to images, audio, video and even sensor observations.*

5. *It is important to get various organizations – private, non-profit, governmental, etc. – involved in the support of PIM research.*

6. *One or more workshops specifically targeting PIM could significantly help to establish current imperatives and priorities of PIM as a field of study and help to bridge across disciplines.*

The chapter provided theoretical overview of the definitions of terms, it addressed the existing challenges in Personal Information Management and the current state of technology to handle the Personal Information Management in an elegant way. Now in the next chapter we go into detail literature research of philosophical theories which are necessary to understand. The following chapter is needed because this area of research has not been explored in the Semantic Desktop context. The research work for this direction has been demanded in PIMO [103].

Chapter 3

Cognitive Aspects

> *The brain is wider than the sky, For, put them side by side, The one the other will contain With ease, and you beside.* – Emily Dickenson

This chapter provides a philosophical grounding to the research in this thesis. A discussion is given on Philosophy of Artificial Intelligence and Cognitive Science. Furthermore, the chapter provides an overview of various philosophical aspects of computer-based activities and discusses the theories relevant to understand what are the goals for the Semantic Desktop community. Philosophical theories are not immediately transparent to the programmers, but the ideas discussed here are intended to emphasize a theoretical foundation with respect to the Semantic Desktop long term goals.

3.1 Philosophy, AI and Cognitive Science

The main philosophy behind Artificial Intelligence (AI) is based on the question *Can machines think*? Although, the questions itself doesn't clearly define what is implied by *think*. When we say, a Server is *running* this doesn't imply literally that it is moving with its leg in an impressive fashion. Words are metaphoric in this context, and thus are in the need of detailed and sufficient explanations to answer similar questions such as: Can machines fly? or Can machines swim? Aeroplanes and Submarines are examples that come to our head but that are not the answers what the questions really imply.

Within the AI community there has always been a debate whether it is possible or not to build intelligent thinking machines which are as good as human in terms of decision making, problem solving, conscious thinking to the extent of making creative discovery or showing sophisticated behavior like understanding the concept of *emotional love*. According to Dietrich [26], the most important of the whether-possible problems lie at the intersection of theories of the semantic *content of thought* and the nature of computation. Human thinking is the manipulation of contentful thoughts, that are involved in cognitive processes as making inferences, recognizing patterns, planning and executing activities. During such processes our thoughts are manipulated to refer to the various things and concepts in our real world. The *content of thought* would possibly mean an expression or summary in our mind about a particular concept. But when this view is translated to computers a real hard problem emerges, because machine cognition is generally based on an algorithmic manipulation and computation of well defined data structures. The role of philosophical problems come to a play at this moment, thoughts have contents or internal states, now the question is when computers do addition of 1 to 2, how internal states are actually denoted to the number 1 or 2 ?, If a computer infers *Fido will chase the cats* from the given facts *Dogs chase the cats* and *Fido is a dog*, do any of its internal states refer to dogs, cats, fido and the act of chasing.

> *If computations are radically different from thoughts in that they cannot have semantic content, then it is unlikely that computers can think* [26].

These problems are addressed in AI and Cognitive Science as *the problem of mental content or representational content*, please refer to [34] for detailed issues related to AI and Cognitive Sciences. Dietrich further refers, the second set of whether-possible problems of AI surrounds *the nature of rationality.* He claims humans constantly evaluate ways of achieving goals and rank them according to various measures such as the probability of success, efficiency and consequences. They evaluate the goals themselves and constantly gauge the relevance of one piece of information to another, the relevance of one goal to another and the relevance of evidence to achieving a goal. Humans are often successful in such evaluation however computers are not, thus human level rationality are not obtainable in an intelligent machine. The third set of whether-possible problems of AI are the issues of addressing the reasoning powers of human mind. In 1931, Kurt Gödel demonstrated by his famous *incompleteness theorem*[1] that within any given branch of mathematics, there would always be some propositions that cannot be proven for true or false using the rules and axioms. Gödel proved that every *consistent* (i.e., that there is no contradiction in a statement and its negation is also true), logical systems are *incomplete* (in the sense that every statement in the language of Number Theory cannot be either proved or disproved). The logical problems surrounding the self-reference and the incompleteness of certain axiomatic systems (logical systems) seem to be a barrier in building an intelligent machine.

Gödel's Theorem has been used to argue that a computer can never be as smart as a human being because the extent of its knowledge is limited by a fixed set of axioms, whereas people can discover unexpected truths. Thus the discussion itself arrives to the point that humans can do something that computers cannot, as humans ability to step out side formal systems is a crucial part of their intelligence, this follows computers cannot be intelligent or not at least in a ways humans are. With relevance to this argument Douglas Hofstader in his famous book, an Eternal Golden Braid [48] writes:

[1] http://mathworld.wolfram.com/GoedelsIncompletenessTheorem.html

> *How can you figure out if you are sane? [...]Once you begin to question your own sanity, you get trapped in an ever-tighter vortex of self-fulfilling prophecies, though the process is by no means inevitable. Everyone knows that the insane interpret the world via their own peculiarly consistent logic: how can you tell if your own logic is "peculiar" or not, given that you have only your own logic to judge itself? I don't see any answer[...] I am reminded of Gödel's second theorem, which implies that the only versions of formal number theory which assert their own consistency are inconsistent. The other metaphorical analogue to Gödel's Theorem which I find provocative suggests that ultimately, we cannot understand our own mind/brains [...]Just as we cannot see our faces with our own eyes, is it not inconceivable to expect that we cannot mirror our complete mental structures in the symbols which carry them out? All the limitative theorems of mathematics and the theory of computation suggest that once the ability to represent your own structure has reached a certain critical point, that is the kiss of death: it guarantees that you can never represent yourself totally.*

Philosophers made AI conceivable by considering the ideas that the mind is in some ways like a machine, that it operates on knowledge encoded in some internal language and that thought can be used to help arrive at the right actions to take [99]. Even the philosophy existed a long before computers came into existence, there has always been a question of how minds work, how do human minds work and can non-human have minds? these are real hard problems and often resulted in heated debates among the Philosophers, AI researchers, Cognitive Scientists. Many have now taken a computational side, because of the various tools available to study the intelligent behavior in detail. At current state of research, AI is still in its infancy to exhibit the higher-level human cognitive abilities and thought processes in computers, mainly AI research is actively viewed with respect to two school of thoughts to achieve machine intelligence. They are termed as *Strong AI* and *Weak AI* by John Searle [110, 97]:

- **Strong AI** is the belief that artificial intelligence can truly reason and solve problems, strong AI supposes that it is possible for machines to become sapient, or self-aware, but may or may not exhibit human-like thought processes. As Searle claimed:

  > *[...]according to strong AI, the computer is not merely a tool in the study of the mind; rather, the appropriately programmed computer really is a mind.*

- **Weak AI** refers to the use of software to study or accomplish specific problem solving or reasoning tasks that do not encompass the full range of human cognitive abilities, Unlike strong AI, a weak AI does not achieve self-awareness or demonstrate a wide range of human-level cognitive abilities, and is merely an (arguably) intelligent, more specific problem-solver. Examples of the current software design are Expert systems that are used commonly for specific purpose for example, there are expert systems that can diagnose human illnesses, make financial forecasts, and schedule routes for delivery vehicles. Some expert systems are designed to take the place of human experts, while others are designed to aid them. Expert systems and Chess program are a part of Weak AIs.

Based on above discussions on *Weak AI* It would be interesting to investigate if the Semantic Desktop is an effort realizing weak AI.
Next section explores the theories of mental representation, in relevance to this thesis they are important to understand how mental representation of the real-world, and Mental Models in particular affect individuals' knowledge formation. It is expected the studies would give an insight for HCI researchers to comprehend how information is represented mentally, and how users' form information to behave while interacting with computer systems.

3.2 Real versus Mental representations

Mental representations of the real-world is generally interpreted by analogy with physical representations [101]. Physical representations can be *picture-like* or *language-like* as described by Paivio [86], refer to Table 3.1. According to Sasse thesis (refer to [101]

Table 3.1 Table (Types of physical representation: Paivio,1986)

physical representation	**picture-like**	**language-like**
examples	pictures maps drawings diagrams	human-language symbolic logic computer programs
properties	analogue iconic continuos	non-analogue non-iconic discrete
mappings	referentially isomorphic	referentially arbitrary

Ch.3 for more details), Picture-like representations are iconic, analogue and continuos (pictures, maps etc.), on the other hand Language-like representations, which include natural language and mathematics, are non-analogue, non-iconic, and digital or discrete. In Figure 3.1 such a representation is shown as two extreme ends of a continuum. The crucial distinction between picture-like and language-like representations lies in the degree of arbitrariness of the mapping relation between the representation and the represented phenomenon: picture-like representations map onto objects in a non-arbitrary manner, i.e. they are referentially isomorphic, whereas with language-like representations, the mapping is constructed in a referentially arbitrary fashion. It is important to note that following this definition, many representations

Figure 3.1 Picture-like and Language-like representation: inspired by Martina A. Sasse [101]

referred to as “pictures” in everyday language are not picture-like, since the mapping relationship between a picture and what it represents can be arbitrary. Picture-like and language-like should be seen as two ends of a continuum, rather than discrete categories: many representations combine picture-like and language-like properties.
The mapping from an object to its language-like representation can be entirely arbitrary, or follow one of an infinite number of mapping rules. In any case, the connection between an object and its language-like representation, or the mapping principle which connects them, has to be established in a person’s mind for the language-like representation to be recognised as a representation of what it stands for. In other words, the representation will only have its intended effect if the connection or the mapping rules have been learnt previously by the viewer [101]. To illustrate this concept with an example would simply mean, in reference to the Figure 3.1, a person who is familiar with the DFKI building will recognise a picture-like representation (e.g. a photograph or drawing) of the DFKI building as such. Similarly, a person who has seen a picture-like representation of the DFKI building in a book is likely to recognise the DFKI building when they set sight on it. In contrast, a person who has only come across a language-like representation of the DFKI (the word “DFKI”) may not recognise the building construction in front of them as the DFKI building.

3.3 Cognitive Maps of Mental Representation

In this section a short discussion is given on another view of mental representation as Cognitive Maps which is considered relevant in the context of the thesis. Interested readers may further refer to the Book *AI and Soft Computing Behavioural and Cognitive Modelling of Human Brain* [65] for detailed discussions of the subject.
Cognitive maps are the internal representation of real world spatial information [65]. The exact form of representation is not clearly known to date. However, most psychologists believe that such maps include both propositional codes as well as imagery for internal representation [65]. For example, if we have to memorize the structural map of a city, we store the important places by their imagery and the relationship among

these by some logical codes [65]. This implies some sort of mental map is encoded, the relationship in this context then refers to the distance between two places or their directional relevance, for example, "city hall is south of railway station at approximate distance of 2 Km". How exactly people represent distance in their cognitive map is yet a mystery [65]. McNamara and his colleagues [22] made several experiments to understand the process of encoding distance in the cognitive maps. They observed that after the process of encoding the road maps of cities is over, people can quickly remember the cities closely connected by roads to a city under consideration. But the cities far away by mileage from a given city do not appear quickly in our brain. This implicates that there must be some mechanisms to store the relative distances between elements in a cognitive map. Besides representing distance and geographical relationship among objects, the cognitive maps also encode shapes of the pathways connecting the objects [65].

3.4 Mental Model

This section discusses Mental Model, the importance of the topic is relevant to the understanding of concepts formation in human mind. This theory is relevant in designing application which models human way of thinking, thus relevant for the Semantic Desktop application.
Mental Models have been studied by Cognitive Scientists as part of efforts to understand how humans know, perceive, make decisions, and construct behaviour in a variety of environments. Philosophers have always been interested in *how we think about the things in our world and how it is represented in our minds*? The term *Mental Model* was first mentioned by Craik in his 1943 book, *The Nature of Explanation* [20]. It said that humans make use of internal models of external reality, which enable them to better understand and react to situations in their environment. From his point of view, people operate on mental representations to simulate real world behaviour and produce predictions. In other words this implies humans are not just physically situated in its environment, but they also have their own internal model of it, which allows them to deal with that external reality of the world.
After Craik, literature on Mental Model appeared in three theoretical approaches are examined: Johnson-Laird's (1983) [53] theory of Mental Models, a collection of work on Mental Models of natural phenomena and devices by Genter and Stevens (1983) [37], and Paivio's (1986) [86] dual coding approach for classification of mental representations.
Johnson-Laird's volume proposed Mental Models as a way of describing the process which humans go through to solve deductive reasoning problems. His theory included the use of a set of diagrams to describe the various combinations of premises and possible conclusions [53]. In order to understand a real-world phenomenon, a person has to hold a what Johnson-Laird [53] describes as a working model of the phenomenon in her mind. Mental Models are not imitations of real-world phenomena, they are

rather simpler. They do not correspond completely to what they model. Laird argues that adding information beyond a certain level does not increase its usefulness. A Mental Model which explains all aspects of the phenomenon that a person interacts with is an appropriate one. In order to provide explanation, it has to have a similar structure to the phenomenon it represents. It is this similarity in structure which enables the holder of the model to make mental inferences about the phenomenon which hold true in the real world.
Johnson-Laird proposed three types of mental representations:

1. Propositional representations : which are pieces of information resembling natural language.

2. Mental Models: which are structural analogies of the world.

3. Mental imagery: which are perceptual correlates of models from a particular point of view.

Another book appeared in the same year by Gentner and Stevens. Gentner and Stevens proposed that Mental Models provide humans with information on how physical systems work. This approach could be generalized to a number of situations that humans face, including the behavior of objects according to laws of physics [37].
The fundamental philosophical issue addressed within the context of Mental Model that *things are not the way it is represented in our thoughts*, for instance thoughts about computer are not computer itself, rather probably a conceptualization of the features of computer. The question is then how the abstract thoughts manage to represent the things in such a way, even though there are missing informations. More interestingly, our thoughts are not always restricted to represent existing things, but there are things that cannot possibly exist(rectangular basketball), things that do no exist (unicorn), things which are not perceivable (limit of universe). How all these representations are possible without the things existing itself or the way it exist. Human thoughts have *semantic content*, that is missed in computers. For instance, when a number is added to itself it is twice the number, this is general principle for computation which an algorithm computes for computers, but for humans we have more intuitive information processing mechanism and deeper understanding, humans can rank the worth of computation based on thought content. According to Dietrich [26], when a computer does addition there occurs a cascade of causal processes which implements an algorithm that in turn, if followed exactly guarantees that two numbers will be added. We can make an analogy to wonder why computers and its processing is different than humans, lets take a Coffee machine example, a coffee machine doesn't know at all about the type of coffee, nor does it represent coffee and also it has no knowledge about the coffee it is preparing. It is given rather a configuration to use different ingredients to produce specific coffee types. Can we encode semantic content to improving this situation in an intelligent machine?. If yes, then we can hypothesize of thinking computer or at least attempting towards a human type information

processing rather than simple procedural computations without any thought content involved.

> *One way out of this dilemma is to attempt to develop a philosophical theory of mental content that clearly explains how thoughts get the content that they do. Then we could just check to see whether computations could get content in the same way. If they can, then AI is on firm ground, if they cannot then AI is without hope [26].*

According to Dieterich's comment the nature of semantics is viewed from two perspectives.

- *world-mind relations*: Treats semantics as essentially associated with truth, causation and getting along in the world.
- *mind-mind relations*: Treats semantics as essentially associated with being able to draw certain inferences, construct plans and in general determine how one thought and representation relates to another.

The two views mentioned above are necessary to understand and develop the theory of representational content. Within the Semantic Desktop framework a computer can be causally connected to the environment and its representations can be implemented. The Semantic Desktop could be a proxy to user's world view to represent and relate concepts a person keeps in his mind. Although a thought content would still remain a problem for computers to comprehend.

The Semantic Desktop is a relatively new research approach motivated to tackle the challenges for Personal Information Management to help the users making sense of their ever increasing personal information. Cognitive Science research perspectives help to develop a theoretical base here, thus the Mental Model would surely become the vocabulary for the Semantic Desktop community for representing complex and ever changing world of information. Also for the HCI practitioners a Mental Model provides a set of beliefs about system functionality. Human interactions with system is based on these beliefs [84].

Usability issues of the Semantic Desktop are also tightly connected to the user's Mental Model. But it is quite challenging to meet the needs of an expert as well as a novice users' Mental Model, further discussion explains the reason. A design of the Semantic Desktop should be consistent with person's natural Mental Model about the concepts, ideas and everyday objects encountered in environment. For instance, the way people organize their paper-work while doing a specific task like writing a thesis or working on a project, this should be reflected in the Semantic Desktop, all the relevant objects should be related and tagged in a sensible way to efficiently organize the work. The Semantic Desktop should provide an interface to model the physical paper-way of organizing with which a user is most familiar in daily activities.

Many existing systems demand the users to adjust the way a system works. A system with inaccurate Mental Model leads to frustration and inconvenience. Moreover with

an increasing demand for usability in technology products and the peoples dependence on computers, we have to expect the non-experts interacting with the system for personal information management. Such user could be lacking technical expertise and tolerance. Role of technology products such as the Semantic Desktop must accommodate the needs of the users of future generation who are more diverse, less technical, very explorative and quite impatient [38]. The system designer bores the responsibility of capturing user's expectations and hypothesize more about user-adaptiveness to deliver intuitive and predictable system consistent with the user's Mental Model. Please refer to Section 4.2 for discussion on design methods for applying Mental Model on the Semantic Desktop goals.
Cognitive Science gives a better insight of understanding Mental Models but capturing and validating users Mental Models poses difficulties, the potential for rewards of improved design and increased usability based on correct Mental Models compensate for the effort, but they are still an open area of challenging research.

3.5 Constructivism

The section highlights the personal constructivism of the real world. An overview of Constructivist theory is discussed. Philosophical thought is considered necessary in order to build a Personal Ontology model which is discussed later in Section 4.4. How a person makes his own sense or meaning of real world to understand this we need to give an insight and gain from the Constructivist theory.
The basic premise of Constructivism is that we construct our perception of the world around us, visually, conceptually, intellectually, and with respect to behaviour, from what is available to our senses and experience that this is not a learned process from an outside source or other form of input, that we gather information via perception and assemble it in human terms because of our internal neural structure, which doesn't vary much from one individual to another.
Each of us generates our own *rules* and *Mental Models* (see Section 3.4) , which we use to make sense of our real world experiences. Our perceptions are thought to be essentially along the same lines because

- we live in the same world among members of our own species, i.e., a human environment.
- our brains are structured to perceive, learn, think, and behave in essentially the same way.
- the outcome of these factors varies only with environmental differences.

In the constructivist perspective, knowledge is constructed by the individual through her interactions with her environment. It is a Conceptual theory for human learning and is applied for instructional design methods. Human learning, is therefore, the process of adjusting our Mental Models to accommodate new experiences.

There are several guiding principles of constructivism according to [51]

1. Learning is a search for meaning. Therefore, learning must start with the issues around which people actively try to construct meaning.

2. Meaning requires understanding wholes as well as parts (see Section 3.6 for Gestalt Theory). And parts must be understood in the context of wholes. Therefore, the learning process focuses on primary concepts, not isolated facts.

3. To construct meaning in people, we must understand the Mental Models (see Section 3.4) that people use to perceive the world and the assumptions they make to support those models.

4. The purpose of learning is for an individual to construct her own meaning, not just memorize the "right" answers and regurgitate someone else's meaning. Since education is inherently interdisciplinary, the only valuable way to measure learning is to make the assessment part of the learning process, ensuring it provides people with information on the quality of their learning.

Martin Dougiamas [29] talks about "faces of Constructivism" as shown in Figure 3.2, the following discussion follows his views *Trivial constructivism*: The simplest idea in

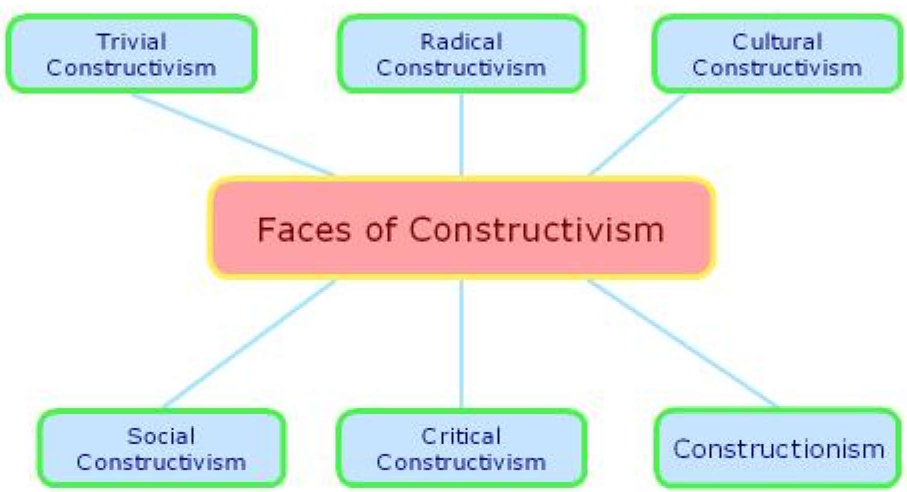

Figure 3.2 Faces of Constructivism

constructivism, and the root of all the other shades of constructivism, is what Ernst von Glasersfeld(1990) calls trivial constructivism, also known as personal constructivism. The principle has been credited to Jean Piaget, a pioneer of constructivist thought, and can be summed up by the following statement: *Knowledge is actively constructed by the learner, not passively received from the environment.* It is not very

much clear here what is environment and how knowledge is built while interacting with environment.
Radical constructivism: Radical constructivism adds a second principle to trivial constructivism (von Glasersfeld, 1990), which can be expressed as: *Coming to know is a process of dynamic adaptation towards viable interpretations of experience. The knower does not necessarily construct knowledge of a "real" world.*
Radical constructivism does not deny an objective reality, but simply states that we have no way of knowing what that reality might be. Mental constructs, constructed from past experience, help to impose order on one's flow of continuing experience. However, when they fail to work, because of external or internal constraints, thus causing a problem, the constructs change to try and accommodate the new experience. So the question arises how can people with different world-views communicate? From a radical constructivist perspective, communication need not involve identically shared meanings between participants. It is sufficient for their meanings to be compatible according to (Hardy and Taylor, 1997). If neither of the parties does anything completely unexpected to the other, then their illusions of identically shared meaning are maintained according (Ernst von Glasersfeld, 1990). The emphasis here is still clearly on the individual learner as a constructor. Neither trivial nor radical constructivism look closely at the extent to which the human environment affects learning: it is regarded as part of the total environment. These issues are focussed on in more detail by social, cultural and critical constructivism. For more detailed discussions on those aspects please refer to [29] as they go beyond the scope of this thesis.

3.6 Gestalt Theory

> *[...] the world we see around us is the real world itself, or whether it is merely a copy of the world presented to consciousness by our brain in response to input from our senses.* - Stevan Lehar Ch.1 in his Book: The World In Your Head [69]

Gestalt theory is based on mental perception of the world. If we look wikipedia we would find its historical origin as the theory that originated in Austria and Germany by the end of 19th century. The founders of Gestalt theory are Germans Max Wertheimer, Wolfgang Kohler, and Kurt Koffka. Gestalt is a German word and its meaning can be translated into English approximately as "form, shape or pattern" (Chambers English Dictionary, 1988). These theorists focused on different aspects of Gestalt that have developed throughout the 20th century across multiple disciplines [117]. The essential idea that dominates the basic tenets of theory in the formation of meaning or concepts: "the whole is greater than summation of its parts". For example, the meaning of a Computer is altogether different than the meaning of its constituents (CPU, monitor, keypad, mouse etc.). When we view the whole, a cognitive process is associated which implies that the mind makes a leap from comprehending the "parts" to realizing the "whole" [117]. The fundamental "formula" for Gestalt Theory according to translation of Wertheimer' classical article by Willis D. Ellis [123] can be illustrated as: There are wholes, the behaviour of which is not determined by that of their individual elements, but where the part-processes are themselves determined by the intrinsic nature of the whole. It is the hope Gestalt theory to determine the nature of such wholes. In the words of Max Wertheimer, the basic thesis of Gestalt is defined as follows:

> *The basic thesis of gestalt theory might be formulated thus: there are contexts in which what is happening in the whole cannot be deduced from the characteristics of the separate pieces, but conversely; what happens to a part of the whole is, in clear-cut cases, determined by the laws of the inner structure of its whole.* - Max Wertheimer, Gestalt theory. Social Research, 11 (translation of lecture at the Kant Society, Berlin, 1924)

Gestalt theory has been proposed for the concrete research during the time when European science had been based on one fundamental characteristics, that "Science" means breaking up complexes into their component elements. Isolating the elements, discovering their laws, then reassembling them. This implied basically all the wholes are reduced to pieces and piecewise relations between different pieces [123]. The theory demanded high attention and scientific investigation in a challenging way, which were apparent from Wertheimer's article, he claimed while proposing Gestalt Theory that; *"This is not merely the proposal of one or more problems but an attempt to see what is really happening in science".* The claim further took strong position that the problem could not be solved by listing possibilities for systematization, classification, and arrangement. Rather the approach should be guided by the new method and by the concrete nature of the things themselves which we are studying, and set ourselves to penetrate to that which is really given by nature [123]. Another challenging difficulty that could be concluded from the example as follows: *Suppose a mathematician shows you a proposition and you begin to "classify" it. This proposition, you say, is of such and such type, belongs in this or that historical category, and so on. Is that how the mathematician works? "Why, you haven't grasped the thing at all, "the mathematician will exclaim. "See here, this formula is not an independent, closed fact that can be dealt with for itself alone. You must see its dynamic functional relationship to the whole from which it was lifted or you will never understand it." What holds for the mathematical formula applies also to the "formula" of Gestalt theory. The attempt of Gestalt theory to disclose the functional meaning of its own formula is no less strict than is the mathematician's.*
Some of the basic laws defined under Gestalt theory, which are further illustrated in details in [117, 77, 15] are as follows:

1. *Law of Proximity*: The law says objects (real or virtual) form the group if they are near, irrespective of their shapes and size [77]. For example, a set of triangles and circles would form a group if both are placed near than if they are placed apart.

2. *Law of Closure*: Gestalt theory seeks completeness; with shapes that aren't closed, they seem incomplete and lead the learner to want to discover what's missing, rather than concentrating on the given instruction. Moore and Fitz draw boxes around the illustrations in their instruction, to separate it from other illustrations and group the elements of one illustration together. Otherwise, the user is not sure which parts belong to what illustration [77].

3. *Law of Symmetry*: Gestalt theory espoused the symmetrical so that the learner is not given the impression that something is out of balance, or missing, or wrong [77].

4. *Law of Good Continuation*: This Gestalt law states that learners "tend to continue shapes beyond their ending points" [77]. The lines identifying switch parts on Moore and Fitz's example simply continued onto the graphic itself. The improved version stopped the lines before reaching the graphic and used arrowheads to identify specifically to which part of the graphic the label belonged [117, 77].

5. *Law of Similarity*: Gestalt theory states that objects that appear to be similar will be grouped together in the learner's mind [77].

Gestalt theorists were interested in the "whole" of the problem or experience, unlike behaviorists who relied on concrete, observable human behavior to determine whether learning occurred. For Wertheimer, truth was determined by the entire structure of experience rather than by individual sensations or perceptions [123]. By contrast, human information processing states that "each human processes in his own distinctive fashion" [100]. We do not go into the details here, but to prune our thoughts to understand what we need to follow from Gestalt theory and its defined laws within the context of this thesis. The Laws defined above can also be used for User Interface design in the Semantic Desktop to improve usability features. Interested readers may refer to [117], [15] to know the overview and different research applications. We are only interested to look into the perspectives of the Theory which could help us develop our sound theory in order to build our Ontology for PIM (see Section 4.4) which should be able to reflect users "world-view" in computers, as artefacts. One possible application of Gestalt theory is found in Learning theory and Instructional design, to develop pedagogical methods for pupils.

3.7 Cognitive Overload

Information bombardment or information overload which is also termed as *infoglut*, and implies the sheer volume of data from internet including e-mail, voicemail, fax, news feeds, commercial online services, keeps on growing. It is growing much faster beyond management by an information worker. It has been proclaimed and cited several times that knowledge workers are becoming overwhelmed with infoglut, one

possible reason has been felt about a gap between the volume of information and the tools we have to assimilate that information into useful knowledge.
As knowledge workers, we know how often we are bombarded with information in our day to day activities. As rightly thought by Kirsh [63], the information comes in all categories of urgency, size, media, complexity and value. To deal with such information we have to make rather quick decisions about its usefulness, re-usability or simply purge if it belongs to trash can. Making decisions for filing information are expensive with respect to time, cost [13], stress, and effort. Even though we have many tools which could support such decisions, we still need to know the filing "sense" of our information, the "sense" has to do something with semantics of filing structure or categorization. In Figure 4.2 a possible categorization is made to illustrate the types of information encountered by a knowledge worker.
Cognitive science has emerged as a new discipline of knowledge that deals with the mental aspects of human beings. The chapter provided a view of cognitive and philosophical perspectives of the human cognition. It elucidated various theories of Cognitive Science and a Contrast has been presented with Artificial Intelligence, which on the other hand, is a young branch of science that is based on building intelligent machines.
This Chapter discussed various philosophical aspects which has been thought to be relevant in context of the Semantic Desktop. In the following chapter we will narrow down our discussion to Mental Models. Mental Models discussed in this chapter seem to be of vital importance for understanding user thoughts, world-view and behaviour. It could be formalized and further studied in developing software to model users personal requirements. With this aim, in the next chapter an attempt has been made to combine philosophical theories to make a formal approach which would help the designers of the Semantic Desktop.

Chapter 4

Cognitive Semantic Desktop

The challenges of Personal Information Management discussed in Section 2.8, could be re-visited with new dimension of Semantic Web technologies. This implies applying the ideas and technologies of Semantic Web to the personal computers to give birth to the Semantic Desktop [104]. The Semantic Desktop was first proposed by Stefan Deckar, since then it has become a topic of interests for the semantic web researchers, specially for personal information management, the first research prototype that implemented the idea was written in Leo Sauermann thesis [102]. The Gnowsis [72] leader Leo Sauermann quite often reports:

> *We think that in anticipation of a world-wide Semantic Web, we have to use the technology on a single PC.*

Modern operating systems lack state-of-the-art support for Personal Information Management. For instance, issues like multiple filing of the same file in different folders or making a link of the photo of a person to the address book entry of the same person is not possible as the system does not know the concept of persons. There are also many issues referred as PIM challenges in Section 2.8.
Moreover, categorization scheme created in the file structure cannot be used to organize bookmarks or emails - we always have to recreate our Mental Models again and again [72, 106]. Solution to this would be an RDF based approach that would enable to build and maintain a network of semantic links between resources, cross-application and cross-media. Existing data sources are converted into the Resource Description Framework and what today is known as a file or an email is tomorrow a resource represented in RDF and described through an ontology. The presentation will include our approach to on-the-fly data extraction and integration, based on RDF-Schemas and a Jena based framework. The architecture is implemented in the Gnowsis[1] open source project and can be used as a basis for your own work and your information management needs.
Given the huge amount of information and incremental nature of PIM activities, indeed a model to deal with personal information should exploit the way humans think,

[1] www.gnowsis.org

we already have the vision from Vannevar Bush *As we may Think* [121]. Many research from the area of Cognitive Science give some generic ideas that human mind is quite flexible, and our learning abilities, memorizing and conceptualization is quite often based on analogy of relationships among the *real-world* objects. In digital ambience in relevance to Human Computer Interaction (HCI) we have distributed and different information but they are often connected with multiple relationships, explicitly or implicitly, which means either it is visible from a given information model (explicit) or it could be inferred (implicit).
Let us take specific example to illustrate this idea. Suppose there is going to be a *Semantic Web Conference* in *Berlin* in *Germany* as represented in Table 4.1 we could see many columns have common entries (like the country *Germany* can be found in several categories, namely ESWC, Location, Europe). This approach is more intuitive and flexible for information filing and thus enables the user to express her personal and often abstract concepts better than the hierarchical structure, which restricts user to strict categorization and this is also not intuitive semantically. This issue is defined and implemented in Gnowsis [72] as a *Personal Information Model*, see PIMO in Section 4.4.

Realizing Semantic Web on Desktop Computers is a main vision of the Semantic

Table 4.1 Table (An example for semantic information model)

ESWC	**Semantic Web Conferences**	**Location**	**Europe**
Germany	International (ISWC)	Europe	ESWC
Berlin	European (ESWC)	Germany	Germany
...	Asian (ASWC)	Shanghai	...

Desktop [104, 24] community, in which all desktop resources can be described with metadata and identified by *uniform resource identifiers* URI [2].
This technology may also be transferred to a desktop computer, and enable users to access personal data resources in a fast and convenient way. The technical extension from the Semantic Web to the personal computer brings the Semantic Desktop, the next-generation PIM and collaboration infrastructure.
A Semantic Desktop provides features for individuals to store all her digital information like documents, multimedia and message. Personal Ontologies are defined which allow the user to express personal Mental Models and form the semantic glue interconnecting information and systems. The Applications respect this and store, read and communicate via ontologies and Semantic Web protocols. The Semantic Desktop is an enlarged supplement to the user's memory [104, 107].

[2] http://www.w3.org/Addressing/

4.1 Semantic Desktop as Cognitive Amplifier

In his paper David Kirsh [63] points out that too often the information falls between the cracks of our classifying scheme and we are faced to go through the challenging process of creating new indices and categories or painfully stretching the old ones. Whenever we create a new category or stretch an old one there is the danger that where we place the information will be forgotten next time we look for it. This is all stressful specially because the less one has system for dealing with invaded information (see Figure 4.2)and the more one must make ad-hoc decisions for each incoming piece of information.

> *The psychological effort of making hard decisions about invaded information is the first cause of cognitive overload* [63]

The amount of *cognitive energy* required to assign a category must be considered when classifying, organizing, and retrieving information from and individual's personal information space [8].
Such classification behaviour in PIM systems raises the questions about individual *productivity*, *organizational efficiency* and the *quality of hardware and software* used to support collaborative work [8].
Vannevar Bush[121] describes how the human mind operates by association. With one item in its grasp it quickly moves to the next item suggested by the association of thoughts stored as a web of trails in its brain cells. He further describes how some of these trails fade over time and are forgotten. The solution he proposed was a desktop memory extender called "Memex", which contains all of the documents and books a person had come across in her lifetime along with the various associative trails she had made through this collection.

> *The physician, puzzled by its patient's reactions, strikes the trail established in studying an earlier similar case, and runs rapidly through analogous case histories, with side references to the classics for the pertinent anatomy and histology. The chemist, struggling with the synthesis of an organic compound, has all the chemical literature before him in his laboratory, with trails following the analogies of compounds, and side trails to their physical and chemical behavior. The historian, with a vast chronological account of a people, parallels it with a skip trail which stops only at the salient items, and can follow at any time contemporary trails which lead him all over civilization at a particular epoch. There is a new profession of trail blazers, those who find delight in the task of establishing useful trails through the enormous mass of the common record. The inheritance from the master becomes, not only his additions to the world's record, but for his disciples the entire scaffolding by which they were erected*
> - V.Bush, As We May Think.

He envisioned these trails being exchanged between people as a way of sharing knowledge and identified a new profession called trail blazers who would create associative trails to guide others through their knowledge [87, 121].

4.2 Applying Mental Models to Semantic Desktop

This section describes how Mental Models as described in Section 3.4 could be applied as design methods for the Semantic Desktop development. The Semantic Desktop should be designed to help users build productive Mental Models of system functionalities. A user should be informed through interfaces in a such a way so that he could exploit the maximum benefit of the Semantic Desktop goals.
There has been excellent efforts in HCI to address the issues of Mental Models [22, 101] to have a better understanding of user-interaction with the systems. According to McDaniel [75] Mental Models are the conceptual representation within the person's mind that helps her to understand the world [67]. Mental Models may be (1) An Image, (2) A script, (3) A set of related Mental Models, (4) A controlled vocabulary, or (5) A set of assumptions.

> We should create these Mental Model descriptions during user analysis to document users' current understanding. Then, during a design phase, we should create the target model to show the Mental Model we want users adopt. - McDaniel [75]

Quite often Mental Model may contain aspects of one or more of these types of models. For example a user may have an image of the look of an interface, a script of the process to be followed while performing certain task, knowledge of the vocabulary system uses, and assumptions about system behaviour. In Gnowsis context we can identify success stories by individual users about their experiences on how the Semantic Desktop should ideally work. Comparing their answers would reflect different Mental Models and expectations. This should be used for redesigning prototype to exploit system features and improve usability.
Let's take a scenario where a user wants to draft a letter using an editor (notepad, word pad etc.). User has certain intention behind and specific goal (purpose and subject), then address book is looked up to find the contacts (in case of mailmerge) and folders are searched to make any file attachment. A user might also like to save draft in case more information has to be added. It is important to follow from the example, that there are two different views to analyze the scenario. On one side we have a user with a "Mental Model" who wants to use the system for a specific task, on the other side there is a computer system which follows user behavior and knows user preference and goals (i.e. the system keeps a user model).
The task of HCI research would be to map the Mental Model to the user model for the person to use the system more effectively. Normally the Mental Models people create of computer systems are inaccurate [83]. By designing the systems that help people

to create a more accurate Mental Model of the system, usability would significantly improve [67].
The idea is that if the designer creates the design model right, and communicates the model successfully through the system image, the users interacting with the system will develop an appropriate user model, which will allow them to interact with the system successfully [101]

> *It could be deduced from the above discussion that the "accuracy of Mental Model is proportional to the usability of the system"*

So far Mental Models are promising human factors in consideration of design, but the real difficulty exist in methodology to design system that would help the user to create best Mental Model [52]. Therefore the efforts should be focused on providing an accurate initial Mental Model and capturing user behavior over time. In this context, PIMO (see Section 4.4) can be referred here as an ontology to support initial Mental Model.
The generic design methods as described in the book *IBM Common User Access Guidelines* [4] and some other related references could be used to support user's Mental Model on the Semantic Desktop, they should be based on following criteria:

- **Simplicity**: Mental Models are meant to simplify the reality, the Semantic Desktop interface design should simplify actual system functions. A function should only be included if a task analysis shows it is needed. Basic, most frequently used functions should be immediately apparent, while advanced functions should be less obvious to users. Cluttering an interface with many advanced functions only distracts users from accomplishing their goals. A well-organized interface that supports users tasks fades into the background and allows the user to work efficiently.

- **Familiarity**: An interface for the Semantic Desktop should allow users to build on prior knowledge, especially knowledge gained from experience interacting in the world. The use of concepts and techniques that users already understand from their real world experiences allows them to get started quickly and make progress immediately. The Windows operating system (and originally the Apple system) uses an office metaphor to leverage existing knowledge in this way. Its folder and document icons combined with drag and drop functionality, allow users to grasp basic concepts more quickly.
  A small amount of knowledge used consistently throughout an interface can empower the user to accomplish a large number of tasks. Concepts and techniques can be learned once and then applied in a variety of situations. By choosing to be consistent with something the user already understands, an interface can be made easier to learn, more productive, and even fun to use.

- **Availability**: An interface should provide visual cues, reminders, lists of choices, and other aids, either automatically or on request. Humans are much better at recognition than recall [4]. Users should never have to rely on their own memory for something the system already knows, such as previous settings, file names, and other interface details.

- **Flexibility**: An interface should support alternate interaction techniques, allowing users to choose the method of interaction that is most appropriate to their situation. Users should be able to use any object in any sequence at any time. Flexible interfaces are able to accommodate a wide range of user skills, physical abilities, interactions, and usage environments.

- **Feedback**: A system should provide complete and continuous feedback about the results of actions [84]. Any feedback a user gets that supports her current Mental Model strengthens it. Feedback that contradicts the current Mental Model causes it to adapt. Immediate feedback allows users to assess whether the results were what they expected and take alternative action immediately if necessary.

- **Safety**: A user's actions should cause the results the user expects. Users should feel confident in exploring, knowing they can try an action, view the result, and undo the action if the result is unacceptable. Users feel more comfortable with interfaces in which their actions do not cause irreversible consequences. This is also relevant in order to provide reliability to user to perform a given task with trust of not loosing important resources and the user security is preserved.

- **Affordances**: An affordance refers to the properties of an object (the kinds of operations and manipulations that can be done to the particular object. For instance, folders afford opening and storing files, a trash can affords throwing something away. Affordances provide clues to how an object can be used. Perceived affordance is what a person thinks can be done with an object. An interface can take advantage of affordances by using real-world representations of objects in the interface. Users will intuitively know what to do with the object just by looking [84].

- **User Expressivity**: The Semantic Desktop should enable the user to express her personal concepts. Users should be allowed to make their real-world concepts in an intuitive way. User tend to categorize their information according to their own sense, thus any strict categorization feature should be avoided. This would support user's information filing behavior.

- **Preserving Association (user context)**: We have known from the vision of Bush [121] that human mind operates by association. With one item in its grasp it quickly moves to the next item suggested by the association of thoughts stored as a web of trails. The Semantic Desktop should be able to provide users with necessary priming needed to preserve the context in which a user is currently in and a possible trails to move other related contexts. For example, a user reading a paper might also like to know the authors homepage, other co-authors and related publications.

- **Improving accuracy in Mental Model**: Accuracy of Mental Model is proportional to Usability of the system. On one side we have a user with a "Mental Model" who wants to use the system for a specific task, on the other side there is a computer system which follows user behavior and knows user preference and goals (i.e. the system keeps a user model). The task of the Semantic Desktop would be to map the Mental Model to the user model for the person to use the system more effectively. Normally the Mental Models people create of computer systems are inaccurate [83]. By designing the systems that help people to create a more accurate Mental Model of the system, usability would significantly improve [83]. This means that if the designer creates the correct design model and communicates the model successfully through the system image. Then users interacting with the system will develop an appropriate user model, which will allow them to interact with the system successfully.

- **Personalization**: Personalization of the Semantic Desktop systems would enhance user satisfaction and productivity. Each person has her own mental representation of the concepts from the real-world. The Semantic Desktop is a way to express these mental concepts with respect to each user. Users prefer to make their own customization according to their interests, motivation and expertise. By giving the user freedom to personalize their concepts would support their memory and familiarity. This would encourage the user to use the Semantic Desktops in an intuitive way.

Mental Models are meant to simplify the reality. They are promising human factors in consideration of design, but the real difficulty exist in methodology to design system that would help the user to create best Mental Model [52]. Therefore the efforts should be focused on providing an accurate initial Mental Model and capturing user behavior over time. This approach has been taken in PIMO- an Ontology to support initial Mental Model of user, see [103] for details.
Cognitive science gives a better insight to understand Mental Models but to capture and validate users Mental Models poses difficulties, the potential for rewards of improved design and increased usability based on correct Mental Models compensate for the effort, but they are still an open area of challenging research.

4.3 RDF model for Semantic Desktop

This section addresses the issue of information modelling suitable for the Semantic Desktop, and how such a model could facilitate user to easily manage their personal resources on desktop computers.
Resource Description Framework (RDF) is the backbone and the main foundation

for Semantic Web technology. It is a method or a data model designed for expressing knowledge in a decentralized world, in which computer applications make use of distributed, structured information spread all over internet.
RDF was originally created in 1999 as a standard on top of XML for encoding metadata that means literally, data about data. Metadata is like who authored a web page, what date a blog entry was published, etc., information that is in some sense secondary to some other content already on the regular web. Since then, and perhaps especially after RDF[3]Specification at W3C, the scope of RDF has really evolved into something greater. The most exciting uses of RDF aren't in encoding information about web resources, but information about and relations between things in the real world: people, places, concepts, etc.[114].
RDF is a general method to decompose knowledge into small pieces, with some rules about the semantics or meanings of those pieces[114]. The main idea is to have a method so simple that it can express any fact and yet so structured that computer Applications can do useful things with knowledge expressed in RDF.
RDF applications can put together RDF files posted by different people around the internet and easily learn from them new things that no single document asserted, this makes RDF very suitable for distributed knowledge representation. This happens b y linking of RDF documents happens with common vocabularies and allowing any document to use any vocabulary. This flexibility is fairly unique to RDF, and thus facilitates knowledge representation better as a *graph* rather than *tables* as in relational databases or *hierarchies* as in XML.

This also leads to point in this thesis to agree that semantic structures as provided by RDF could better replace hierarchical structures for creating and organising resources in the Semantic Desktop

The specific use cases, as described by Richard Cyganiak on the W3C's Semantic Web mail list:

- *You want to integrate data from different sources without custom programming.*
- *You want to offer your data for re-use by other parties*
- *You want to decentralize data in a way that no single party "owns" all the data.*
- *You want to do something fancy with large amounts of data (browse, query, match, input, extract), so you develop (or re-use) a generic tool that allows you to do this on top of the RDF data model (which has the advantage of not being tied to a proprietary data storage/representation technology, like a database dialect).*

RDF is very much suitable model for representing, modelling and storing personal information. It provides interoperability between applications that exchange machine

[3]http://www.w3.org/TR/rdf-primer/

understandable information. It is well suited for facilitating Web Services in resource discovery, cataloging, content rating and privacy policies [25].
RDF as a flexible semi-structured data model is appealing for several reasons. First, RDF supports ontologies created by the user and tailored to the user's needs. At the same time, system ontologies can be specified and evolved to support a variety of high-level functionalities such as flexible organization schemes, semantic querying, and collaboration.
RDF can be well exploited for managing users' information. The semi-structured nature of RDF lends itself well to the heterogeneous disposition of personal information corpora. In addition, since RDF provides a standard, platform-neutral means for exchanging metadata, it naturally facilitates sophisticated features such as annotation and collaboration. In this thesis, we propose and demonstrate a personal information management system that employs RDF as its primary data model [30, 61]. In addition, RDF can be used to engineer a component architecture that gives rise to a semantically rich and uniform user interface.
By aggregating various types of user's data together in a homogeneous representation, an opportunity is created for agents to make more informed deductions in automating tasks for users [25].

4.4 Ontology based approaches to PIM

The Ontology based approaches have many advantages. The section explores some of the several research directions to deduce this claim. One of the most common citation for ontology definition in Computer Science is *a shared and common understanding of a domain that can be communicated between people and across application systems* [39]. There are many possible benefits of using ontologies to construct the kind of tools that support knowledge management. This includes knowledge reuse, knowledge retention, managing change and adaptability, better documentation, improved maintainability, reliability, interoperability and better access to information [120]. Knowledge workers are accustomed to the use of applications such as email, appointment, document, calendar etc. Each of these applications exist as stand-alone entities, although all of them facilitate particular task but they are no way *integrated* in a sense that we could call a *semantic* connection between those entities. Therefore an appropriate interpretation of John Staurt Mill's [76] call for fundamental changes in our modes of thought would suggest that we look at *semantic integration* of the tools with which we perform knowledge work. In [5] the benefit of Ontologies are broadly defined as:

1. *Ontologies support knowledge visualization*:

2. *Ontologies support knowledge search, retrieval and personalization*:

3. *Ontologies serve as a basis for information gathering and integration*:

All the above mentioned advantages are relevant to the application of ontologies to the PIM.
There have been several initiatives [122, 126]to address the Ontology based approaches to PIM. Sauermann proposed (Personal Information Model)PIMO [103] for the Semantic Desktop and identified flaws in existing approaches in handling PIM. PIMO is expected to assist users for organising their personal information with higher expressive and flexible formalisms. In PIMO, there is a way to express mental concepts (Mental Model) in a formalized domain ontologies, that describes person's domain of interests. At the same time the separation between a mental concept and the resources are being taken care of, such that, what a user perceives in her life experiences, could be represented in computer systems using the PIMO model in the form of artefact. The essential idea has been to provide user with a set of features in PIMO to represent her Mental Model as an artefact on Personal Computers. In the Figure 4.1 my personal information structure is depicted, that highlights my current work involvement, my project associations as well as people I know along with my personal places of interests etc.

- *Thing*: Everything is considered as a thing (abstract concepts, physical objects, people, places etc.).
- *Resource*: An artefact of users personal information (web page, personal-note, publications etc.)
- *Mental Concept*: *A thing that represent the mental conceptualization of a user inside his information model, stored on a computer. The mental conceptualization is part of the cognitive system of the person, the concept in the information model is the point where such a mental conceptualization can be represented, identified and visualized on a computer system* [103].

Technically, the idea has been inspired by different ontology languages (RDF, OWL, SKOS and Topic Maps) and further work are to be done to incorporate theories of Mental Model and Ontology in Philosophical sense from the disciplines of Cognitive Science as discussed in this thesis.

4.5 Semantic Desktop Information-types

In Section 2.6 we described different organizing strategies, in this section we illustrate a possible model of information types for the Semantic Desktop. In the Figure 4.2 we illustrate a typical scenario of the information types encountered by knowledge worker in her daily activities. By knowledge worker we mean any user who has to deal with information for different tasks, knowledge workers(students, secretary, researchers, scientists etc.) are ideally considered to be those peoples who have the tendency towards organizing their (personal) information.
In the given figure (see Figure 4.2) we broadly categorize four different situations,

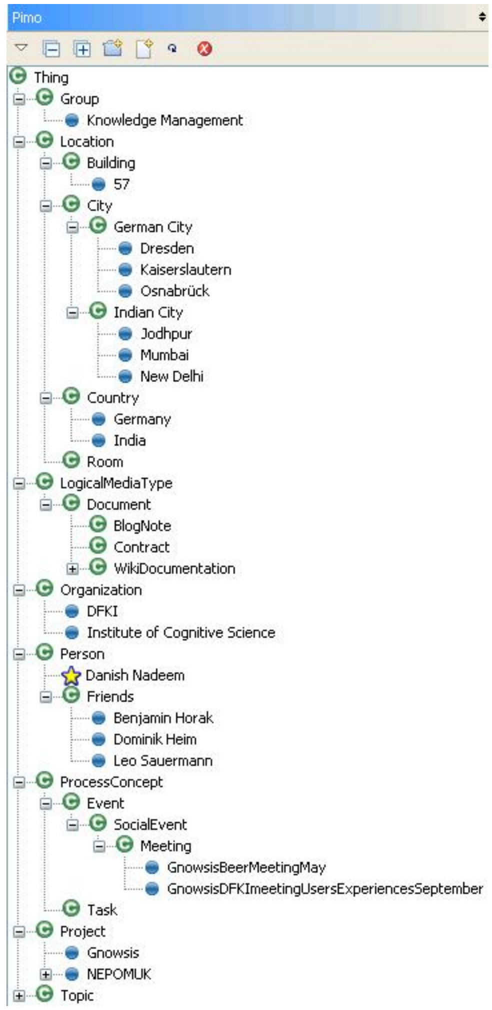

Figure 4.1 A example for Personal Information Model in Gnowsis

depicted as eclipse (namely- mended, invented, needed, invaded), each of the green arrows shows, user behaviour towards making information, inventing information, or the information needed by the user to support her daily chores. Also, one arrow in grey, that points towards user depicts, burden imposed on user by invaded informations, such information may consists of emails, newsletters, forums, mailing lists news, spams etc. We would like to fit in the Nepomuk scenario in the Figure 4.2, as defined earlier (see Section 1.9.5). A scenario may involve *Personas*, so according to the Nepomuk common understanding, a persona is simply a fictitious person that represents a target user group. Personas are a detailed description of the users and they are based on users studies on real people. They have goals and scenarios. They are useful to focus on the users during the design and give all stake holders in the project a clear picture of the users' needs and requirements. Everyone in the project

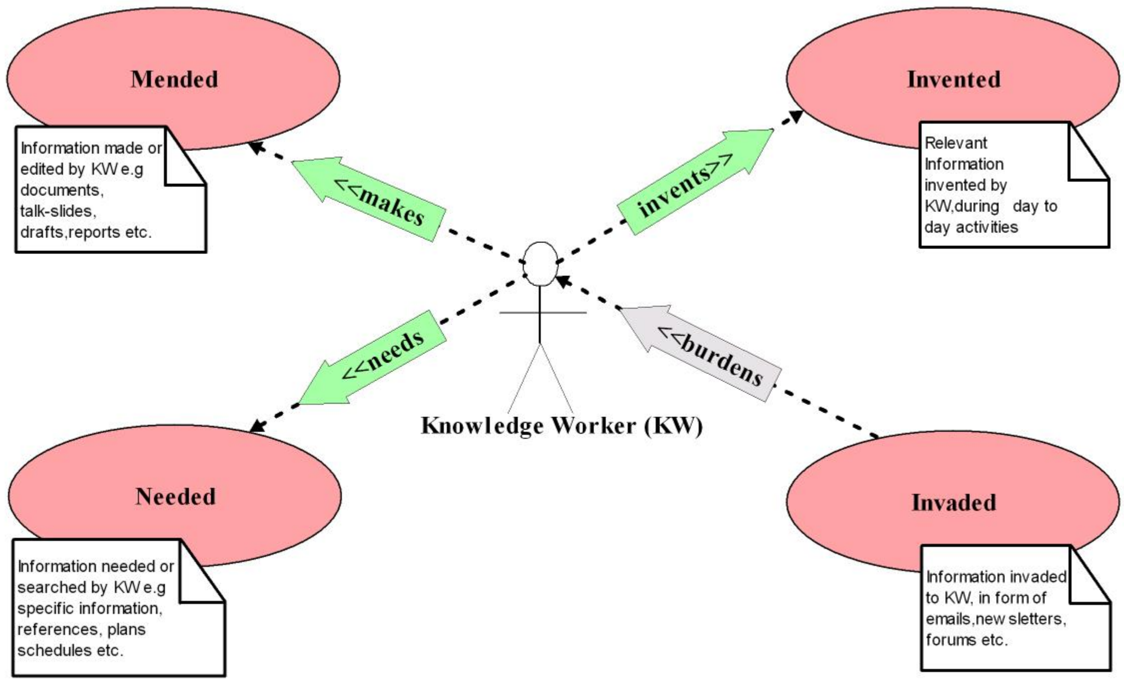

Figure 4.2 Daily Information Types for typical Knowledge Worker

has the same view of the users, thus personas are also a constant reminder of the users. In any given scenario, every persona has certain goals to fulfill.
We describe Dirk as a persona according to common understanding in Nepomuk (see Section 1.9.5):

Persona description

"Dirk is from Offenburg in Southern Germany and lives now in Karlsruhe. He is 28 years old and is semi-single. He has been dating Anna for a few weeks and it is starting to feel like a serious relationship. In his free time he likes to go running and he also likes to spend time with his friends. Dirk has a diploma in computer science and is doing his PhD at SAP Research in Karlsruhe. He has been working on a project that has just finished, but now he is starting to work on a project called CID, a large EU project with partners from many European countries. He reads and writes deliverables for projects and he travels a lot to the different partners and to SAP's headquarters in Walldorf where he has meetings with developers to coordinate the transfer of project results. Being creative and coming up with different ideas for a prototype is his favourite part of the job. Dirk does not have much control over how he spends a large part of the working week. He gets meeting invitations in his calendar and they become his to-do list for the week because he usually has to prepare for those meetings by reading or writing some report, deliverable or a presentation. He has a "real" to-do list where he adds tasks that are more general or long term. In the meetings he has a note book where he writes down things that he needs to remember

or when he get an idea of something to do in the project".
Goals

- Current goal: Manage the tasks he has in the project
- Current goal: Do good work in project CID
- Long-term goal: To get contacts in order to get a job after he is done with his PhD.

Scenarios

- DirkGettingInvolvedInAProject
- DirkGetTaskFromClaudia
- DirkDealWithE-mails
- DirkWritePaper
- DirkPlanTimeForWork

Within the scope of this thesis, we explain some of the above mentioned scenarios and goals to see how information types (see Figure 4.2) could help the persona to achieve the main goals.
When a given scenario is that *Dirk Getting Involved In A Project* or *Dirk Get Task From Claudia*, Dirk needs to categorize information according to the projects priority. This implies he has to decide which information he needs more frequently than others, thus in the given figure "needed" information is categorised accordingly by the actor:Dirk. In the next scenario when *Dirk Deals With E-mails*, one of his goal is to *Manage the tasks he has in the project*, he has to decide which emails are important and which are not, he is "invaded" by emails which might not be useful for his goals, thus tagging e-mails becomes his immediate task this feature are to be supported in the Semantic Desktop to minimize his information overload. In a scenario where *Dirk Writes Paper*, he makes notes and drafts, which is a type of "mended" information (see Figure 4.2).
Therefore, we summarize as follows from the above discussions that the given information type is a model for a typical knowledge worker working in a given scenario:

- Dirk Write Paper (Making information, inventing information, drafting notes)
- Dirk Deal With E-mails (Mending Information, drafting emails, tagging emails)
- Dirk Plan Time For Work (Needed information about appointment, calendar and schedules to plan for work)

This chapter identified the technical means of realizing the Semantic Desktop. The author's position is to claim Cognitive Semantic Desktop needs the application Mental Model (see Section 3.4) for the Semantic Desktop. Thus a discussion has been made and many guidelines have been suggested in Section 4.2. The chapter also explored Nepomuk project scenario and an attempt has been made to map this to the Semantic Desktop information types.

Chapter 5

Evaluating the Semantic Desktop

This chapter characterizes the evaluation challenges of the Semantic Desktop. The sections in this chapter are carefully written within the context of the Semantic Desktop evaluation. We first give a holistic overview about the PIM behaviour, which is a necessary step before we identify the goals and steps of evaluation. Then an overview is given of software usability evaluation to identify the forms of evaluation in practices. We highlight the challenges associated with evaluation design of PIM supporting software. Then certain evaluation criteria are elicited for the evaluation of PIM tools. Later in section, we explore several techniques which could be a relevant approach for the evaluation. We conclude the chapter with some results and methods we took for the evaluation of the Semantic Desktop prototype Gnowsis.

5.1 Holistic understanding of PIM behaviour

This section reports an exploratory study of everyday Personal Information Management, mainly the practices inspired from Section 2.7 and proposal made within the latest PIM Workshop report [60]. The findings would provide an empirical basis for the design of the Semantic Desktop prototypes and enhance features in Gnowsis[1].
The major challenges and difficulties involved in PIM study are because of the evolutionary nature of PIM behaviour. Apart from that one has to predict what kind of personal data would be needed by user at a future point of time. Boardman's cross-tool approach also highlighted the need to independently analyse PIM behaviour with respect to different set of tools like email files, and bookmarks for managing personal information. He also referred to Context and Consciousness: Activity theory and human-computer interaction [12], to claim that people often employ multiple PIM tools in support of their high-level activities (see Section 2.7). Challenges of PIM evaluation have also been reported in Teevan latest PhD thesis in context of *Personalized Search Systems* [115]. The evaluation approaches taken thus far in context of PIM involve the direct involvement of people finding information. This is a good in-

[1] http://gnowsis.opendfki.de/

sight about individual behaviour but it also poses difficulties in comparison of findings across different studies and test criteria. Evaluation of human-factors in interactive software design should be integrated with development phase to prove to be effective, because of the drawbacks reported in [6]. Evaluation should be used as a tool for information gathering within iterative design. User studies for PIM is a broad field and several aspects can be covered in study, nevertheless, some points are significant for example:

- User Study based on users would investigate users' requirements, contexts, motivations, expectations and tasks.
- Study based on usage would investigate what is the purpose of a particular information source to be used.
- Study focussed on the information system or service will investigate aspects of technology, design and evaluation [7].
- Study focus on the organization will provide the understanding of contextual aspects of the organizational setting. All the information highlighted above are needed to make a holistic case study.

As the user studies are context driven, and are typically multidimensional, which covers at least some of the topics and foci described above, they will generally require multidimensional methods with which to study their associated research questions [7].

According to the latest PIM Workshop report on Measurement and Evaluation by Diane Kelly [60], mixed-method approaches are recommended for the study of PIM. This applies to the use of both quantitative and qualitative methods to study users PIM behaviour. Quantitative data can be seen objective, quantifiable, discrete, generalizable, in contrast to the qualitative data which can be subjective, intuitively created and non-generalizable. User studies are, by definition, about people, behaviour and contexts. They need both quantitative and qualitative approaches to be combined to produce both the holistic view and the robust data needed to triangulate and thereby validate data collected [7].

In [59] Kelly proposed *Sharable Test Collections*. The creation of such a sharable test collections facilitates discovery and allows for rapid progress since building a good test collection is such a difficult and time-consuming task. For instance, according to Kelly, the test collection should contain more than just documents, topics and relevance judgments. Such a collection should contain information about users, their information needs and goals, their information-seeking context and their behaviours within this context. Sharable test collection is a good approach towards understanding holistic PIM behaviour. But at the same time it has several pros and cons associated. Summarized as follows:

- Pros

1. Test collection facilitate comparison of result across several tools.
2. Standard test collections makes possible the replication of earlier findings.
3. It allows investigation of alternative hypothesis.

- Cons

1. Difficulty in test collection because of major users' privacy concerns.
2. Since individual behaviour varies, collecting data from generic tasks and generalization over a small set of user would pose invalidity risk.

Thus concerning above issues, an ideal approach for test collection would include; for example, deciding what types of information to collect and what data types concern users' privacy which means asking users on what data to collect (avoiding others contacts from address book, emails etc.). The construction of test collection is a challenging issue needed to study PIM behaviour is of vital importance.

5.2 Software usability evaluation overview

A usability evaluation is any analysis or empirical study of the usability of a prototype or system [95, 96]. Ideally, the evaluation goal should provide feedback in software development, supporting an iterative development process. Usability evaluation helps designers to identify the problem related to the software's usefulness, understand the problem and its causes, so they could rectify and make necessary changes.
According to Scriven [108], evaluation is identified in two forms namely: *Formative evaluation* and *Summative evaluation*

- *Formative evaluation*: During the design process prototypes are produced and they are evaluated where the prototypes could be as simple as a sketch of few basic screens or a detailed description and implementation of a software architecture. In principle, the actual goal of formative evaluation is always to identify aspects of a design that can be improved to set priorities, and in general to provide guidance in 'how' to make changes to a design. An example of a typical formative evaluation would be to ask a user to think aloud while attempting a series of realistic tasks with a prototype system [95].

- *Summative evaluation*: The summative evaluation provides the measure of quality. It is performed to assess design result. A summative evaluation would answer the questions like: *Does this system meet its specified goal ?* or *Is this system any better than its predecessors and competitors ?*. They are mainly performed at the end of the development process to test if the system meets usability objectives. It may also be performed at the critical points during development to check if the system is meeting its usability objectives. This helps in deciding how much additional resources are required for a project. A typical summative evaluation would be to measure *performance times* and *error rates* for standard user tasks.

The differences between Formative and Summative evaluation was summarized by Bob Stake as cited in [109]:

> "When the cook tastes the soup, that's formative; when the guests taste the soup, that's summative".

The purpose of formative evaluation is to improve a software project. The purpose of summative evaluation is to support external decision-makers in making decisions about the future of a software project, usually in deciding whether a project is going to meet its initial defined goals. Scriven's view of formative and summative evaluation is now a days less relevant from the methodological point of view. In a sense that they give a holistic view for generic software evaluation to support usability but doesn't provide specific methods to meet the usability needs of current software systems. The usability scenario changes with the demand of more and more non-technical users. *Usability*, has traditionally been viewed as - the quality of software with respect to ease of learning, ease of use and user satisfaction. The modern views of *Usability* as identified in [95], are based on three distinct perspectives namely:

1. human performance, time and errors
2. learning and cognition (mental models of plans and action)
3. collaborative activity (group dynamics and workplace context)

These perspectives are dependent and complimentary to provide a generic view of usability. Generally in usability studies, human factors are the most challenging task. They are based on simple laboratory settings and the result becomes the basis for developer guidelines. Quality assurance testers tests whether the product meets the design guidelines. This is generally summarized as human factor evaluation. In the context of this thesis, we are interested in identifying the evaluation criteria to support users PIM behaviour on the Semantic Desktop tools, such as Gnowsis. This poses many challenges and still the topic of considerable research. In the next section we have identified some of the challenges involved with evaluation design of PIM tools based on current research efforts.

5.3 Evaluation design challenges

Some the challenges associated with evaluation design as proposed in [60] are mentioned here, it is expected that these issues are to be taken in consideration before formulating any design methods.

1. PIM behaviour changes constantly resulting in major challenges in analysing PIM data. Many PIM related data are stored with the expectation to be reused at some future point of time. Thus such collection is difficult to analyse and hypothesize because they are rather stored in “raw” form which user might like to organize in any given context possibly in future point of time.

2. Information for each user varies and they are rather personal, this poses another serious difficulty in studying them.

The solution to the above challenges till date is the result of naturalistic and longitudinal study that is designed to collect information about users' information-seeking activities, context and behaviours in a natural setting over an extended period of time. This approach has been taken in Gnowsis evaluation (see Section 5.8, the empirical result has been reported in [45]).
But there are also difficulties involved in longitudinal method which we faced in Gnowsis evaluation namely:

1. We don't know the time interval for which the measurements should be taken. In Gnowsis we allowed users to use the system for a period of one month, then we collected the feedback as reported in [45]. But we don't know if a month is a reasonable time for collection of data, what would happen if the data collection is of two months old and so on. In realistic situation PIM behaviour is also affected by external events. We have to take into considerations such issues (for example, during Gnowsis evaluation the FIFA world cup 2006 was held in Germany, this external event affects many peoples plans, schedules and way of organizing their personal digital resources).

2. In this context, it is also important to consider, *When* you measure is just as important as *what* you measure [60]. This is clear from the FIFA event example, what people do at a certain point of time varies, so we have to identify what data is needed to understand PIM behaviour. In Gnowsis context we have to know how PIMO (see Section 4.4) gets changed with respect to external events like FIFA.

5.4 Goals of evaluation

Ideally, software evaluation have specific goals. One main goal is to assess the usability issues in order to identify the usefulness of the software. As reported in [42], the goal of software evaluation can be characterised by one or more of three simple questions:

1. *Which one is better?* The evaluation aims to compare alternative software systems to choose the best fitting software tool for given application, for a decision among several prototypes, or for comparing several versions of a software system.

2. *How good is it?* This goal aims at the determination of the degree of desired qualities of a finished system. The evaluation of the system with respect to "Usability-Goals" [96] is one of the application of this goal. Other examples are the certification of software, and the check on conformity with given standards.

3. *Why is it bad?* The evaluation aims to determine the weaknesses of a software such that the result generates suggestions for further development. A typical instance of this procedure is a system developing approach using prototypes or a re-engineering of an existing system [47].

The first two goals can be subsumed under the concept of summative evaluation, while the third goal is an instance of the formative evaluation approach as described in earlier section (see Section 5.2). With respect to the Semantic Desktop tools our goals would be to find out how well is the tool helping users to make sense of her own resources (files, folders, emails etc.) and facilitate her in daily PIM behaviour. Our main evaluation goal would still be to find how useful is the software (Semantic Desktop applications) but we need to investigate detailed cognitive aspects of human information management behaviour, to specify evaluation criteria. We think for the Semantic Desktop both summative and formative evaluation has to be incorporated. summative evaluation is desired to know the overall usability of the Semantic Desktop but Formative evaluation would enhance features development meeting the needs of different expertise of users (novel user or power-user). It should rather be an iterative evaluation based on users feedback. The results of evaluation can be classified as follows, which were identified in [42, 47].

- *Objective*: Directly observable data; typically user behaviour during the use of the interface or the application system.
- *Subjective*: Opinions, normally expressed by the user with respect to the usability of the interface or the application system.
- *Quantitative*: Numerical data and results, e.g. user performance ratings.
- *Qualitative*: Non-numerical data, e.g. lists of problems, suggestions for modifications to improve the interaction design.

The *Quantitative* and *Qualitative* data provide the description of progress and hint to identify the usability problems of the software system respectively. They could help in realizing usability goals.

5.5 Evaluation criteria

The evaluation criteria should be concrete and measurable parts of evaluation as advised in [33]. In case of a concrete evaluation project, there needs to be a proper operationalisation of the general guidelines and standards [42], which takes into account the context in which the system will be applied. The context of use is defined in ISO 9241 (Part 11) [2] in terms of the user, the task, the equipment, and the environment. Following this description of the components of the context of use, every evaluation has to take into account the following restrictions (see [42] for details).

1. The characteristics of a system users such as experience, age, gender or other more specific features.
2. The types of activity or tasks that the user will perform.
3. The environment of the study itself, ranging from controlled laboratory conditions to largely unstructured field studies.
4. The nature of the evaluation object, which can be a paper prototype, a software mock-up, a partially functional prototype or an accomplished system.

Even expert based evaluation should consider all of these four contextual restrictions in order to achieve a valid evaluation result. *Objective* measurements in evaluation such as the time required for learning a system are preferred measurements, and should be used as criteria for software evaluation [119]. Although objectivity and reliability of such measures are generally accepted, there are doubts about their validity:

> *the so-called objective measurements of performance, for example the number of problems completed within a fixed time span, are widely applied; they are, however, rarely valid as criteria, since the underlying causal relationships are not sufficiently investigated or stated" (translated from* [43]).

The derivation of *Subjective* criteria such as acceptable levels of human cost in terms of tiredness, discomfort, frustration and personal effort, or even an operational definition of attitude, is much harder. On this Whitefield et al. [124] had come to the conclusion that there is at present no support for the specification and operationalisation of such criteria.

In context of this thesis, we have identified other critical criteria which could help us to understand the usability of PIM tools. In the discussion of PIM Workshop, some of the issues were identified and reported in [60]. For the Semantic Desktop evaluation we can use these criteria to evaluate systems support as follows:

1. *Tasks*: Users' tasks are very broad and contextual, moreover each task may be defined at different details. Tasks also differ according to time taken to accomplish the task and frequency with which user work on the tasks. This implies that the Semantic Desktop tools should consider these factors and support user with context switching and integration of related activities. Ideally this would be an important criteria to keep the user stick to such tool support.

2. *Re-finding*: Re-finding information is another challenging issue for PIM supporting prototypes, a good tool should be able to give enough clues about users context to easily support user with her original interpretation and intentions behind viewing the information in the first place, as also reported in [60].

3. *Profiling users according to different Cognitive abilities*: User can have different level of cognitive abilities and skills mainly spatial, intellectual, motor skills etc. It is also considered important to gather information about users like age, sex, experience and educational qualifications. These factor are important specially for user studies in lab settings.

4. *Efficiency and Time*: Efficiency is a valuable measurement criteria. According to the report a "good" PIM should support person to spend more time on certain types of tasks than supporting completion of more tasks in the same amount of time". Efficiency measure should be based on time and, quantity and quality of output. Time is an important measure for re-finding tasks, a PIM supporting re-finding could ideally be judged according to time it takes to support re-finding informations.

5. *Flow*: Flow is another criteria identified to judge how good is PIM support. PIM tools should support work "flow" to the user without any external cognitive distractions.

6. *Usage*: Usage is considered another important criteria, which identifies the value of PIM. Use or abuse also determines the merits and flaws of the tools.

7. *Quality of life*: Ideally a PIM is way to save our precious time. Successful PIM should improve our quality of life, which would also allow to understand how PIM affects our lives in a broad sense. Quality of life questionnaire [35] might contribute to understand the overall impact of PIM in our daily lives.

This section described evaluation criteria for PIM tools which should be viewed by the communities interested in prototyping PIM, to measure the usability issues with which their tools support. These issues are very well applicable to the Semantic Desktops' vision and it is an interesting issue for research. Some of the mentioned criteria would also be a good measure to evaluate Gnowsis prototype. In the following section we present the several standard techniques of evaluation. We used some of the mentioned techniques for Gnowsis evaluation.

5.6 Techniques of evaluation

Evaluation techniques are activities of evaluators that are defined in *behavioural* and *organizational* terms. It is important to differentiate *evaluation techniques* and *evaluation models*. Evaluation models constitute a combination of evaluation techniques

[42]. According to Hamborg et.al [42], the classification of evaluation techniques includes two categories, *the descriptive evaluation techniques* and *the predictive evaluation techniques*, both of which are advised to be presented in every evaluation:

- **Descriptive evaluation techniques** are used to describe the status and the actual problems of the software in an objective, reliable and valid way. These techniques are user based and can be subdivided into several approaches:

  - *Behaviour based evaluation techniques* record user behaviour while working with a system which *produces* some kind of data. These procedures include observational techniques and *thinking-aloud* protocols.
  - *Opinion based evaluation* methods aim to elicit the user's (subjective) opinions. Examples are interviews, surveys and questionnaires.
  - *Usability Testing* stems from classical experimental design studies. Nowadays, Usability Testing (used as a technical term) is understood to be a combination of behaviour and opinion based measures with some amount of experimental control, usually chosen by an expert.

  Observe that all descriptive evaluation techniques require some kind of prototype and at least one user. Moreover the data gathered by a descriptive technique need some further interpretation by one or more experts in order to result in recommendations for future software development.

- **Predictive evaluation techniques** have as their main aim to make recommendations for future software development and the prevention of usability errors. These techniques are expert – or at least expertise – based, such as Walkthrough or inspection techniques. Even though the expert is the driving power in these methods, users may also participate in some instances. Note that predictive evaluation techniques must rely on *data*. In many predictive evaluation techniques, such *data* are produced by experts who simulate *real* users. The criteria *objectivity* and *reliability*, which are at the basis of descriptive techniques, are hard to apply in this setting. Because *validity* must be the major aim of evaluation procedures, there are attempts to prove the *validity* of predictive evaluation techniques directly, for e.g. by comparing *hits* and *false alarm* rates of the problems detected by a predictive technique [82]. See [42] for detailed description of state-of-the-art evaluation techniques practised in the field of Software evaluation.

In this thesis we are looking for concrete measurements to identify PIM behaviour, at the current state of research the techniques of evaluation for PIM supporting tools (such as the Semantic Desktop) is an open area of research. In general, evaluation of software is based on different aspects namely, functionality, reliability, usability, efficiency, maintainability and portability [3]. In the thesis we would rather concentrate on the Semantic Desktop evaluation from cognitive point of view. Our concern is to highlight the aspects of usability for software that is interactive and supports PIM. There are other commonly used techniques studied in HCI for capturing users' requirements, expectations and Mental Models [88, 89]. In the past some steps were taken to formalize user behaviour while her interaction with the system. One such model of Cognitive Complexity can be depicted in Figure 5.1 according to the work of Rauterberg [90]. He modelled user interaction with database system while performing specially designed tasks with Petri-nets. He derived, based on his empirical results, that the complexity of the observable behaviour of novices is larger than the complexity of experts, he concluded that the behavioural complexity is negatively correlated with the complexity of the Mental Model [88]. For detailed discussion on Cognitive Complexity refer to [91]. In context of the Semantic Desktop, instead of

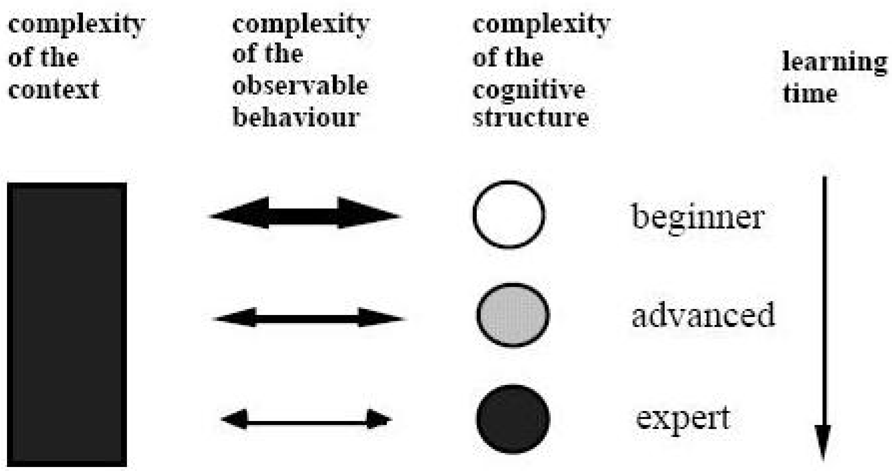

Figure 5.1 A schematic overview about knowledge acquisition and behavioural complexity. M.Rauterberg, 1995 [90].

thinking about Petri-nets, we have a rather new model which could define system processes in terms of Unified Modeling Language (UML)[2]. To deal with new set of challenges of PIM based activity, we have to think creatively for the evaluation of the Semantic Desktop. As discussed in earlier section (see Section 5.3), there are several challenges faced when gathering user information. First, it is expensive and time-consuming. Second, it may be difficult to identify and locate actual users or those who fit the target user profile, hypothesizing users goal is also a challenging issue and the purpose for which the Semantic Desktop could be effectively used has to be determined very clearly, evaluation is rather based on case studies. Although the target users are knowledge workers and evaluation has shown efficient management of tasks, but in addition, it is important to select a representative cross-section of users. This

[2]http://en.wikipedia.org/wiki/Unified_Modeling_Language

includes users from different work areas, with different levels of experience, and with different usage patterns. In the following section we describe the techniques involved to capture users' information and Mental Model with respect to a given set of tasks. This is inspired from [22].

- **Surveys and Questionnaires**: Surveys and questionnaires are useful for collecting demographic and opinion data. They can help determine users' background and levels of subjective satisfaction. Questions may be open-ended, fill-in-the-blank, multiple choice, or rating scales. Questions should be prepared in such a way to give the user maximum flexibility in expressing her experience. Even though data from questionnaires is relatively easy to tabulate and analyze, but questionnaires usually cannot provide in-depth information [36].

- **Focus Groups and Interviews**: Focus groups and interviews are widely-used informal techniques that can be useful for planning or evaluating a system design. A focus group involves a moderator questioning a group of users. An interview is conducted one-on-one with an individual user. These methods are valuable for questioning users about their work or their opinion about a system. Interviewers may ask users to describe a typical day or task, why they do certain things, what they would do when certain events occur, etc. Interviews or focus groups may also include asking users to evaluate simple sketches of a system design.
  When analyzing data from focus groups and interviews, it is important to identify patterns of responses and not to overemphasize any single user's comments. Like questionnaires, focus groups and interviews collect self-reported data. This may be problematic because users often do not remember or accurately describe what they do.

- **Thinking-aloud technique**: The evaluation with thinking-aloud technique provides information about cognitions and emotions of a user while (s)he performs a task or solves a problem. Examples for this are elicited in [58, 70, 14]. The user is instructed to articulate what (s)he thinks and what (s)he feels while working with the prototype. The utterances are recorded either using paper and pencil [80, 81] or with more modern techniques using audio or video recording [58, 70]. In connection with synchronised log-file recordings, the evaluator has the chance to interpret the user's reaction based on contextual information [58]. Nielsen [81] expresses the opinion that a large amount of overhead is unnecessary, and that simple paper-pencil recordings suffice to elicit the relevant contextual information. The procedure of analysing thinking-aloud techniques has not much changed since the paper by Lewis [70] in 1982: The protocols are scanned, and those episodes are extracted which describe the users' problems and their complaints. The episodes are listed and coded by a user number and an episode number. Afterwards, the episodes are matched with one *feature* of the system. These *features* define the grouping criteria for the episodes. The

design aspect of the *feature* and the frequency information provide further help for the interpretation of the results.
By using thinking-aloud techniques, the evaluator obtains information about the whole user interface. This type of evaluation is oriented towards the investigation of the user's problem- and decision behaviour while working with the system [43]. This evaluation technique is one of the most common technique for qualitative data generation [42].

- **Usability Testing**: Usability testing is an effective way to verify an existing design or system. It is a structured observation of users in a experimental setting. Users are observed performing tasks with a working system or prototype. They are asked to think aloud while completing the tasks. This includes describing what they are trying to do, the hypotheses they are forming, their expected results of an action, etc. The evaluator observes the user's performance noting problems, comments, circuitous paths, etc. Usability tests are useful for collecting quantitative data regarding time per task and number of errors [98]. Rubin identified two different approaches to Usability Testing:

  1. *Formal tests conducted as true experiments*: This approach is characterised by the use of classical experimental designs for testing hypotheses and for deriving causal dependencies.
  2. The second class of usability tests, described to be a less formal one, employs an iterative cycle of tests intended to expose usability deficiencies, and gradually shape or mold the product in question.

  Whereas both approaches differ in their proximity to classical experimental designs in terms of the accuracy of the description of the independent factors, the problem of defining dependent variables – the measurables – is common to both approaches. The dependent variables are chosen pragmatically according to the evaluation goals [42].
  Conducting a usability test requires a great deal of planning and effort. It involves high personnel and equipment costs and requires a controlled testing environment. Users who meet the target profile must be located, a script must be created that uses representative tasks, a large amount of data must be analyzed, the results must be prioritized, and design changes must be made based on the results. The evaluator always explains to users that only the software is being tested, not the user themselves. Debriefing is usually included to get gather additional information about the user's experience. A usability test is typically videotaped so the evaluator may perform more detailed observations and analysis after the test. Because of the high resource requirements, usability tests are not always conducted by software development teams [74].

According to the recommendation by [60] other traditional experimental design techniques can also provide a basic frameworks in studying PIM behaviour. these are briefly explained as follows:

- Classical pretest-post test: In this approach, the test collections are randomly divided into two samples, namely, the control sample, and the experimental sample. The experimental sample is exposed to the manipulated variable. Comparison are made between the pretest results and the post test results for both samples. The variance between these two samples is assumed to be a result of the experiment.

- Solomon four group design: The test collections are randomly divided into four samples. Two of the groups are experimental samples. The two other groups experience no experimental manipulation of variables. Two of the groups receive a pretest and a post test. The two other groups receive only a post test. This is an improvement over the classical design because it controls the effect of the pretest.

- Factorial design: This is similar to a classical design. Additionally samples are used and each group is exposed to a different experimental manipulation.

Techniques described above, including Questionnaires and interviews, Observational methods, Think-aloud technique, are used to measure the impact of differences in system design, or different versions of a prototype on the usability of the product. Additionally, so called measurement criteria [119] are used. These are task specific measures such as *time to complete a task* or *percentage of tasks completed*, which can be easily applied, if tasks are accurately described [42].
In this section we have discussed several approaches that could help us to study PIM behaviours like naturalistic approaches, including fieldwork and longitudinal methods. Longitudinal approaches allow us to capture data over an extended period and take measurements of behaviour at fixed points in time, then they can be combined with naturalistic inquiries and case studies [61]. Moreover, creation of sharable test collections has been proposed that could be used to examine techniques based on specific applications. Case studies that provides subject details and are practically feasible are also appropriate. But Case studies cannot fulfill the understanding of the user behaviour of large population. We would like to explore further *Standard* methods and discuss their possible application for the Semantic Desktop evaluation.

5.7 Evaluation -ISO standards

The International Standards Organization [3, 1, 2], which is well-known for its development of standards for industrial processes and product quality, defines usability as follows: Usability is the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in a particular environment, (ISO 9241) [27] The standard further defines the components of the usability definition [22]:

1. *Effectiveness*: accuracy and completeness with which specified users can achieve specified goals in a particular environment.

2. *Efficiency*: the resources expended in relation to the accuracy and completeness of the goals achieved.

3. *Satisfaction*: the comfort and acceptability of the work system to its users and other people affected by its use.

While many HCI practitioners use the ISO 9241 definition, it is not very suitable for the purposes of the Semantic Desktop. It describes only performance and does not include some of the elements that actually lead to effectiveness, efficiency, and satisfaction for the evaluation of PIM activities.
Cosantine and Lockwood define usability as being composed of the leachability, returnability, efficiency of use, and user satisfaction of a product [19]. This inclusion of leachability and returnability helps us to understand the role of Mental Models in usability. To the extent that a correct Mental Model can be learned and retained by a human, that product will be more usable. The user will be more effective, efficient, and satisfied. In fact, if we knew what caused correct and incorrect Mental Models to be formed, we should be able to develop systems that would help users to form correct Mental Models and consequently, improve usability (Rogers, et.al., 1992).

5.8 Gnowsis evaluation

We have found from our discussions that evaluation of the Semantic Desktop prototypes poses new challenges and demands serious research attention. The prototype that supports user with information finding and reminding to the extent of high-level PIM tasks such as organising resources according to her Mental Model (see Section 3.4), would need a more naturalistic and flexible approaches as well as valid and reliable methods for evaluation [28]. As we have seen defining a fixed set of metrics would restrict the user to behave according to specific usage scenario for a generic task, thus limiting her freedom and creativity. An ideal strategy would be first to classify and identify peoples PIM behaviour. People have to be observed in their real-time settings, during their work or at home when they engage in doing PIM, recording both the process and the consequences of the behaviour as emphasized in [32].
It is only through an iterative combination of several evaluation techniques (see Section 5.6) that we will be able to understand PIM behaviour, and then construct tools to support it and perform valid and reliable evaluations. Keeping these challenges in mind we advocate that evaluation and system development life cycle should go hand in hand in order to model ongoing activity of user PIM behaviour. We favour that the Semantic Desktop should become an *addiction* for PC users for her PIM tasks as the user tends to spend more time with desktop in day to day activities. Our motivation for evaluation is to measure *Intoxication* level (see Chapter 6) of such an addiction of user with the Semantic Desktop.
Gnowsis development maps close to the spiral model of software development, our

approach towards the Gnowsis has been to writing a prototype, define initial use-case and evaluate it with domain experts.
The techniques of evaluation for Gnowsis were mainly by personal interviews and preparing the questionnaires (See Appendix for sample Questionnaire). User were also asked to think-aloud, with respect to the given task they could perform using Gnowsis. Although, these techniques are in one sense very effective as they identify clear tasks that could be performed by the users. But on the other hand they are not very standard because PIM activities are highly contextual, rather dynamic and flexible. We need more studies about user behaviour in a given context on a given task. Enhancing and defining a software process model for the Semantic Desktop development would be another area of interesting research.
The main goals of Gnowsis evaluation has been to show that Personal Information Management can be improved. Another goal was to evaluate the usability of the implemented Graphical User Interface. A user evaluation of Gnowsis based on structured questionnaire has been made on power users to elicit their experiences (see Heim thesis [45]). We evaluated Gnowsis version 0.8 in the EPOS project with domain experts [105]. Standard evaluation methods to get information on how people use the system and interact with it were used:

- A questionnaire about the interaction of the user with the software. Each user had to fill out the questionnaire once a day, preferably after he worked with the software
- Getting the log file information of the actual use of the system

Efforts have been made to enhance usability features which could be compared between different versions. The following are the highlights of the features which has been evaluated for usability in Gnowsis.

- The drop-box component increased productivity as it allows to file items faster than without the assistance.
- The possibility to add multiple categories to a document was used, in the mean 2.5 categories were attached to a file, which is significantly more than the single category a hierarchical file system provides.
- The Gnowsis desktop search was used very frequently. Users answered in the questionnaire that they found unexpected information and that the categories provided by the PIMO helped during retrieval.
- The subjects stated, that the context-sensitive assistance came up with unexpected, surprising information items (e.g., documents) revealing new, useful,cross-references.
- The participants agreed that the PIMO reflects their personal Mental Models Gnowsis now fulfills the general expectations of a Semantic Desktop application, it is easy to learn and support the user in structuring their documents by

providing a semantic search and the possibility for cross-application linking of resources.

The main lesson learnt from the evaluation of Gnowsis is that an evaluation of single use cases instead of the whole system is much more definable and practical due to the fact that there is only a limited amount of un-controllable factors. The difficulty concerning a system evaluation of the Gnowsis Semantic Desktop is to find a way to enforce people getting addicted to Gnowsis. The method of thinking-aloud (see Section 5.6) was also incorporated to understand users expectations. Our plan was to use a combination of various evaluation methods that address either only usability aspects or merely architectural ones. The evaluation were performed in two steps they included:

1. A questionnaire at the beginning of the evaluation to show expectations.

2. A questionnaire at the end of the evaluation to show if the expectations were met.

Moreover, a statistical logging software that records usage statistics of the software by the user were used. The first part of the plan was to hand out a questionnaire that should reflect their general expectations towards the Semantic Desktop as well as some basic information about the way users interact with their computers.
The evaluation were mainly based on usage and cognitive aspects (for e.g. satisfaction, preference, desire, etc.) questions, for two reasons: On one hand we can get a general overview of what people want from a PIM software and on the other hand the results from the questionnaire can be compared with the results from the long term evaluation to figure out to what extent our software met their expectations. After the questionnaire we wanted to know how the software is used over a longer period of time, where all participants have time to develop their very own Personal Information Model consisting of their own datasets from their local computers. The advantage of such a user-specific evaluation is the fact that the existing dataset is well known to every single participant and as it brings a direct benefit to the users local desktop, he might be more interested in testing the software and thus benefiting from its features [45]).
We have evaluated Gnowsis by preparing user questionnaire 1) *Expectations questionnaire* 2) *Final questionnaire* and 3) *Evaluation log* information about usage based on longitudinal methods. This has given us some empirical results (for results and tables of Gnowsis evaluation see Heim thesis [45]) which are useful to claim usability of Gnowsis as theoretically discussed in this Chapter. This chapter provided several current research methods and techniques used to evaluate PIM based activity which needs further research attention to explore usability features of the Semantic Desktop. The evaluation of PIM based software prototypes is a current research challenge. A PIM tool could take several years to develop [60].

Chapter 6

Intoxication

This chapter is the author's position and his sole interpretation form his research work. The main idea of writing this chapter is to provoke thoughts and invite constructive criticism. *Intoxication* addressed here could be simply understood as "user's addiction towards organising her personal digital resources". Specifically in context of this thesis the position is taken for the Semantic Desktop as a way to handle the Personal Information Management.

Inspired by the article, e-mail as habitat [31], it could be simply deduced that we are now living in a distributed digital ambience where we have handy tools to annotate, capture and record our daily events. PIM is an ongoing activity, everyone has an inclination to organise and record the valuable and meaningful information encountered in day to day life. We need the tool to make sense of our ephemeral and archival information (discussed in Section 2.6), that should deliver information at the right time when demanded, that could be shared at ease and minimize our cognitive overload in memorizing all the bytes of information we encounter, if we have a tool which facilitates such features, this would surely make us *addicted* to it, an interesting challenge would be to measure the intoxication level of the user with her ongoing PIM activity. Such a quantifiable Intoxication measure would be an implicit feedback for evaluation (see Chapter 5). Both the designer and the user would benefit from the tools to effectively use and provide intuitive feedbacks to enhance its features. This approach has been taken in Gnowsis evaluation, (see Heim thesis [45], Ch.5). The Semantic Desktop prototype as a cognitive aid to measure the intoxication level of user's PIM behaviour would be an interesting area of research in academic arena of Personal Information Management.

A typical Knowledge Worker should always be aware of her working context. Information needed to perform a specific task should be available within the reach and easily retrievable without involving much costs.

> *The sources of information take different forms–from paper documents to machines to people, but, nevertheless, each piece of information has a cost associated with finding and accessing it* [13].

In paper [13] the cost structure of information from secondary storage to immediate use is taken into consideration. Information processing systems, like the Semantic Desktop should be able to minimize cost structure involved in information gathering, organising and processing. Like the human eye, tend to be organized to minimize the cost structure of information processing [13]. Observations deriving from studies of natural cognitive systems would help us to formulate systems goals for the design of user interfaces for information access, this approach could be taken in the Semantic Desktop design to meet these mentioned goals. For users to get addicted to her PIM we should design a semantic structure of the relevant resources which she needs in her task responsibility. Such an addiction should be empirically measured to get an idea of users' benefits. The author makes a claim that if a user keeps mental map of her resources and knows the degree of association between the given set of resources (e.g., emails, files, folders, bookmarks, concepts and ideas), she would perform better in an organised way.
It is suggested that the Semantic Desktop should provide following features to get an idea of user-dependence on her PIM.

- *Degree of association*: Degree of association is a *view* given to the user which shows how each resource is connected to others with respect to relevance.
- *Ranking of resources*: Ranking of resources should be based on time (frequency of usage) and priority (high or low). This approach has been taken by Paul Chirita [18].
- *Assignment of weight*: Resources should be assigned weight (currently star features are being used in Gnowsis), it has to be more specific to define relationships between resources.

In order to be successfully deploying such features and evaluations, we need to define success criteria and develop metrics to assess success with respect to these criteria to show that the Semantic Desktop approach is a user-adaptive cognitive amplifier and helps user to minimize her cognitive overload, facilitating her in easy filing and retrieving information resources.

Chapter 7

Conclusion

The thesis made an extensive literature research and brought many ideas with possible applications to the Semantic Desktop prototypes development. The thesis concludes with several ideas and suggestions for future research direction. The work should not be considered as an end but an initiative to report various usability aspects of the Semantic Desktop to perform PIM. There has been latest research attention and submissions in the area.

> *the Personal Information Management workshop at SIGIR 2006 funded by NSF, [...] where around 32 accepted submissions which is amazing for a field which was extremely quiet only a matter of years ago. [...] Its a busy year for PIM, just go back 3 years and there was barely anything presented at CHI on this field [...]* - Richard Boardman in his Blog[1].

7.1 Recapitulation

This research has been done within the context of the Semantic Desktop prototype: Gnowsis [72] being developed at DFKI. The work is summarized from individual Chapters as shown in fishbone Figure 7.1. In Chapter 1 definitions of the technical terms are given which are relevant to the scope of the thesis. In Chapter 2 Cognitive Science is introduced, basic definition, of the terms different views on Cognitive Science and the timeline of research direction is illustrated, a position has been proposed to view Cognitive Science theory in Semantic Web developments, which would give understanding to the developers in developing user based applications using Semantic Web technologies. Further, in the chapter Boardman thesis is introduced which made comprehensive studies on PIM behaviour and suggested the value of user studies in order to develop PIM prototype. The chapter concluded with discussion on existing challenges in PIM. In Chapter 3 various philosophical theories have been introduced which the author feels necessary to understand for the design of the Semantic Desktop.

[1] http://rickb.wordpress.com/tag/personal-information-management/

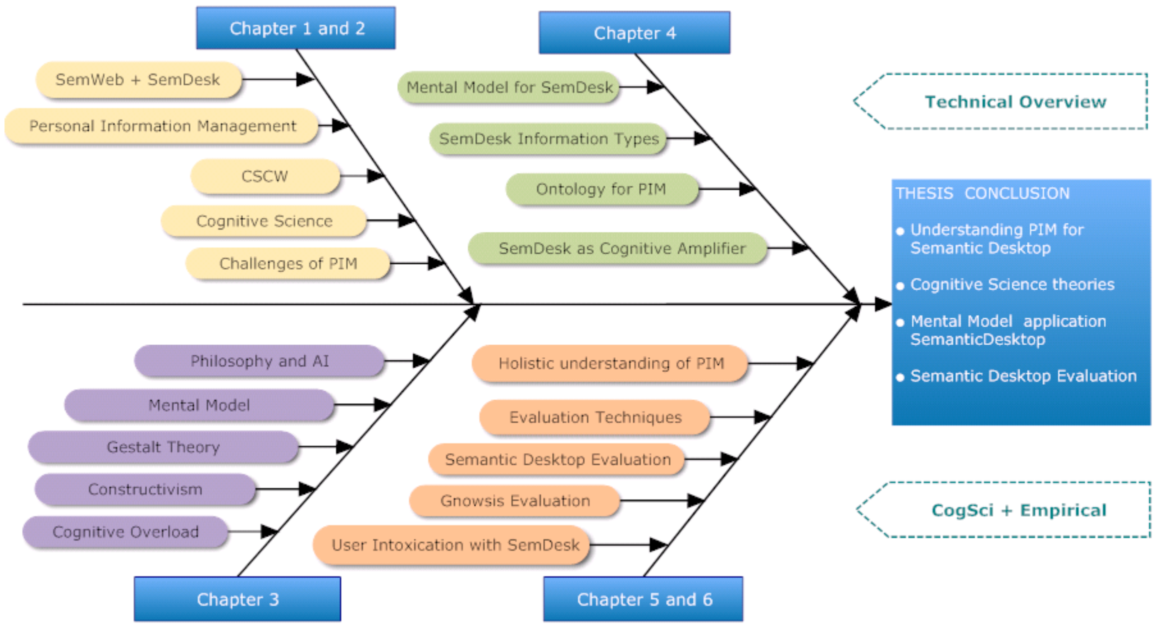

Figure 7.1 Thesis Recapitulation

The author's position is to view the Semantic Desktop development as a step towards *Weak AI* (see Section 3.1). The theory of Mental Model has been illustrated (see Section 3.4), and author claims Mental Model should be understood in the Semantic Desktop scenario and applied while designing the Semantic Desktop prototypes. The possible application of Mental Model has been discussed in the following Chapter 4 in the Section 4.2. The author views the Semantic Desktop as an approach to amplify human cognition, in terms of reducing information overload and as a memory aid. This has been the main theme of the Chapter 4 thus various aspects are discussed to realize this goal. In Chapter 5, the Semantic Desktop evaluation has been discussed and techniques are explored, the evaluation of the Semantic desktop is a new direction of research and authors position has been to make literature review of the current state of research in evaluation of PIM activities, which included challenges, criteria and techniques for evaluation. The research for evaluation of PIM came to the suggestion that both Quantitative and Qualitative measures are necessary with longitudinal approach to study PIM activities. The chapter further discusses the evaluation approach taken for Gnowsis [72], at DFKI. More detailed and empirical studies of individual GUI features and PIM based use-cases in Gnowsis are discussed in Heim thesis [45]. In Chapter 6 a new term *Intoxication* is introduced with authors sole interpretation. The author claims that *Intoxication*, the term which might be renamed in future research, is a measure to evaluate user's addiction with the Semantic Desktop, which would be a measurable factor to understand PIM activity. The chapter takes the position to provoke thought among future researchers without giving any formal solution rather some ideas are introduced which is understood as a necessary direction of thought for further research in evaluation of the Semantic Desktop.

7.2 Contributions

The main research contributions of this thesis could be summed up as follows:

- A detailed literature review has been done on Theories of Philosophy and Cognitive Science to explore the ideas which are relevant in context of the Semantic Desktop as an approach to efficiently handle Personal Information Management. Mainly, the following theories has been investigated

  1. Mental representation
  2. Cognitive Maps of Mental Representation
  3. Gestalt Theory
  4. Constructivist view
  5. Cognitive Overload

- An attempt has been made in this thesis to apply Mental Model theories which are important to understand, in order to design user-centric Semantic Desktop prototype. Moreover, for developing the conceptual idea of PIMO [103].
- The work is a first attempt to explore the user benefits from the Semantic Desktop. The idea has been explored to support how the Semantic Desktop indeed handles the difficulties faced by users in PIM. Moreover, current challenges and methods of evaluation have been explored for evaluating the Semantic Desktop prototypes.
- This work supports the designers of the Semantic Desktop towards considering users' Mental Model as discussed in (see Section 3.4) to take into consideration to improve usability.
- An information type model for the Semantic Desktop categorization is proposed (see Figure 4.2) which is inspired by the earlier work on Pushed and Pulled information by David Kirsh [63].
- A novel chapter on Intoxication (see Chapter 6) as a measure for user dependency on the Semantic Desktop has been discussed.

7.3 Future research

Evaluation of PIM based on Semantic Web technologies is a challenge for the Semantic Desktop development. Current state-of-the-art Semantic Desktop prototypes like

Gnowsis [72], Haystack [30], IRIS [16], DeepaMehta [93] and many others are still in their development phase. Their claim to support PC users with efficient Personal Information Management depends on how well we know about the behaviour of user while she organizes her personal information.
Evaluation of such systems needs research focus in future to claim their usability. With in the scope of current thesis an initiative is taken to report the challenges involved in PIM evaluation with some of the latest research efforts are highlighted in this work. Based on the research questions we asked in Section 1.1 we conclude following points:

- The Semantic Desktop should facilitate our every-day Personal Information Management (PIM). They should help the user formalize knowledge in a more or less structured way. They help in bringing the ideas that reside in a someone's mind and are often only vague, into explicit knowledge that can be communicated.
- This way the Semantic Desktop minimizes information overload by facilitating user with filing and retrieving information, in an associative manner. Users need not file their personal information in strict hierarchy but in a semantically connected ways.
- The thesis also suggested information types encountered by knowledge worker. The Semantic Desktop should provide features to categorise information specific to user needs, priorities and contexts. Although different views exist on this idea.
- *Personal information* should be further divided into clear *set of resources* and they have to be studied to understand, how they are used in specific scenario to assess PIM behaviour.
- PIM is not uniform or structured behaviour rather it is dynamic, diverse and flexible, based on context. PIM behaviour has to be studied in particular context (e.g. working, education, projects, research). The strategy to study PIM behaviour would involve *"divide and conquer"*. We should analyse behaviour versus time with respect to specific tasks (scenario). The good idea would be to formalize the behaviour in a given scenario and see how users behave over time. The ideas discussed about Mental model in Section 3.4 would be beneficial to understand.
- Personal information defines personality, people would like to freely control information they share. People in research organisation have to know clearly, what information to share and what information are internal, while in business environment information about company's policies and strategies is kept secret and information for marketing purposes is more highlighted. People living in

these two different organisation setups would definitely have different behaviour for managing their personal information and information sharing attitude.

- Evaluation of PIM is challenging, major issues involve privacy and users different world-view. It is also ambiguous to generalize PIM behaviour based on limited subjects experiments in laboratory settings [60].
- Workflow has to be formalized and scenario has to be evaluated to claim user-adaptive Semantic Desktop prototype. It would also be a proposal to formalize PIM behaviour like PIMO [103], that reflects users Mental Model (world view) with respect to a given scenario.
- Understanding Mental Model to explicitly define user scenario: Mental model as discussed in Section 3.4, are a hint (clue) in peoples mind to the concept they represent. In physical sense they may represent an operation of a device, in abstract sense they may represent system process.
- Representing Mental model in PIMO [103] or CDS [122]: As discussed in Section 4.4, Mental Model needs to be formalised, they should serve as an analytical tool that should provide features to document user's current mental images, vocabulary and assumptions [75].
- Defining what could be done from the Semantic Desktop: Competency questions [41] (litmus test)
- A further study should be conducted to evaluate the Semantic Desktop based on the criteria discussed in Section 5.5. The criteria described are among the latest research proposals, where a rapid prototyping is an urgent suggestion.

The ideas discussed in this thesis provides a holistic view from the perspective of Philosophy and Cognitive Science theories, which could help in building the Semantic Desktop to meet the users requirements. Specially, the theories of Mental Models discussed in the thesis are important knowledge needed for any steps in building the Semantic Desktop, to emphasize a theoretical foundation as well as practical applications of Mental Model. This has to be kept in mind while designing specification for the Semantic Desktop long term goals.
Cognitive Science gives a better insight to understand Mental Models but to capture and validate users Mental Models poses difficulties. The potential for rewards of improved design and increased usability based on correct Mental Models compensate for the effort, but they are still an open area of challenging research. In Gnowsis context, we can identify success stories by individual users about their experiences on how the Semantic Desktop should ideally work. Comparing their answers would reflect different Mental Models and expectations. This should be used for redesigning prototype to exploit system features and improve usability. We still lack the proper evaluation of the Semantic Desktop systems, specially with the non-expert users to

judge how well the systems adopts to user's Mental Model. Moreover, it would be also be an interesting step to investigate if the Semantic Desktop is an effort in realizing *Weak AI* (see Section 3). One such research direction would be to investigate experimentally, how the Semantic Desktop systems provide an aid to human memory.

Appendix A

Appendix

A.1 Semantic Desktop prototypes

DBin	http://www.dbin.org/
Gnowsis	http://www.gnowsis.org/
Haystack	http://haystack.lcs.mit.edu/
IRIS	http://www.openiris.org/
Fenfire	http://www.fenfire.org/
Chandler	http://chandler.osafoundation.org/
DeepaMehta	http://www.deepamehta.de/
MindRaider	http://mindraider.sourceforge.net/

A.2 SemDesk Evaluation Questionnaire

For evaluating the Semantic Desktops, we prepared a semi-structured questionnaire. Some of the questions were structured because we wanted to save time of users from generalized thinking but to answer what is expected, on the other hand most questions were semi-structured which gave users much freedom to share their experiences with respective Semantic Desktop prototypes. The questions were posed as follows:

- Did you evaluate your Semantic Desktop related approach? (yes/No) If yes, did you publish some work on this? (add a link to your publication(s), you can also refer to them in the next questions)
- What evaluation methodology did you use? (Interviews, Statistical Analysis, Measurement of features and comparison to existing numbers, etc)
- Did you evaluate user satisfaction, for a given domain or task? Are users so satisfied that they get "addicted" to the Semantic Desktop? Is this measurable?
- Did you collect feedback and wishes from users - and what did users expect from a Semantic Desktop? (Any user feedback).

- Did you find a factor that is measurable? Is it possible to measure the improvement realized by the Semantic Desktop?
- Anything else you think we should consider: (with respect to Evaluation)

A.3 German Laws concerning Usability

In Germany three laws exist to deal with minimum requirements for the usability of software products. This information would be interesting for the Semantic Desktop developers around Germany.

German Usability Laws http://www.procontext.com/en/guidelines/laws.html

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Bibliography

[1] *ISO, EN ISO 9241-10. Ergonomic requirements for office work with visual display terminals (VDT's). Part 10, ISO, Geneva, 1996.* 73

[2] *ISO, EN ISO 9241-11. Ergonomic requirements for office work with visual display terminals (VDT's). Part 11, ISO, Geneva, 1997.* 67, 73

[3] *ISO/IEC 9126. Information technology- Software product evaluation - Quality characteristics and guidance for their use, ISO, Geneva, 1991.* 69, 73

[4] *Object-Oriented Interface Design: IBM Common User Access Guidelines*. Que Corp. Indianapolis, IN, USA, 1993. 51, 52

[5] Andreas Abecker and Ludger van Elst. *Handbook on Ontologies*, chapter Ontologies for Knowledge Management, pages 435–454, Springer. Springer, 2004. 11, 55

[6] A.Whitefield, F.Wilson, and J.Dowell. A framework for human factors evaluation. *Behavioural Information Technology*, 10:65–79, 1991. 62

[7] L. Banwell and G. Coulson. Users and user study methodology: the jubilee project. *Information Research*, 9(2) paper 167, 2004. 62

[8] Deborah K. Barreau. Context as a factor in personal information management systems. *American Society for information Science*, 46(5):327–339, 1995. 30, 49

[9] Tim Berners-Lee and Mark Fischett. *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web by Its Inventor*. Harper San Francisco, 1999. 22

[10] Tim Berners-Lee, James Hendler, and Ora Lassila. The semantic web. *Scientific American*, 89, May ,2001. 2, 22, 23

[11] Richard Boardman. *Improving Tool Support for Personal Information Management*. PhD thesis, Imperial College London, 2004. 3, 6, 7, 23, 25, 27, 28

[12] B. A. N. Bonnie. *Context and Consciousness: Activity Theory and Human-Computer Interaction*. The MIT Press, November 1995. 61

[13] Robertson G.G. Mackinlay J.D. Card, S.K. The information visualizer, an information workspace. *CHI '91 Conference Proceedings, ACM press*, pages 181–188, 1991. 26, 46, 77, 78

[14] J. M. Carroll and R. Mack. Learning to use a word processor: By doing, by thinking and by knowing. in j. thomas and m. schneider (eds.),. In *Human Factors in Computing Systems, 13–52, Norwood. Ablex.*, 1984. 71

[15] Dempsey Chang and Keith V. Nesbitt. Developing gestalt-based design guidelines for multi-sensory displays. In *MMUI '05: Proceedings of the 2005 NICTA-HCSNet Multimodal User Interaction Workshop*, pages 9–16, Darlinghurst,Australia, 2006. Australian Computer Society, Inc. 44, 45

[16] Adam Cheyer, Jack Park, and Richard Giuli. Openiris. In *Proc. of Semantic Desktop Workshop at the ISWC, Galway, Ireland*, 2005. 82

[17] Paul Alexandru Chirita, Rita Gavriloaie, Stefania Ghita, Wolfgang Nejdl, , and Raluca Paiu. Activity based metadata for semantic desktop search. 2004. 30

[18] Paul Alexandru Chirita and Wolfgang Nejdl. Analyzing user behavior to rank desktop items. *In Proceedings of the 13th International Symposium on String Processing and Information Retrieval (SPIRE), Glasgow, United Kingdom*, 2006. 78

[19] Costantine, Larry L., Lockwood, and Lucy A.D. *Software For Use - A Practical Guide to the Models and Methods of Usage-Centered Design.* Reading MA: Addison-Wesley, 1999. 74

[20] K. Craik. *The Nature of Explanation.* Cambridge University Press, London, New York., (1943). 19, 38

[21] Jennifer Cram. Whose knowledge? whose management? cognitive considerations for the provision of virtual library services to school communities. *School Libraries Worldwide*, 8 (2):65–81, 2003. 1

[22] Mary Jo Davidson, Laura Dove, and Julie Weltz. Mental models and usability, on the web at http://www.lauradove.info/reports/mentalTechnical report, Depaul University, Chicago, November 15, 1999. 24, 25, 50, 71, 73

[23] Stefan Decker and Martin Frank. The social semantic desktop. WWW2004 Workshop Application Design, Development and Implementation Issues in the Semantic Web, 2004. 9, 10

[24] Stefan Decker, Jack Park, Dennis Quan, and Leo Sauermann, editors. *The Semantic Desktop - Next Generation Information Management and Collaboration*

Infrastructure. Proc. of Semantic Desktop Workshop at the ISWC, Galway, Ireland, volume 175 of *CEUR Workshop Proceedings ISSN 1613-0073*, November 2005. 9, 48

[25] D.Quan D.Huynh, D.Karger. Haystack: A platform for creating, organizing and visualizing information using rdf. *Semantic Web Workshop, Hawaii, USA*, 2002. 24, 55

[26] Eric Dietrich. Philosophy of artificial intelligence. In *The Encyclopedia of Cognitive Science (pp.203-208)*, 2002. 33, 34, 39, 40

[27] Alan Dix, Janet Finlay, Gregory Abowd, and Russell Beale. *Human–Computer Interaction (2nd Edition)*. Printice Hall, 1998. 73

[28] D.Kelly. Evaluating pim behaviours and tools. *Communications of ACM*, Vol.49 (1), January 2006. 74

[29] M. Dougiamas. A journey into constructivism, on the web at http://dougiamas.com/writing/constructivism.html. Technical report, 1998. 42, 43

[30] D.Quan, D.Huynh, and D.R Karger. Haystack: A platform for authoring end user semantic web applications. *ISWC*, pages 738–753, 2003. 2, 9, 24, 55, 82

[31] Nicolas Ducheneaut and Victoria Bellotti. E-mail as habitat: an exploration of embedded personal information management. *interactions*, 8(5):30–38, 2001. 77

[32] Cutrell E. Cadiz J. Jancke G. Sarin R. Dumais, S. and D. Robbins. A system for personal information retrieval and re-use. ACM Press, New York, 2003, 72-79., In Proceedings of the 26th Annual ACM International Conference on Research and Development in Information Retrieval (Toronto, July28-Aug. 1), 2003. 7, 74

[33] W. Dzida. Qualitätssicherung durch software-ergonomische normen. *In E. Eberleh,H. Oberquelle & R. Oppermann (Eds.), Einführung in die Software-Ergonomie, Berlin. de Gruyter.*, page 373–406, 1994. 66

[34] Lynn Nadel (editor-in chief), editor. *The Encyclopedia of Cognitive Science*. Nature Publishing Group, November 2002. 3, 18, 19, 34

[35] J. Endicott, J. Nee, W. Harrison, and R. Blumenthal. Quality of life enjoyment and satisfaction questionnaire: A new measure. *Psychopharmacol Bulletin*, 29(2):321–326, 1993. 68

[36] Christine Faulkner. *The Essence of Human-Computer Interaction*. Hempstead UK: Prentice Hall, 1998. 71

[37] D. Gentner and A.L. Stevens. *Mental Models*. Hillsdale, New Jersey, Lawrence Erlbaum Associates, 1983. 38, 39

[38] Dr. William M. Gribbons. Knowledge-infused design, the “ultimate solution” to product usability. *Help 99 Proceedings*, pages 153–156, November 1999. 41

[39] T.R Gruber. A translation approach to portable ontologies. *Knowledge Acquisition*, 5(2):199–220, 1993. 55

[40] J. Grudin. Cscw introduction. *Communications of the ACM*, Vol. 34, No. 12:31–34., 1991,. 10

[41] M. Gruninger and M.S. Fox. Methodology for the design and evaluation of ontologies. In *In: Proceedings of the Workshop on Basic Ontological Issues in Knowledge Sharing*, IJCAI-95, Montreal. 83

[42] K. Hamborg, G. Gediga, and I. Duntsch. Evaluation of software systems. *Evaluation of Software Systems, in Kent, A., and Williams, J.G., (Ed.) Encyclopedia of Library and Information Science*, 72:166–192, 2002. 65, 66, 67, 69, 72, 73

[43] W. Hampe-Neteler. Software-ergonomische bewertung zwischen arbeitsgestaltung und software-entwicklung. Technical report, Frankfurt: Lang, 1994. 67, 72

[44] M. T. Hansen, N. Nohria, and T. Tierney. What’s your strategy for managing knowledge? *Harvard Business Review*, 77(2):106–16, 187., 1999. 11

[45] Dominik Heim. Semantic wikis in knowledge management. Master’s thesis, Fachhochschule Kaiserslautern, 2006. 7, 65, 75, 76, 77, 80

[46] James Hendler. Science and the semantic web. Vol. 299. no. 5606:520 – 521, Science 24 January 2003. 5, 16

[47] Deborah Hix and H. Rex Hartson. *Developing User Interfaces - Ensuring Usability Through Product and Process*. New York: John Wiley & Sons, 1993. 66

[48] Douglas R. Hofstadter. *Godel, Escher, Bach: An Eternal Golden Braid*. Basic Books, Inc. New York, NY, USA, 1979. 34

[49] David. F Huynh. A user interface framework for supporting information management tasks in haystack. Master’s thesis, Massachusetts Institute of Technology, May 2003. 22

[50] Indratmo and Julita Vassileva. Human and social aspects of decentralized knowledge communities. In Stefan Decker, Jack Park, Dennis Quan, and Leo Sauermann, editors, *Proc. of Semantic Desktop Workshop at the ISWC, Galway, Ireland*, volume 175, November 2005. 8, 29, 30

[51] Martin G Brooks Jacqueline Grennon Brooks. *In Search of Understanding :The Case for Constructivist Classrooms*. ASCD, January , 1999. 42

[52] Helen Sharp David Benyon Simon Holland Jenny Preece, Yvonne Rogers and Tom Carey. *Human-Computer Interaction .* Wokingham, UK: Addison-Wesley, 1994. 51, 53

[53] P. N. Johnson-Laird. *Mental models:Towards a cognitive science of language, inference, and consciousness.* Cambridge, MA: Harvard University Press, 1983. 38

[54] W. Jones, H. Bruce, and S. Dumais. Keeping founds things found on the web. *Proceedings of the Tenth International Conference on Information and Knowledge Management (CIKM 2001),Atlanta, Ga*, page 119–126., 2001. 7

[55] William Jones. Finders, keepers? thepresent and future perfect in support of personal information management. *First Mondy: Peer-Reviewed Journal on the Internet*, Volume 9, No 3, March, 2004. 25, 29

[56] William Jones and Harry Bruce. A report on the nsf sponsored workshop on personal information management. Technical report, University of Washington, Seattle, WA, 2005. 4, 6, 13

[57] William Jones, Manuel Perez-Quinones, Marcia Bates, Mike Franklin, David Karger, David Levy, and Mel Knox. Towards a field of pim inquiry (draft). Technical report, University of Washington. 2, 6, 8

[58] A. H. Jørgensen. Using the thinking-aloud method in system development. *In G. Salvendy and M. J. Smith (Eds.), Desingning and Using Human-Computer Interfaces and Knowledge Based Systems, Amsterdam. Elsevier*, page 743–750, 1989. 71

[59] D Kelly. Building a test collection for investigating contextual information retrieval. In *International Conference on Research and Development in Information Retrieval (SIGIR '04), Workshop on Information Retrieval in Context, Sheffield, UK.*, 2004. 62

[60] Diane Kelly. Pims workshop report: Measurement and evaluation. *PIM Workshop Report*, January 2005. 61, 62, 64, 65, 67, 68, 72, 76, 83

[61] Kelly.D. *Understanding implicit feedback and document preference: A naturalistic user study.* PhD thesis, Rutgers University, 2004. 55, 73

[62] David Kirsh. The intelligent use of space. *Artif. Intell.*, 73(1-2):31–68, 1995. 26

[63] David Kirsh. A few thoughts on cognitive overload. *Intellectica*, 1:19–51, 2000. 25, 29, 46, 49, 81

[64] Rob Kling. Cooperation, coordination and control in computer-supported work. *Commun. ACM*, 34 (12):83–88, 1991. 10

[65] Amit Konar. *Artificial intelligence and soft computing: behavioral and cognitive modeling of the human brain*. CRC Press, Inc., Boca Raton, FL, USA, 2000. 37, 38

[66] Fallin Kristi. Entropy: Managing data in an electronic world. Technical report, University of Calgary. 1

[67] Andrew Kurtz. Mental models - a theory critique. 2003. 50, 51

[68] M. Lansdale. The psychology of personal information management. *Applied Ergonomics*, 19(1):55–66, March 1988. 27

[69] Steven M. Lehar. *The World In Your Head: A Gestalt View of the Mechanism of Conscious Experience*. Lawrence Erlbaum Associates, 2003. 43

[70] C. Lewis. Using the "thinking aloud" method in cognitive interface design, new york: Ibm research reports rc 9265 (40713),. Technical report, IBM Thomas J. Watson Research Center., 1982. 71

[71] Man Lou. Semantic meeting annotation : A meeting management tool based on the semantic desktop. Master's thesis, Technische Universität Berlin, 2006. 7, 29

[72] L.Sauermann. the gnowsis : using semantic web technologies to build a semantic desktop. Master's thesis, Technical University of Vienna, 2003. 9, 47, 48, 79, 80, 82

[73] David Maier and William Jones. Personal information management group report. Technical report, NSF IDM Workshop, 2003. 28, 29, 30

[74] Deborah J. Mayhew. *The Usability Engineering Life Cycle*. San Francisco: Morgan Kaufmann Publishers, 1999. 72

[75] Scott McDaniel. What's your idea of a mental model? Technical report, 2003. 50, 83

[76] John S. Mill. Autobiography. 1873, On the Web at http://www.utilitarianism.com/millauto/seven. 55

[77] P. Moore and C Fitz. Gestalt theory and instructional design. *Journal of Technical Writing and Communication*, 23(2):137–157, 1993. 44, 45

[78] Lynn Nadel and Massimo Piatelli-Palmarini. What is cognitive science ? In *The Encyclopedia of Cognitive Science*, 2002. 18, 19, 20

[79] B. Nardi and Barreau D. Finding and reminding: File organization from the desktop. *ACM SIGCHI Bulletin*, 27,3:39–43, July 1995. 25

[80] J. Nielsen. Usability engineering at a discount. *In G. Salvendy and M. J. Smith (Eds.), Desingning and Using Human-Computer Interfaces and Knowledge Based Systems, Amsterdam. Elsevier*, page 394–401, 1989. 71

[81] J. Nielsen. The usability life cycle. *IEEE Computer,*, 25:12–22, 1992. 71

[82] J. Nielsen and R. L. Mack. *Usability Inspection Methods.* New York: Wiley, 1994. 69

[83] D.A. Norman. Some observations on mental models. *In D. Gentner and A.L. Stevens, Eds. Hillsdale, NJ: Lawrence Erlbaum*, pages 7–14, 1983. 50, 53

[84] Donald Norman. *The Design of Everyday Things.* New York: Doubleday/Currency, 1990. 40, 52

[85] JS Olson and GM Olson. *Handbook of applied cognition:Computer-supported cooperative work (pp. 409-442).* New York: Wiley and Sons Ltd., (1999). 10

[86] A. Paivio. *Mental representations: A dual coding approach.* New York: Oxford University Press., 1986. 36, 38

[87] Kim Tighe Pat Croke, Ann Johnston. Using named entities as a basis to share associative trails between semantic desktops. In *Proceedings of the ISWC 2005 Workshop on The Semantic Desktop*, 2005. 50

[88] M Rauterberg. Amme: an "automatic mental model evaluator" to analyse user behaviour recorded on logfiles. In *In: H. Luczak, A. Cakir, G. Cakir (eds.), Work With Display Units–WWDU'92 (Abstract Book, p. E44). Berlin: Technische Universität - Institut für Arbeitswissenschaften*, 1992. 70

[89] M Rauterberg. A method of a quantitative measurement of cognitive complexity. In *In: G. van der Veer, M. Tauber, S. Bagnara, M. Antalovits (eds.), Human-Computer Interaction: Tasks and Organisation–ECCE'92 (pp. 295-307). Roma: CUD*, 1992. 70

[90] M. Rauterberg and R. Aeppli. Learning in man-machine systems: the measurement of behavioural and cognitive complexity. In *Proceedings of IEEE International Conference on Systems, Man and Cybernetics–SMC'95 (Vol. 5, IEEE Catalog Number 95CH3576-7, pp. 4685-4690). Piscataway: Institute of Electrical and Electronics Engineers.*, 1995. 70

[91] Matthias Rauterberg. How to measure cognitive complexity in human-computer interaction. 70

[92] Krueger H. Ravasio P., Guttormsen Schär S. The virtual desktop: Selected results of a user study. *50th Spring Conference of the German Association for Ergonomy*, March, 2004. 27

[93] Jörg Richter, Max Völkel, and Heiko Haller. Deepamehta - a semantic desktop. In *Proceedings of the 1st Workshop on The Semantic Desktop. 4th International Semantic Web Conference (Galway, Ireland)*, Nov 2005. 82

[94] Y. Rogers. New theoretical approaches for hci. *To appear in ARIST: Annual Review of Information Science and Technology*, 38, 2004. 23

[95] Mary Beth Rosson and John M. Carroll. *Usability engineering: scenario-based development of human-computer interaction*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 2002. 63, 64

[96] Mary Beth Rosson and John M. Carroll. Usability engineering: Scenario-based development of human-computer interaction. *i-com*, 2(2):46–, 2002. 63, 66

[97] John R.Searle. *Minds, Brains, and Programs*. The Behavioral and Brain Sciences, vol. 3. Copyright 1980 Cambridge University Press., 1980. 35

[98] Jeffrey Rubin. *Handbook of Usability Testing*. New York: John Wiley & Sons, 1994. 72

[99] Stuart J. Russell and Peter Norvig. *Artificial Intelligence: A Modern Approach*. Pearson Education, 2003. 35

[100] P. Saettler. *The Evolution of American Educational Technology*. Englewood, CO: Libraries Unlimited, 1990. 45

[101] Martina Angela Sasse. *Eliciting and Describing Users' Models of Computer Systems*. PhD thesis, School of Computer Science,The University of Birmingham,B15 2TT, England., April 1997. 24, 36, 37, 50, 51

[102] Leo Sauermann. The gnowsis semantic desktop for information integration. In *Proceedings of the WM 2005*. Springer, 2005. 23, 47

[103] Leo Sauermann. Pimo-a pim ontology for the semantic desktop (draft). Draft, DFKI, 2006. 4, 31, 53, 56, 81, 83

[104] Leo Sauermann, Ansgar Bernardi, and Andreas Dengel. Overview and outlook on the semantic desktop. In *Proc. of Semantic Desktop Workshop at the ISWC, Galway, Ireland*, 2005. 2, 8, 47, 48

[105] Leo Sauermann, Andreas Dengel, Ludger van Elst, Andreas Lauer, Heiko Maus, and Sven Schwarz. Personalization in the epos project. In *Proceedings of the Semantic Web Personalization Workshop at the ESWC 2006 Conference*, 2006. 75

[106] Leo Sauermann, Gunnar Aastrand Grimmnes, Malte Kiesel, Christiaan Fluit, Dominik Heim, Danish Nadeem, Benjamin Horak, and Andreas Dengel. Semantic desktop 2.0: The gnowsis experience. In *Proceedings of the ISWC 2006*, 2006. 47

[107] Leo Sauermann and Sven Schwarz. Introducing the gnowsis semantic desktop. In *Poster at the International Semantic Web Conference ISWC*, 2004. 48

[108] M. Scriven. The methodology of evaluation. *In R. W. Tyler, R. M. Gagné, and M. Scriven (Eds.), Perspectives of curriculum evaluation, Chicago, IL: Rand McNally*, pages 39–83, 1967. 63

[109] M. Scriven. *Evaluation thesaurus.* Sage Publications. 4th ed. Newbury Park, CA, 1991. 64

[110] John Searle. Is the brain a digital computer? on the web at http://www.ecs.soton.ac.uk/ harnad/papers/py104/searle.comp.html. Technical report. 35

[111] York Sure, Pascal Hitzler, Andreas Eberhart, and Rudi Studer. The semantic web in one day. *IEEE Intelligent Systems*, vol. 20, no.3:85–87., 2004. 24

[112] A. Sutcliffe. On the effective use and reuse of hci knowledge. *ACM Transactions on Computer- Human Interaction (TOCHI),*, 7(2)::197–221,, 2000. 23

[113] J. Swan, S. Newell, H. Scarbough, and D. Hislop. Knowledge management and innovation: networks and networking. *Journal of Knowledge Management*, 3,4::262–275., 1999. 12

[114] Joshua Tauberer. What is rdf. *On the Web at http://www.xml.com/pub/a/2001/01/24/rdf.html*, 26 july, 2006. 24, 54

[115] Jaime Teevan. *Supporting Finding and Re-Finding Through Personalization.* PhD thesis, Department of Electrical Engineering and Computer Science, MIT, October, 2006. 61

[116] Jonathan Grudin Thomas Erickson. Nsf workshop on pim: Problems and opportunities “from pim to gim” breakout group report. Technical report, University of Washington, January 2005. 13

[117] Clare Torrans. Gestalt and instructional design. Technical report, George Mason University, March 1999. 43, 44, 45

[118] Ralph Trittmann. The organic and the mechanistic form of managing knowledge in software development. In *Advances in Learning Software Organizations : Third International Workshop, LSO 2001, Kaiserslautern, Germany, September 12-13, 2001, Proceedings.* Springer Berlin / Heidelberg, Volume 2176/2001, 2001. 11

[119] D. A. Tyldesley. Employing usability engineering in the development of office products. *Computer Journal*, 31:431–436, 1988. 67, 73

[120] Mike Uschold. An ontology research pipeline. *Applied Ontology IOS Press*, Vol.1:13–16, 2005. 55

[121] V.Bush. As we may think. *Conversational Computers*, pages 10–12, 1968. 48, 49, 50, 52

[122] Max Völkel and Heiko Haller. Conceptual data structures (cds) – towards an ontology for semi-formal articulation of personal knowledge. In *14th International Conference on Conceptual Structures, Aalborg University, Denmark*, 2006. 56, 83

[123] Max Wertheimer. Untersuchungen zur lehre von der gestalt ii. *Psycologische Forschung*, 4:301–350, 1923/1938. Trans. as "Laws of Organization in Perceptual Forms," in W. Ellis, ed. *A Source Book of Gestalt Psychology*, 71-88. London: Routledge & Kegan Paul, 1938. 44, 45

[124] Wilson F.and Dowell J. Whitefield, A. A framework for human factors evaluation. *Behaviour and Information Technology*, 10:65–79, 1991. 67

[125] Steve Whittaker and Julia Hirschberg. The character, value and management of personal paper archives. *In ACM Transactions on Computer Human Interaction*, Vol. 8, No.2.:150–170, June 2001. 30

[126] Huiyong Xiao and Isabel F. Cruz. A Multi-Ontology Approach for Personal Information Management. In *Proceedings of the 1st Workshop on The Semantic Desktop (associated with ISWC 2005)*, 2005. 56