Sophia: Towards a Personal Digital Workspace for Knowledge Workers

S.J. Overbeek[1], D.B.B. Rijsenbrij[2], and H.A. (Erik) Proper[2]

[1] e-office B.V., Dolderseweg 2, 3712 BP Huis ter Heide (Utrecht), The Netherlands, EU
Sietse.Overbeek@e-office.com
[2] Institute for Computing and Information Sciences, Radboud University Nijmegen, Toernooiveld 1, 6525 ED Nijmegen, The Netherlands, EU
{D.Rijsenbrij, E.Proper}@cs.ru.nl

Abstract. Present day knowledge workers interact with a digital world which is full of digital services intended to support these workers in their knowledge intensive tasks. Digital services include the use of applications in general, tools that support knowledge generation, or knowledge transfer, but may also support the proliferation of knowledge in order to improve organizational decision making and value addition. However, it often occurs that contemporary digital services are not user-friendly, impersonal, and ambiguous in use. Therefore, the notion of Sophia[1] is presented: a reference model of and a development framework for a personal digital workspace for knowledge workers, aiming to integrate and personalize all digital services, digital information items, and digital knowledge items, so that an individual knowledge worker can carry out his work related activities pleasantly, effectively, and efficiently in every context. We further argue that digital architecture plays an important role when realising a development methodology.

1 Introduction

Our society is changing under the influence of advanced information technologies. Various authors who try to assess the influence of computer and information technology on humans, society, and organizations use metaphors such as: Being Digital [1], Digital Economy [2], and Digital Places [3]. It shall need no further arguing that information technology has an increasing influence on the way we work and live [1, 4]. In 2003, the world produced about 800MB of information for each man, woman, and child on earth. Well over 90% of information currently produced is created in a digital format, and this percentage will increase substantially in the future. At the same time, much of the existing content which is currently only available in a physical format will be digitized soon as well [5]. Contemporary businesses demonstrate significant concerns on how all this available information can be converted into knowledge. With the growth of clerical occupations at the turn of the century, the ascendancy of knowledge-producing occupations has been an uninterrupted process. While an information

[1] Sophia is the Greek word for wisdom.

worker is busy producing, processing, storing, transferring, and comparing information, a knowledge worker crafts and tunes the available information to create, distribute, and apply knowledge. Information is an enabler of these actions, so the work of an information worker is closely related with the work of a knowledge worker. Knowledge workers have high degrees of expertise, education, or experience, and the primary purpose of their jobs involves the creation, distribution, or application of knowledge [6].

The contributions we would like to make with this paper to anticipate on the swiftly changing work environment of knowledge workers by the influence of advanced information technologies are as follows: an explanation why a personal digital workspace for knowledge workers is necessary to support the knowledge worker in his work (section 2 and 3), an outline of a reference model of a personal digital workspace for knowledge workers (section 4), a further elaboration of this reference model in terms of a conceptual model (section 5), and a discussion on how actual personal digital workspaces for knowledge workers may be developed using the conceptual model (section 6). Finally, section 7 concludes this paper.

2 A Hierarchy of Digital Spaces

Present day knowledge workers interact with a digital world which is full of digital services. Digital services can be defined as any computer based tool which supports the performance of applications, activities, or actions such as knowledge generation and knowledge transfer, and may also support the proliferation of the knowledge produced by knowledge workers in order to improve organizational decision making and value addition [7]. All these services are intended to support these workers in their knowledge intensive tasks. However, it often occurs that these digital services are not user-friendly, impersonal, and ambiguous in use.

In order to anticipate more rapidly and adequately to these concerns in the swiftly changing digital environment of a knowledge worker, his workspace should be digitized in a way so that digital services properly assist the knowledge worker in his work [8, 9]. Both academia and industry gradually anticipate on these developments. Malhotra and Majchrzak [9] introduced the virtual workspace, Forrester [10] the concept of an adaptive workspace, Gartner the e-workplace [11], Bafoutsou and Mentzas [12] the electronic workspace, while Rijsenbrij [13] coined the concept of a digital workspace. Industry figures show that an increasing number of companies have decided that digital services required to anticipate on the swiftly changing digital environment of a knowledge worker are classified as core investments, and as a result more money is spent on data warehousing[2] and portals[3] [14]. A survey at 83 firms with more than

[2] A data warehouse is a central store of data common to the organization [7]. It is a central repository of information drawn from disparate and physically distributed operational source systems of an enterprise, as well as external data.

[3] Portals can be seen from several perspectives. 'Portal' means 'large door' or 'gateway', indicating that the portal itself is not the final destination but a way to reach many other places

$100 million in revenue shows that the largest segment of companies expects to spend between $1 million and $5 million to roll out portals and to employ a staff of three to manage a portal during the first three years [15]. Portal enthusiasm continues despite tighter budgets and post-dot-com scepticism. The largest number of companies which were part of the survey counted between 1,000 and 10,000 portal users today, and respondents at $1 billion-plus companies expect to drive this number into the tens of thousands one year from now [14].

Figure 1 helps to clarify on which type of digital space (in which the aforementioned digital services like data warehousing and portals play an important role) the focus lies in this research and to position the various digital spaces in a hierarchy.

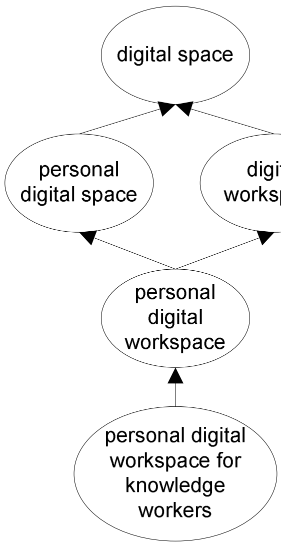

Fig. 1. A digital space hierarchy

As a first step, we might say that a digital space integrates all digital services and digital information items, so that people can carry out their private and work related activities pleasantly, effectively, and efficiently in every context. When considering the hierarchy in figure 1, it is clear that a digital space can be personalized (a personal digital space) and that a digital space can be work-related (a digital workspace). When these two variants of the digital space are combined we will achieve the personal digital workspace. In this research, we will initially focus on the personal digital workspace for knowledge workers, which is actually a bottom-up approach in the proposed digital space hierarchy. This enables us to define initial groundwork and to scope the research. Thus, 'Sophia' can be defined as a reference model of and a development framework for a personal digital workspace for knowledge workers, aiming to integrate and personalize all digital services, digital information items, and digital knowl-

[7]. A portal integrates and personalizes digital services, information items, and knowledge items in one environment, so that the individual knowledge worker is facilitated in his work.

edge items, so that an individual knowledge worker can carry out his work related activities pleasantly, effectively, and efficiently in every context.

3 Ensuing Research Questions

In this section we provide a brief outline of related work. Taking the definition of Sophia provided in the previous section as a starting point, we then identify the research questions which we aim to answer in our future research activities.

Current research [8, 9, 10, 16, 17] is mostly aimed at the supply side of information and the technological construction of a digital space, without bringing forward the need for a well-organized, structured, and user-centric development process. The latter is absent in current research on digital spaces, risking an unstructured and unorganized development process without placing the human in the centre of attention. Current research on user-centric development methodologies [18, 19] are based solely on digital services, and not yet on an entire digital space, or even more specifically a personal digital workspace for knowledge workers.

Given the basic research problem:

How to support knowledge workers in their work so that digital services enable them in their drive to create, distribute and apply knowledge in a pleasant, effective and efficient way?

the goal of our current work:

How to create a reference model for Sophia?

the longer term goal and the suggested solution to the problem:

How to create a development framework for Sophia?

three basic research questions can be formulated:

Q1 Which reference model enables us to describe how Sophia integrates and personalizes digital services, digital information items, and digital knowledge items so that knowledge workers can carry out their work related activities pleasantly, effectively, and efficiently in every context?

Q2 Which development framework enables us to describe and analyze the environment and the concepts of Sophia? This includes the selection and / or the creation of modeling techniques that clearly take the objectives of knowledge workers as a starting point.

Q3 What is an operational form of this reference model and associated development methodologies which we can use as a working-method in order to create personal digital workspaces for knowledge workers?

What is especially important in this research are the concepts necessary to design Sophia from a demand side perspective. The knowledge worker is the centre of attention in this research, not the technology. Thus, the development of Sophia has a close relationship with the fields of information science, sociology, psychology, and business administration. Actually, we scope this research so that the correlation between technology and the interacting knowledge worker is emphasized. This means in fact that concrete adjacent fields are (but not limited to): computer-supported cooperative work (CSCW), human-computer interaction (HCI), user interface design, knowledge management, and cognition. These fields also take the knowledge worker as a starting point.

4 Reference Model of Sophia

The reference model of Sophia is shown in figure 2 and is divided in three main parts: the physical world, the social world, and the digital world [20].

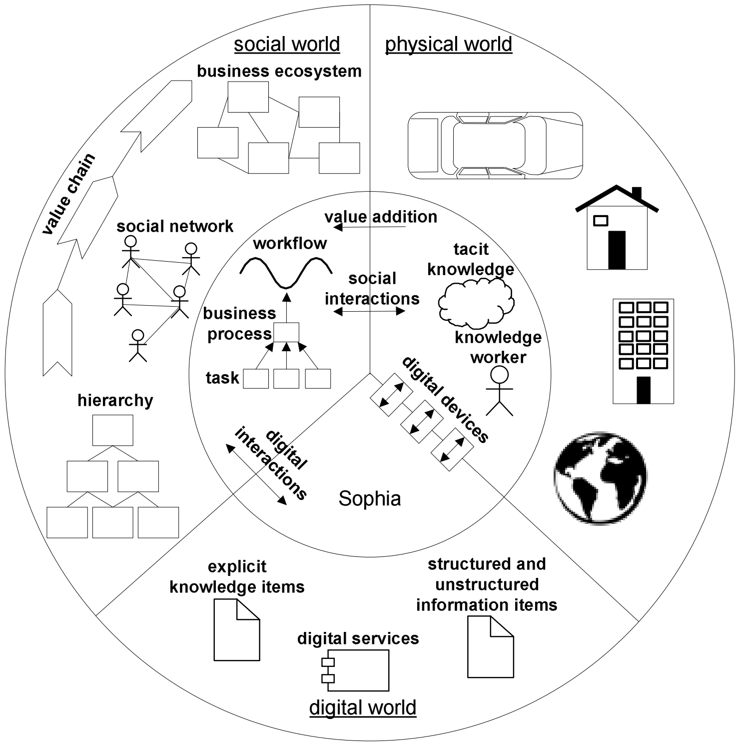

Fig. 2. Reference model of Sophia

One of the challenges is the alignment of the three worlds. This alignment puts specific requirements on the modeling techniques to be used when developing a personal digital workspace for knowledge workers. The three worlds communicate with each other by social and digital interactions, so that information and knowledge can be transferred from one world to the other. The knowledge worker accesses the digital world by using digital devices (on which the digital services are displayed). The social world is accessed from the physical world by social interactions and vice versa. The knowledge worker can also transfer value to the social world as part of the social interactions.

4.1 The Physical, Social, and Digital World

The *physical world* is the world of cars, computers, houses, office buildings, people, and in general anything that can be described using the basic measuring units of physics, e.g. meters, kilograms, seconds, and amperes.

The *social world* consists of roles people play, organizations, departments, responsibilities, rights, delegations, business processes, and in general the processes and structures defined by human institutions. The social world in the reference model includes the social network. Three social network archetypes can be distinguished [21]: customized response, modular response, and routine response. Customized response networks exist in settings where both problems and solutions are ambiguous. New product-development companies, high-end investment banks, and strategy consulting firms require networks that can rapidly define a problem or an opportunity and coordinate relevant expertise in response. Modular response networks thrive in settings where components of a problem and solution are known but the combination or sequence of those components is not yet known. Surgical teams, law firms, and business-to-business sales require networks to identify problem components and address them with modularized expertise. Routine response networks are commonly found in environments where work is standardized. Problems and their solutions are well defined and predictable. Call centers and insurance claims-processing departments require the reliable coordination of relevant expertise to solve common issues. Because Sophia is specialized as a *work*space, the social world includes the hierarchy, the value chain, and the business ecosystem as well. A hierarchy represents the centralization of control or decision making in classical management theory [22]. Empowerment or delegation of authority from manager to subordinates reflects the amount of decentralization of control. With such empowerment or delegation, however, a manager has central control, even if the subordinates can make some decisions. The value chain denotes all activities performed by an organization and how they are linked with each other [23]. The business ecosystem is in principle an addition to the value chain and consists of organizations which produce value so that a value network develops [24]. Such a networked industrial environment can be compared to biological ecosystems. Like their biological counterparts, these business ecosystems are characterized by a large number of loosely interconnected participants who depend on each other for their mutual effectiveness and survival. Three other components of the social world which have a hierarchical relationship with each other and require clarification are: the task, the business process, and the workflow. Workflow is a key area of CSCW research which relates to this research. A workflow reflects the processes that an organization has created to coordinate the activities of different individuals, to ensure the successful completion of work, and to improve the overall efficiency of workers. Workflow specifications can be understood, in a broad sense, from a number of different perspectives [25]:

- the control-flow perspective (or process) perspective describes tasks and their execution ordering through different constructors, which permit flow of execution control, e.g. sequence, choice, parallelism, and join synchronization;
- the data perspective deals with business and processing data. This perspective is layered on top of the control perspective. Business documents and other objects

which flow between activities, and local variables of the workflow, qualify in effect pre- and post-conditions of task execution;

- the resource perspective provides an organizational structure anchor to the workflow in the form of human and device roles responsible for executing tasks;
- the operational perspective describes the elementary actions executed by tasks, where the actions map into underlying applications. Typically, (references to) business and workflow data are passed into and out of applications through activity-to-application interfaces, allowing manipulation of the data within applications.

At one extreme, application developers carefully design the application to fit the specific work practices of its users [26]. Under this model, users do not change their work practices at all, because the technology accommodates their specific needs and work styles. The alternative extreme is to reshape the processes of the organization around the new application. For this approach to be successful, the users must change their work habits to fit the introduced technology. Although both extremes have occurred in practice, a personal digital workspace for knowledge workers has to be designed in a way so that the technology accommodates the specific needs and work styles of knowledge workers as best as possible. Business processes are part of the organizational workflow. A business process is a set of one or more tasks which collectively realize a business objective or policy goal, normally within the context of an organizational structure defining functional roles and relationships. A business process is decomposed into tasks, as figure 2 shows. As a commonsense concept, a task is a human activity to achieve some purpose. In the context of Sophia, a task is a subpart of a business process that: represents a goal-oriented activity adding value to the organization, handles inputs and delivers outputs in such a way so that the knowledge worker is satisfied, consumes resources, requires (and provides) knowledge and other competences, is carried out according to given quality and performance criteria, and is performed by responsible knowledge workers [27].

The *digital world* consists of digital services, digital information items, and digital knowledge items. Software by nature consists of symbols, and the digital world is part of the symbol world, that also includes text on paper, traffic signs, and in general any physical entity that has been given a meaning by people. Characteristic of the symbol world, and therefore of the digital world, is that there is a meaning convention that is not given by the physics of the entity. The symbols appearing on a screen, the signals sent by a computer to peripheral devices, are physical phenomena for which people defined a meaning by convention [20]. In the reference model, information is differentiated to structured and unstructured information. Information is a flow of messages or meanings which might add to, restructure or change knowledge. Information can be divided in structured and unstructured information and is part of the digital world as structured and unstructured information items [27]. Unstructured information is any document, file, image, report, or form that has no defined, standard structure that enables convenient storage in unit record or similar automated processing devices such as Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM). It can also not be defined in terms of rows and columns or records, and the data cannot be examined with standard unit record access. E-mail, instant messaging, web-logs, and websites are examples which contain unstructured information. Structured information is any document, file, or form that has a defined standard structure that enables convenient storage in unit record or similar automated processing devices. Since Sophia is geared towards knowledge workers, knowledge is introduced as a component in the reference model. Besides the differentiation in two types of information, knowledge is differentiated into tacit knowledge and explicit knowledge. Knowledge is a justified belief that increases an individual's capacity to take effective action in a certain context [28]. Explicit knowledge is knowledge which is transmittable in formal, systematic language and is part of the digital world as an explicit knowledge item. Tacit knowledge has a personal quality, which makes it hard to formalize and communicate instead. Tacit knowledge is deeply rooted in action, commitment, and involvement in a specific context. Tacit knowledge remains in the human mind and is thus not part of the digital world, but of the physical world.

4.2 Digital Services

We have chosen to use a modified version of Nonaka and Takeuchi's [29] knowledge conversion model as a reference model from which to consider the activities of knowledge workers, as depicted in figure 3. As stated in the definition of a knowledge worker, the primary purpose of their jobs involves the creation, distribution, or application of knowledge. Nonaka and Takeuchi's model describes the typical main processes which take place during the creation, distribution, and application of knowledge.

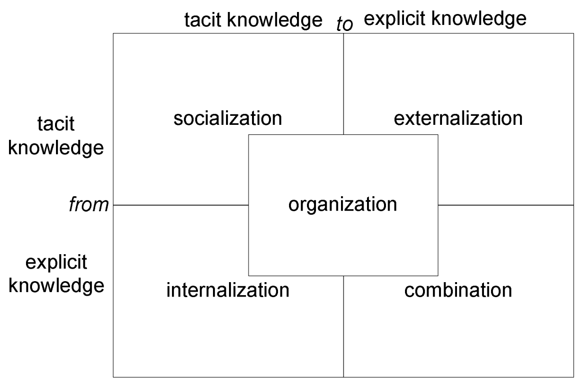

Fig. 3. Four modes of knowledge conversion added with an organization component

As is shown in figure 3, a knowledge worker can convert knowledge. These different conversion modes are called socialization, internalization, externalization, and combination respectively. An additional 'organization' component is added to the diagram as well. This is not a knowledge conversion mode, but complements the four modes of knowledge conversion instead. Organization involves setting an order and time for planned events and digital services can handle organization tasks for the knowledge worker. Such intelligence may lead to an example scenario in which the knowledge worker wants to plan a meeting with another person and that the appropriate digital service is selected for the task and finalizes the organization event. Socialization is a process of sharing experiences and thereby creating tacit knowledge such as shared mental models and technical skills. Internalization is the process of embodying explicit knowledge into the knowledge worker's tacit knowledge bases in the form of shared mental models or technical know-how. Externalization is a quintessential knowledge-creation process in that tacit knowledge becomes explicit, taking the shape of metaphors, analogies, concepts, hypotheses, or models. Finally, individuals exchange and combine knowledge through such media as documents, meetings, telephone conversations, or computerized communication networks.

Digital services enable the knowledge worker in such a way that socialization, internalization, externalization, and combination phenomena occur with additional organization activities. Figure 4 shows examples (this is definitely no complete list, it just gives an idea of which digital services belong to which group) of digital services.

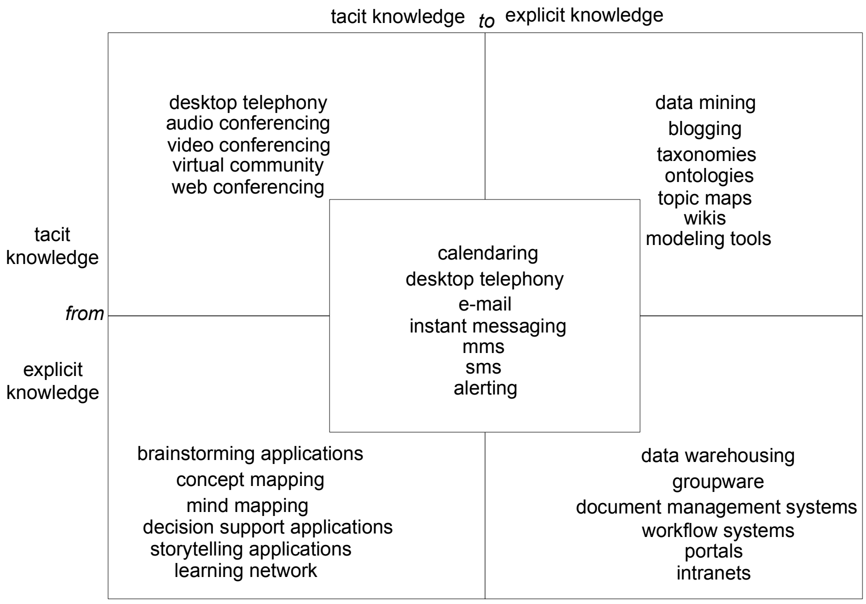

Fig. 4. Examples of digital services for Sophia

Several digital services mentioned in figure 4 require further clarification [7]:

- alerting is a technology used to inform the knowledge worker when certain events in his personal digital workspace have happened which the knowledge worker wishes to be informed about.
- desktop telephony involves every digital telephony service, like VoIP, IP telephony, and 'softphones';
- audio, video, and web conferencing comprises the use of audio or video to enhance human presence in meetings. Web conferencing utilizes the internet as a conferencing platform. Video is advantageous when visual information is discussed, and may also be used in less direct collaborative situations, such as for providing a view of activities at a remote location;

- a community of practice is a group of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly;
- concept mapping is a visual representation of core concepts showing the relationships between them. A typical concept map comprises a set of nodes or bubbles (the concepts) with arrowed links between them (the causal relationships);
- mind mapping is a specific form of concept mapping, where ideas branch out from a central point;
- decision support applications assist lower- and middle management to analyze large amounts of data so that they can make better decisions;
- storytelling applications facilitate the use of stories in the organizational context, as a way of sharing knowledge and helping the process of learning;
- a learning network is a network of individuals who share knowledge for the primary purpose of personal development and learning;
- data mining techniques are the processes that focus on the automatic exploration and analysis of large quantities of raw data in order to discover meaningful patterns and rules [30];
- blogging is a way to show a string of thoughts in chronological sequence on a webpage, often with hyperlinks to sources that have stimulated thinking;
- taxonomies, ontologies, and topic maps relate with each other. A taxonomy is a system of classification, where a typical taxonomy is a hierarchy of terms (nodes), where lower level terms are more specific instances of higher level ones. Ontologies are extensions to a taxonomy which add specifications of relationships between entities plus a set of automatic inference rules and associated actions. A topic map describes relationships of nodes in an ontology independent of its underlying resources;
- wikis are used as a collaboration tool to allow multiple authors to create and update webpages;
- modeling tools support the knowledge worker in the process of constructing or modifying certain models, e.g. ER, ORM, or UML models [31].
- groupware is a technology designed to facilitate the work of groups;
- document management systems utilize the following activities: storing files in a central library, controlling access to files both for security purposes and collaboration needs, keeping an audit of activity and changes in the managed documents, and searching documents on either content or index terms.

5 Initial Conceptual Model of Sophia

Figures 5, 6, and 7 are initial diagrams defining the core concepts of Sophia, which are refined by future research. The notation used is from the *Unified Modeling Language Specification* [31]. In the figures, boxes represent classes of things. Lines connecting boxes represent associations between things. An association has two roles (one in each direction) and a role can optimally be named with a label. The role from A to B is closest to B, and vice versa. For example, the roles between knowledge worker and digital device can be read: A knowledge worker interacts with a digital device. A role can have a multiplicity, e.g. a role marked with '1..*' is used to denote *many*, as in a one-to-many or many-to-many association. A diamond (at the end of an association line) denotes a part-of relationship. For example, tacit knowledge is a part of knowledge. The initial conceptual model of Sophia is split in three parts: Sophia concepts in the physical world, the social world, and the digital world.

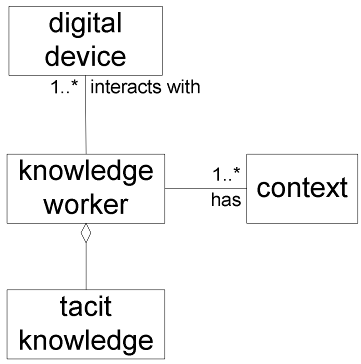

Fig. 5. Sophia concepts in the physical world

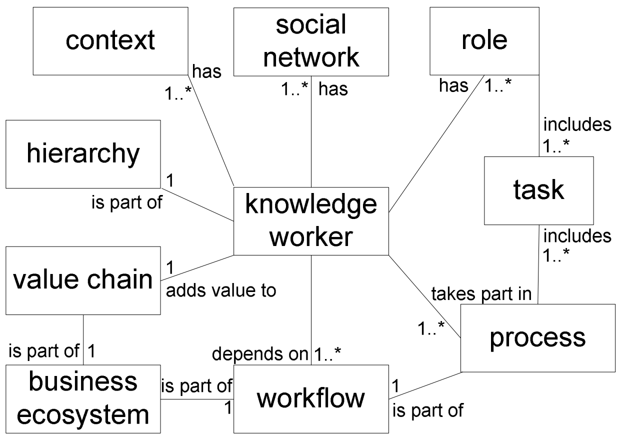

Fig. 6. Sophia concepts in the social world

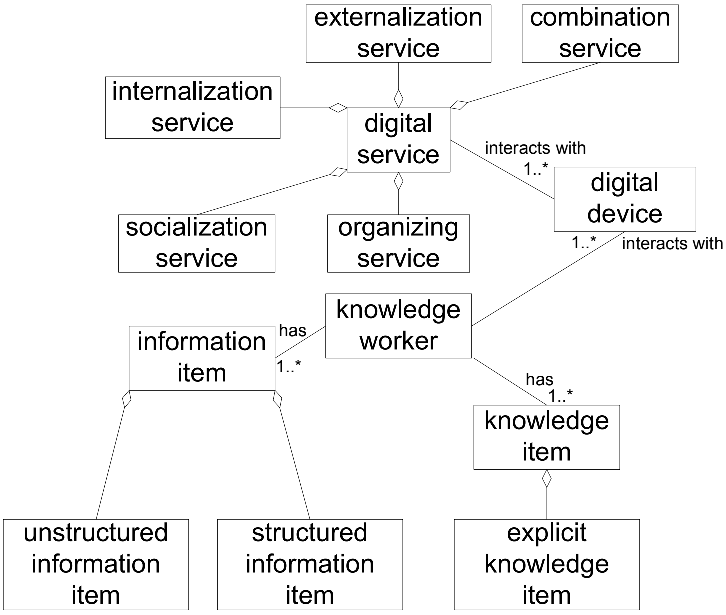

Fig. 7. Sophia concepts in the digital world

6 Development Methodology

Sophia comprises a reference model, as well as a development framework (comprising the conceptual model and a development methodology) to develop actual personal digital workspaces for knowledge workers. This section will discuss the requirements for this development methodology. We will particularly argue that a user-centric architecture based development methodology is needed. Such an approach enables a well-organized, structured, and user-centric development process, placing the knowledge worker in the centre of attention. The unprecedented rates of advance in the computer and information sciences have increased complexity in today's architecting and engineering challenges. The precipitous drop in computer hardware costs has generated a major design shift, from 'keep the computer busy' to 'keep the user busy'. When the cost of software development dominates, development methodologies should be organized to simplify software development. This is where architecture in the digital world comes into play.

We denote architecture in the digital world as 'digital architecture'. Architecting is the art and science of designing and building systems. Architecting, the planning and building of structures, is as old as human societies and as modern as planning the exploration of the solar system. The word 'architecture' is now widely used in communications, space systems, computers, software, and networks, which implies that architecture is also part of the digital world. Despite 5000 years of history, even the notion of architecture in the physical world is not clearly and crisply defined.

Maier and Rechtin [32] define architecture as: The structure (in terms of components, connections, and constraints) of a product, process, or element. This definition specifically focuses on structure. Components, connections, and constraints are descriptive terms for architecture and as a consequence this definition focuses on the possible solution. A more prescriptive definition is desirable if the knowledge worker with his ideas and wishes is to be placed in the centre of attention. IEEE [33] defines architecture (of software intensive systems) as: The fundamental organisation of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution. This definition tries to recognize that, for most systems, most of the time, the architecture is in the arrangement of physical components and their relationships; but, sometimes, the fundamental organization is on a more abstract level.

Our views on digital architecture as a user-centric development methodology are mostly indebted to ongoing work by Daan Rijsenbrij [13], and we define digital architecture as follows: Digital architecture is a coherent, consistent collection of principles, differentiated to rules, guidelines, and standards which describe how an enterprise, the information supply, the applications, and the infrastructure are shaped and behave in their usage. In this definition architecture is the tool for the architect to guide and bound the engineering processes to develop architecture artefacts. Digital architecture can contribute to our research by guiding and bounding engineering processes so that the development process is of a well-organized, structured, and user-centric fashion. The principles influence the way the artefact is used. Further specification of principles in rules, guidelines, and standards guarantees clarification of these principles. Principles indicate *what* is guided and bounded in the engineering processes and rules, guidelines and standards indicate *how* the engineering processes are guided and bounded. Rules are mandatory, and standards are required for internal and external communication, and for the compatibility of bought components. Guidelines have some more interpretation freedom compared to rules, they are in fact ‘best practices’. We have chosen this so-called prescriptive definition of architecture, because this definition approaches architecture from a demand side perspective, which is necessary to place the *knowledge worker* in the centre of attention instead of the *technology*. The specifics of what architects will produce, that is what an architecture actually looks like, will differ from domain to domain. Ideally, the definition should come from that knowledge; the knowledge of what is needed to successfully define a system concept and take it through development. If that knowledge is present a formal definition should encapsulate that [32].

8 Conclusion

We have presented the area of tension a knowledge worker has to deal with in his daily work: performing knowledge intensive tasks using digital services which are often not user-friendly, impersonal, and ambiguous in use. We selected a range of current research and compared our research approach with current research approaches and discussed the fact that our research approach focuses on the *knowledge* *worker*, instead of the *technology*. Furthermore, the specific research goals were outlined. We have shown and explained the outlines of a reference model of Sophia, including the components which are included in the reference model. The reference model positions the knowledge worker and Sophia within three worlds: the physical world, the social world, and the digital world. An initial conceptual model of Sophia has been depicted as well. The initial conceptual model is a more formal description of the concepts of Sophia and shows the relations between these concepts. We introduced *digital architecture* as a development methodology so that personal digital workspaces for knowledge workers can be developed in a well-organized and structured way.

References

1. Negroponte, N.: Being Digital. Vintage Books, New York, NY (1996)
2. Tapscott, D.: Digital Economy, Promise and Peril in the Age of Networked Intelligence. McGraw-Hill, New York, NY (1996)
3. Horan, T.A.: Digital Places, Building our City of Bits. The Urban Land Institute (ULI), Washington, DC (2000)
4. Tapscott, D., Caston, A.: Paradigm Shift, the New Promise of Information Technology. McGraw-Hill, New York, NY (1993)
5. Varian, H.R.: Universal Access to Information. Communications of the ACM. 48 (2005) 65–66
6. Davenport, T.H.: Thinking for a Living: How to Get Better Performance and Results from Knowledge Workers. Harvard Business School Press, Boston, MA (2005)
7. Tyndale, P.: A Taxonomy of Knowledge Management Software Tools: Origins and Applications. Evaluation and Program Planning. 25 (2002) 183–190
8. Lui, D.R., Wu, I.C., Yang, K.S.: Task-Based K-Support System: Disseminating and Sharing Task-Relevant Knowledge. Expert Systems with Applications. 29 (2005) 408–423
9. Malhotra, A., Majchrzak, A.: Virtual Workspace Technologies. MIT Sloan Management Review. 46 (2005) 11–14
10. Rasmus, D.W.: Adaptive Workspaces: Preparing for the Future of Work. No. RPA-122002-00021. Forrester, Cambridge, MA (2002)
11. Bell, M.A., Joroff, M., Hayward, S., Porter, W., Young, C., Feinberg, B. et al.: The Agile Workplace: Supporting People and Their Work – A Research Partnership Between Gartner, MIT, and 22 Industry Sponsors. Gartner, Stamford, CT (2001)
12. Bafoutsou, G., Mentzas, G.: Review and Functional Classification of Collaborative Systems. International Journal of Information Management. 22 (2002) 281–305.
13. Rijsenbrij, D.B.B.: Architecture in the Digital World (Version Zero-Dot-Three). Inaugural Speech (in Dutch). Radboud University Nijmegen, The Netherlands, EU (2004)
14. Pisello, T.: IT Value Chain Management – Maximizing the ROI from IT investments. Alinean Press, Orlando, FL (2003)
15. Ramos, L., Orlov, L.M., Teubner, C.: Portal Projects in Search of a Purpose. Trends. Forrester, Cambridge, MA (2004)
16. Gutwin, C., Roseman, M., Greenberg, S.: A Usability Study of Awareness Widgets in a Shared Workspace Groupware System. In: Ackerman, M.S. (ed.): Proceedings of the 1996 ACM Conference on Computer Supported Cooperative Work. ACM Press (1996)

17. Nomura, T., Hayashi, K., Hazama, T., Gudmundson, S.: Interlocus: Workspace Configuration Mechanisms for Activity Awareness. Proceedings of the 1998 ACM Conference on Computer Supported Cooperative Work. ACM Press (1998)
18. Pahl, C.: Adaptive Development and Maintenance of User-Centric Software Systems. Information and Software Technology. 46 (2004) 973–986
19. Spink, A.: A User-Centered Approach to Evaluating Human Interaction with Web Search Engines: An Exploratory Study. Information Processing and Management. 38 (2002) 401–426
20. Wieringa, R.: The Alignment Problem. Project GRAAL Whitepaper. Technical Report. Centre for Telematics and Information Technology (2004)
21. Cross, R., Liedtka, J., Weiss, L.: A Practical Guide to Social Networks. Harvard Business Review. 83 (2005) 124–132
22. Ishida, K., Otha, T.: On a Mathematical Comparison Between Hierarchy and Network with a Classification of Coordination Structures. Computational & Mathematical Organization Theory. 7 (2001) 311–330
23. Porter, M.E. Competitive Advantage. The Free Press, New York, NY (1985)
24. Iansiti, M., Levien, R.: The New Operational Dynamics of Business Ecosystems: Implications for Policy, Operations and Technology Strategy. No. 03-030. Harvard Business School, Cambridge, MA (2002)
25. Aalst, W.M.P. van der, Hofstede, A.H.M. ter: YAWL: Yet Another Workflow Language. Information Systems. 30 (2005) 245–275
26. Pratt, W., Reddy, M.C., McDonald, D.W., Tarczy-Hornoch, P., Gennari, J.H.: Incorporating Ideas from Computer-Supported Cooperative Work. Journal of Biomedical Informatics. 37 (2004) 128–137
27. Schreiber, G., Akkermans, H., Anjewierden, A., Hoog, R. de, Shadbolt, N., Velde, W. van de et al.: Knowledge Engineering and Management: The CommonKADS Methodology. Massachusetts Institute of Technology (2000)
28. Alavi, M., Leidner, D.E.: Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues. MIS Quarterly. 25 (2001) 107–136
29. Nonaka, I., Takeuchi, H.: The Knowledge Creating Company. Oxford University Press, New York, NY (1995)
30. Agrawal, R., Imielinski, T., Swami, A.: Mining Association between Sets of Items in Large Databases. Proceedings of the ACM-SIGMOD International Conference on Management of Data. ACM Press (1993)
31. Object Management Group. Unified Modeling Language Specification. Version 1.1. No. OMG ad / 97-08-05. Technical Report (1997)
32. Maier, M.W., Rechtin, E.: The Art of Systems Architecting. CRC Press, Florida, FL (2002)
33. The Institute of Electrical and Electronics Engineers, Inc. IEEE Recommended Practice for Architectural Description of Software-Intensive Systems. No. SH94869. IEEE Computer Society, New York, NY (2000)