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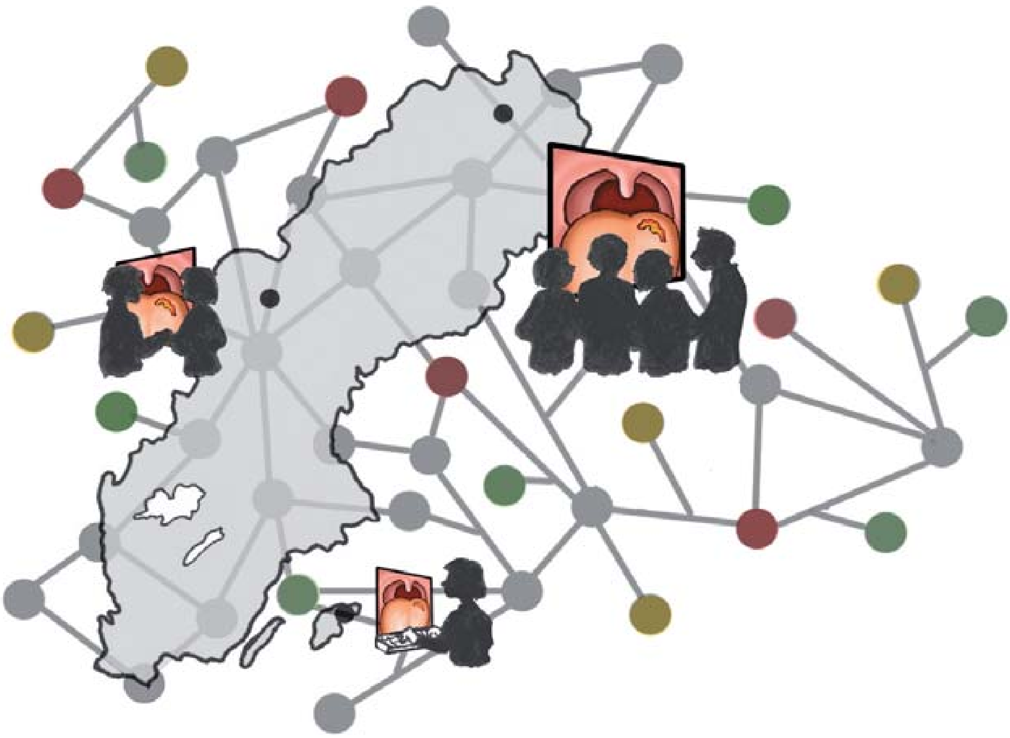

SOMWeb: Supporting a Distributed Clinical Community of Practice Using Semantic Web Technologies

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THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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ABSTRACT

This thesis concerns supporting the collaboration and knowledge sharing of distributed clinicians of oral medicine, a sub-discipline of dentistry. The Swedish Oral Medicine Network (SOMNet) holds monthly telephone conferences where a group of clinicians discuss interesting and difficult cases, which distinguishes it from one-to-one teleconsultations. SOMNet can be seen as a distributed community of practice, that is, a group of people sharing a concern and who interact regularly to extend their individual and collective expertise. Related to this, several topics need further investigation: How can geographically distributed clinical collaboration be characterized? What is appropriate functionality for a Web-based system supporting such collaborations? What are the impacts of such systems on collaboration? Further, Semantic Web technologies, such as the Web Ontology Language (OWL), have been proposed as a means of enhancing knowledge sharing. What are benefits and limitations of using these technologies to encode domain knowledge in oral medicine and to support clinical collaboration, and what practical issues face developers?

The developed system, SOMWeb, focuses on functionality for meetings and structured cases, and has been regularly used for three years. Interviews, observations, a questionnaire, system log analysis, and case analysis were used to study SOMNet's collaboration and identify system impacts. The documentation of the forms of collaboration in SOMNet can serve as a model for other groups of clinicians wishing to establish a distributed collaboration. SOMNet's meetings provide a necessary rhythm for the community and the cases give context to the clinicians' learning which point toward that the centrality of meetings and cases in a tool will benefit collaboration. Impacts on SOMNet's collaboration include enabling the participation of a wider range of clinics. Factors influencing this are the more accessible submission process as well as the increased tangibility of the collaboration. The thesis also provides recommendations for developers of systems supporting clinical collaboration and knowledge sharing.

The use of OWL in examination descriptions has enabled reasoning over cases in the system to provide improved case browsing. At the same time, limitations were found in using OWL for examination templates. Based on the lessons learned in this development, the thesis provides recommendations for using Semantic Web technologies, which can be of value for other developers and to guide future research.

Keywords: clinical collaboration, distributed communities of practice, knowledge management, medical informatics, online communities, ontologies, Semantic Web

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Further, I am grateful for the recommendations already provided by my thesis opponent, Patty Kostkova.

This thesis has been dependent on teaming up, as a part of the MedView project, with the Clinic of Oral Medicine, faculty of Odontology, University of Gothenburg, specifically Mats Jontell and Marita Nilsson. I also want to thank the members of SOMWeb. Further, SOMWeb would not have been possible without the programming efforts of Andras Argirakis, Daniel Roth, and most importantly Fredrik Lindahl. I also want to thank Hajar Kashfi, my fellow graduate student in the MedView project, for her input.

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I also want to thank Anna Friberger for giving this thesis its cover illustration.

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Marie Gustafsson
Annelund, May, 2009

Contents

List of Figures

List of Tables

Chapter 1

Introduction

This thesis investigates the problems associated with supporting the collaboration and improving the knowledge sharing of geographically and organizationally distributed clinicians of oral medicine,[1] a sub-discipline of dentistry. This sub-discipline often deals with disorders of low prevalence, which means that cooperation between geographically distributed clinics is needed to collect diverse and numerous cases for analysis, as well as to provide a means of consultation and learning for a broader audience. For these reasons, the Swedish Oral Medicine Network (SOMNet) holds monthly telephone conference meetings to discuss difficult and interesting cases. This collaboration is carried out under the auspices of the Swedish Oral Medicine Society (SOMS),[2] a professional organization which provides specialist eduction in the form of a certification with both theoretical and practical components. SOMNet was initiated in the early nineties and, since then, they have used different variants of information technology (IT) to support their collaboration. Figure 1.1 shows a timeline of SOMNet, with a focus on the kind of technology support provided.

In order to give an impression of SOMNet's collaboration and to illustrate technical and social issues that need to be dealt with to improve knowledge sharing and learning, a scenario of a meeting is provided. This scenario is predominantly based on the form of collaboration prevailing prior to the beginning of the research of this thesis. After this scenario, motivations for the research of the thesis are presented (Section 1.2), followed by aims and objectives (Section 1.3). Then, research contributions are listed (Section 1.4), as well as the publications on which the thesis builds (Section 1.5). Finally, an overview of the rest of the thesis is provided (Section 1.6).

1.1 A Scenario of SOMNet's Collaboration

"What do you think? We've seen this patient over several years, tried different treatments, but the symptoms have remained the same." The dentist, Alex, heard over the telephone

[1] Oral medicine concerns diseases related to the oral and paraoral structures. This includes the principles of medicine related to the mouth, as well as diseases specific to the orofacial tissues and oral manifestations of systemic diseases.

[2] `http://www.soms.se/`

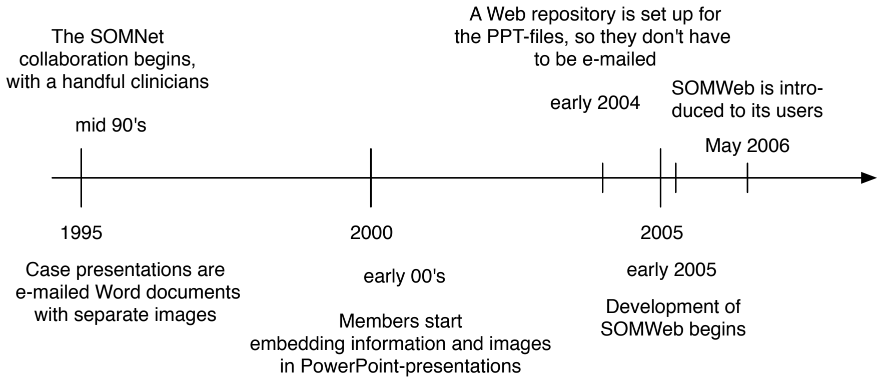


Figure 1.1: Timeline of SOMNets activities and the IT support used.

conference speakers, has just finished describing the case history to his colleagues at clinics and hospitals all over Sweden, and has shown images of the patient's oral mucosa at different points in time.

Many cases are brought to SOMNet's meetings to answer a specific question about diagnosis and treatment. The participants have **varying levels and fields of expertise**, which makes the meetings both interesting and useful but also a challenge to the organization and a system supporting it. For example, a clinician **seeking advice** may be either an expert in the field with a very rare case, or a general practitioner seeking treatment advice. However, they all participate out of professional interest as SOMNet participation in itself does not award points in any continuing professional development program.

In order for the discussion at the meetings to be fruitful, participants must have **access to case data and images**, both to prepare and to follow the meeting. The scenario continues by looking back to when Alex submitted the case.

In order to inform the other participants about the case, Alex must decide what information and images are relevant to include. The common way of doing this in SOMNet (prior to the subsequently presented system) is to create a PowerPoint presentation that includes the history of the patient, often told mainly through images. After viewing some of the presentations from previous meetings, Alex decides to add information under each image about the attempted treatment, but he still is not sure that the relevant details are included.

When entering data using this format, **no structured data** is captured, which makes later retrieval more difficult. Further, the lack of a template for what to enter means that **different members enter different information**. Also, **newer members may be at a loss** about what kind of information is usually included. Another drawback is that **no common vocabulary** is used to describe cases. Another point is that a presented case often contains data from **several examinations** of the patient, but these distinctions are often lost.

Before returning to the meeting discussion, we first consider what happened when Alex tried to find relevant cases among those previously discussed at meetings.

Alex decides that it would be interesting to see what other, similar cases, have been brought up at previous meetings. These are contained in separate PowerPoint presenta-

tions, named after each presenter. He starts opening some of the PowerPoint presentations from the last meeting, and tries to determine if the diagnosis or treatment is relevant to his problem. However, this process is slow, Alex runs out of time, he has only found one case that might be relevant. Further, he has no way of knowing what was decided at the meeting.

This scenario illustrates the need for a **case repository** and descriptive titles for cases. Prior to 2004, there was no shared Web repository of PowerPoint presentations and such a repository only alleviates some of the issue. With a **structured representation** of cases and a **taxonomy of different diagnoses and treatments**, Alex would more easily be able to find cases with his tentative diagnosis, in order, for example, to compare the images of his case with others. The limited time available for clinicians is also apparent.

Before we return to the meeting, where participants begin by asking Alex about the treatment he has tried, it should be mentioned that while most dental clinics in Sweden have electronic health records, these are provided by different vendors and have different information content, making it difficult to extract case information for SOMNet automatically.

"This is Bill. How much Klobetasol did you use?"
"15 milligrams, three times each day."
"And was it oral base or as gel?"
"The oral base," Alex replies.
"Sometimes the gel is easier to apply, you might want to try that. I found several articles related to this, but the conclusions are contradictory. I'll give you the articles though."
"Karen here. The presentation says that you tried Fillijox also."
"Yes, but there was no effect at all."
"Bill, what do you think about cutting it out?"
"You could do that, but I don't think that it will help the patient totally."

Again, this discussion illustrates the **value of the expertise that the individual clinician gains access to**. It also indicates that the discussion includes different viewpoints of how best to treat a given patient. It is the goal of SOMNet to include more **external evidence** in the form of research articles to inform their decisions. However, for this to have any impact, relevant articles have to be noted, and ideally, included in the case record. In the discussion above, the articles might have reached Alex, but probably not the other participants.

The chairperson sums up: "Alright, lets try Klobetasol as a gel first. Alex, let's bring this up again after the summer."

But what happened to the decision? And how will the next presentation of this case be connected to the one from this meeting? For the group to **learn from their experiences**, such records are necessary. In order to have a common record, somebody must be assigned to **record the decision**, and in SOMNet this is the meeting's chairperson. There must also be a place to record the decision and make it **available to all members**.

The system described in this thesis, **Swedish Oral Medicine Web (SOMWeb)**, was inspired by problems such as those illustrated in this scenario. The next section presents motivations for the research aims of the thesis.

1.2 Supporting Distributed Clinical Knowledge Sharing and Collaboration

It has been proposed that healthcare should be evidence-based, meaning that clinical decisions should be based on finding, evaluating, and using the latest research results [132]. To practice evidence-based medicine (EBM) means integrating the expertise among individual clinicians with the best clinical evidence that can be obtained from external sources [135]. However, changing clinical practice to incorporate more external evidence is to a large extent determined by organizational culture [50], relevant evidence may not be available [99], and the value of clinical expertise cannot be disregarded [62]. The collaboration of SOMNet can be seen as a means of promoting EBM: a larger audience can come in contact with experts in the field, and through this get access to credible external sources. Further, there is the potential of building up a collection of cases that can be used for learning and research.

Supporting collaboration in medicine is one aspect of the field of *medical informatics*, which studies how biomedical information, data, and knowledge can be stored, retrieved, and used for problem-solving and decision-making [144]. While the computerization of healthcare was previously the focus of medical informatics, there is a tendency today to reduce the emphasis on computers and focus instead on the meanings of information in the daily work of healthcare professionals. This includes communication, shared knowledge, decision-making, and the social and functional needs of healthcare organizations. Developing tools to support SOMNet can be seen as a part of these newer developments.

If we look at how IT can facilitate distributed[3] clinical collaboration, supported activities include distance consultation and accessing remote expertise [119], sharing clinical data and imagery, dissemination of information and knowledge through broadcasted seminars and online courses [139], and distributed virtual workplaces [143]. However, compared to one-to-one telemedicine approaches and consumer health informatics, systems that provide means for collaboration and distributed clinical teamwork have received little attention thus far [160, 126, 139, 83]. The issue of **developing online support for distributed clinicians** thus needs further investigation. SOMNet's need of a system to support their meeting and case activities provides an opportunity for such a study, and given the developments since the early 1990's in using the Web to support distributed activities, it seems natural such a system be Web-based.

An understanding of the characteristics of distributed collaboration is needed in order to construct adequate online support. However, according to Gennari et al. [47], the communication among teams of healthcare providers and experts has not been sufficiently studied. Wiecha and Pollard [160] hold that "having a clear understanding of team structure and function" is necessary for putting such teams together and supporting them electronically. Furthermore, Pan and Leidner [115] put forth that a knowledge management system "can only be effective if it is congruent with existing work practices rather than imposing new practices" while holding that IT can also be a facilitator for the introduction of new practices. Thus, **studying how distributed clinicians communicate and collaborate** is necessary in investigating how to provide collaborators with adequate systems.

[3] Here and in the rest of the thesis, distributed indicates being *geographically* distributed.

One way of conceptualizing SOMNet is as a *community of practice*, a group of people who share “a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis” [159]. To be more precise, SOMNet is a *distributed* community of practice, in that they are not co-located and seldom communicate through face-to-face communication. In the literature other terms, such as online or virtual communities of practice are also used, but since SOMNet shared a practice long before they went online and virtual indicates that the community is not real, the term distributed is preferred in the thesis. The theory of communities of practice provides a conceptual framework for describing SOMNet’s activities. At the same time, what is learned about SOMNet can be applicable to other distributed communities of practice.

Coming back to the use of IT to support clinical collaboration, an important part of clinical computer applications is gathering and storing clinical information. Data must be recorded in such a way that it can be understood and interpreted by all members of the health care system. This necessitates a formalization and harmonization of clinical knowledge, where formalization is taken to mean the establishment of formal definitions that can provide an explicit structure for intelligent reasoning and harmonization concerns the process of assimilating these formalized activities within a community [24, 104, 121].

One way of representing knowledge and making it machine-processable is through the use of *ontologies*, which in the computer science sense can be defined as an “explicit specification of a conceptualization” [52]. Ontologies are an example of *Semantic Web technologies*, which have been proposed to support information sharing and knowledge-intensive tasks [115, 123]. The Web Ontology Language[4] (OWL) and the Resource Description Framework[5] (RDF) are recommendations of the World Wide Web Consortium (W3C) related to the Semantic Web. However, there is a need for **more experience on the applicability of these technologies in different domains, as well as practical issues facing developers** [114] in order to, for example, provide feedback to developers of standards and tools, to elucidate the benefits and limitations of the technology, and to provide realistic descriptions of what the technologies can achieve, which will contribute to making them more accessible. As seen in the scenario of the previous section, SOMNet lacks a common vocabulary and structure for cases, and as a consequence there are obstacles both when entering new cases and when wanting to find previous ones. Thus, there is a opportunity of investigating the use of Semantic Web technologies in representing oral medicine knowledge and community resources related to SOMNet’s activities.

To summarize, the Web can provide support for distributed communities of practice, but more research is needed on the forms this support can and should take. The characteristics of existing collaboration needs more investigation, as do the effects of such support on collaboration. In addition, the use of Semantic Web technologies to encode domain and community knowledge needs to be explored, to provide experience of their use, both in general and in the setting of knowledge management for health care.

[4] http://www.w3.org/2004/OWL

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

1.3 Aims and Objectives

As indicated above, this thesis investigates how the collaboration and knowledge sharing of distributed oral medicine clinicians can be supported by an online system based on Semantic Web technologies. Three aims associated with this investigation can be discerned from the previous section:

1. Characterize how geographically distributed Swedish clinicians in oral medicine collaborate and share knowledge.

2. Explore the benefits and limitations of using Semantic Web technologies to support distributed clinical collaboration, and through this identify practical issues facing developers.

3. Study the design and development of Web-based tools for distributed clinical collaboration, as well as investigate the impacts of such tools on the collaboration they support.

In order to fulfill these aims, five objectives are put forth:

1. Study the collaboration and knowledge sharing of geographically distributed healthcare professionals in oral medicine, as seen in SOMNet. This covers who participates, their collaboration process, and outcomes, as well as challenges to collaboration and knowledge sharing. Also included is the relation of these results to the theory of communities of practice.

2. Employ Semantic Web technologies, OWL and RDF, to describe oral medicine knowledge and community resources. The oral medicine knowledge focuses on the formalization of examination templates and terminology applied when clinicians enter data about individual patients. Community resources are aspects of the collaboration related to users, meetings, and case metadata.

3. Design and develop a Semantic Web-based system, SOMWeb, to support a community of practice of oral medicine in managing its meetings and cases. This includes design decisions and functionality, as well as technical aspects of the system architecture and how the ontologies resulting from the previous objective are used.

4. Evaluate SOMWeb. This entails its general functionality, structured case-entry, how the system is used, as well as a comparison of cases before and after the introduction of SOMWeb. This also includes the identification of impacts of SOMWeb on SOMNet's collaboration.

5. Extract recommendations for developers of Semantic Web-based systems and systems supporting clinical collaboration and knowledge sharing.

Objectives one to three correlate with aims one to three, the fourth objective also concerns the third aim, and the fifth objective regards recommendations relating to aims two and three.

The work of this thesis is carried out in the **MedView** research group, a general overview of which is given in Jontell et al. [75]. Specifically, MedView's knowledge model is taken as a starting point for the SOMWeb ontologies, and MedView's Java code base is employed and extended by the SOMWeb system.

Early results regarding objectives two and three are presented in my licentiate thesis [56]. Figure 1.2 provides an overview of the results of this thesis and those of the licentiate thesis, and how these relate to the thesis objectives.

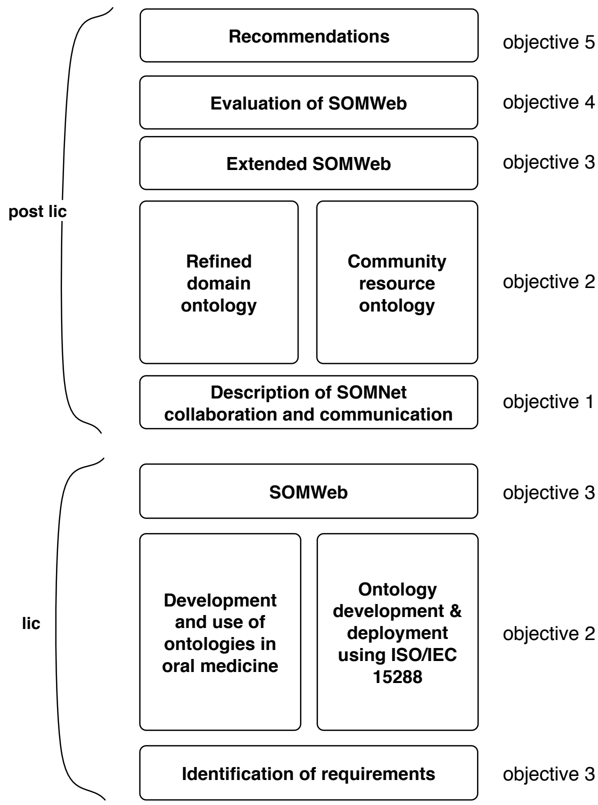


Figure 1.2: Overview of the thesis results, indicating how they relate to the thesis objectives. Also included is the previous iteration of results related to objectives two and three, as presented in my licentiate thesis [56].

1.4 Contributions

What sets this research apart from previous work is that few systems focus on this kind of collaboration and knowledge sharing for this type of users applying a thorough Semantic Web approach. Furthermore, it has been in regular clinical use for three years, which means it is possible to evaluate the system and assess its impact. I now outline the contributions of this thesis, organized according to the thesis aims. The **first set of contributions** regards the collaboration and knowledge sharing of distributed clinicians:

- Description of the structure of SOMNet's collaboration, in terms of participants, collaboration process, and outcomes (Sections 4.1 through 4.3).
- Identification of challenges for SOMNet's collaboration and knowledge sharing (Section 4.4).
- Characterization of SOMNet as a community of practice (Section 4.5).

The **second set of contributions** focuses on the exploration of benefits and limitations of using Semantic Web technologies to support distributed clinical collaboration and the identification of practical issues facing developers:

- The SOMWeb ontologies of oral medicine and community resources (Chapter 5).
- Discussion of design decisions made in developing the SOMWeb oral medicine ontologies (Sections 5.1.5 and 5.1.6), related to taking a previous representation as a starting point, the appropriate use of OWL, as well as ontology develoment in general.
- Recommendations for prospective developers of systems based on Semantic Web technologies (Section 9.1).
- Demonstration of how Semantic Web technologies can be used in a clinical knowledge management system (Section 6.6).

The **third set of contributions** concerns the SOMWeb system:

- The SOMWeb system (see Figure 1.3), which has been in use since May 2006 and includes such functionality as case-entry, case browsing, and meeting support (Chapter 6).
- The evaluation of the general functionality of SOMWeb (Section 7.2) and the systems' structured case entry (Section 7.3).
- The identification of SOMWeb's impact on SOMNet's collaboration (Section 7.7).
- Recommendations for developers of systems supporting clinical collaboration and research (Section 9.2).

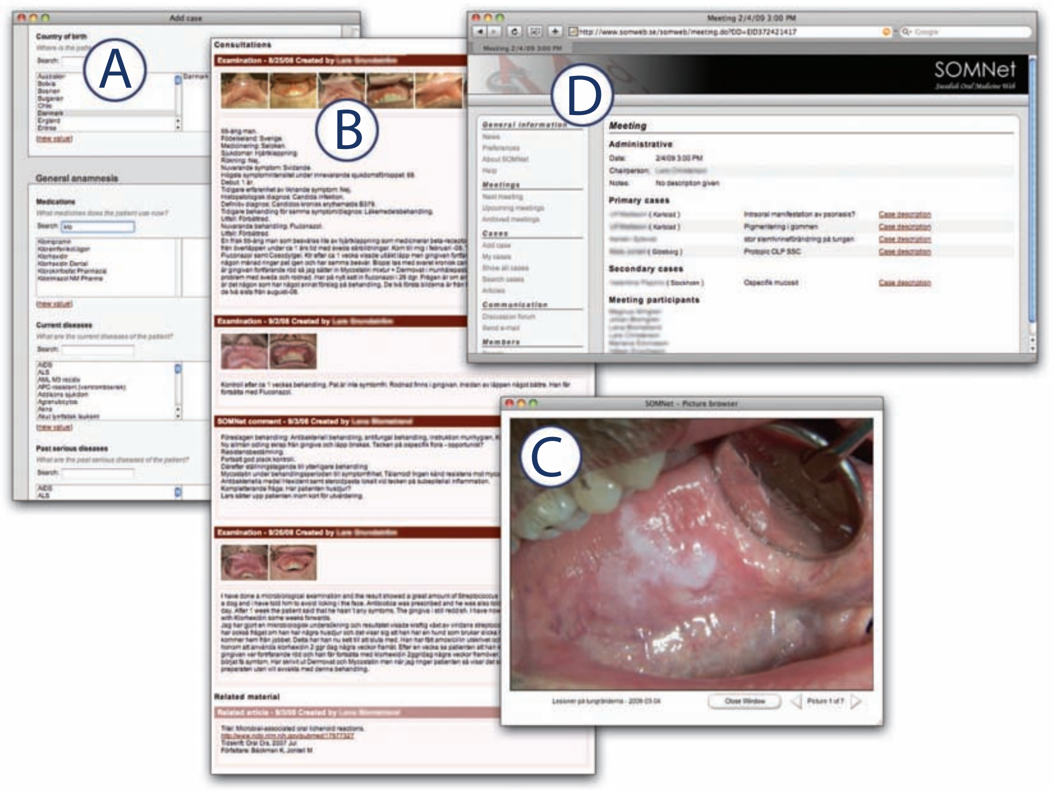


Figure 1.3: The figure shows screenshots of some key parts of SOMWeb: part of an examination data entry form (A), case presentation with several consultations (B), the image browser for showing enlarged images (C), and a meeting page (D).

To summarize, SOMWeb is a succesful system in that it is regularly used for meetings, has enabled the number of participants to grow, and is seen as beneficial by its users. The shared record of cases and the increase in the number of users of the system mean that more clinicians have access to expertise and a growing source of knowledge. The work presented in this thesis has thus enhanced the collaboration support for distributed clinicians in oral medicine in Sweden, and consequently improved their knowledge sharing and learning. Further, the documentation of the forms of collaboration in SOMNet can serve as a model for other groups of clinicians wishing to improve their knowledge sharing and learning. The use of OWL in examination descriptions has enabled reasoning over cases in the system to provide improved case browsing. However, limitations in using OWL to represent examination templates have been identified. The lessons learned and recommendations extracted from the development of the SOMWeb ontologies and system are a useful resource to prospective developers of systems for clinical knowledge sharing and for those wishing to use Semantic Web technologies. The recommendations related to ontology development also indicates areas where further research is needed. Thus, this thesis combines practical and theoretical contributions.

1.5 Publications

A list of my publications, including my contributions and how the papers relate to the chapters of this thesis follows.

1 Falkman, G., Torgersson, O., Jontell, M., Gustafsson, M. (2005) SOMWeb: Towards an Infrastructure for Knowledge Sharing in Oral Medicine. In: Engelbrecht, R. et al. (eds.): Connecting Medical Informatics and Bio-Informatics. Proceedings of MIE2005, vol. 116 of Studies in Health Technology and Informatics, pp. 527–532. IOS Press.

  This paper presents the overarching ideas for the SOMWeb project, in which this research was carried out. I contributed by elaborating on the initial ideas of the project. The contents of this paper cannot be tied to any one chapter of the thesis.

2 Gustafsson, M., Falkman, G. (2005) Representing Clinical Knowledge in Oral Medicine Using Ontologies. In: Engelbrecht, R. et al. (eds.): Connecting Medical Informatics and Bio-Informatics. Proceedings of MIE2005, vol. 116 of Studies in Health Technology and Informatics, pp. 743–748. IOS Press.

  I contributed to the list of requirements and provided examples of how OWL and RDF could be used to address them. These results are part of Chapter 5.

3 Gustafsson, M. (2006) Ontology Development and Deployment Using ISO/IEC 15288 System Life Cycle Processes. In: Baumeister, J. et al. (eds.): Proceedings of the Second Workshop on Knowledge Engineering and Software Engineering, June 14–19, 2006, Bremen, Germany. pp 15–26.

  Results from this paper are part of Section 5.1.3 concerning how the SOMWeb ontologies were developed.

4 Gustafsson, M. (2006) Representing Knowledge in Oral Medicine – Remodeling Clinical Examinations Using OWL, Technical Report no. HS-IKI-TR-06-009, School of Humanities and Informatics, University of Skövde, Sweden.

  These results are part of Chapter 5.

5 Gustafsson, M., Lindahl, F., Falkman, G., Torgersson, O. (2006) Enabling an Online Community for Sharing Oral Medicine Cases Using Semantic Web Technologies. In: Cruz, I. et al. (eds.): The Semantic Web. Proceedings of the 5th International Semantic Web Conference, ISWC 2006, Athens, GA, USA, November 5–9, 2006, vol. 4273 of LNCS, pp. 820–832. Springer-Verlag.

  I provided all the aspects related to the use of Semantic Web technologies, contributed to the development of the general motivations and requirements of the community, and to the testing of the Web features. These results are part of Chapters 5 and 6.

6 Gustafsson, M. (2006) Design, Development, and Adoption of Ontology-Driven Clinical Software. Göteborg : Chalmers University of Technology (Licentiate thesis).

Work from my licentiate thesis is included in Chapters 5 and 6.

7 Gustafsson, M., Falkman, G. (2007) Experiences in Modeling Clinical Examinations in Oral Medicine Using OWL. In: Proceedings of the 3rd International Workshop on OWL: Experiences and Directions (OWLED 2007), Innsbruck, Austria, June 6–7, 2007, vol. 258 of CEUR Electronic Workshop Proceedings.

This paper builds on paper 4. I carried out the OWL modeling and provided reflections on this, the results of which are part of Chapter 5.

8 Gustafsson, M., Falkman, G. (2007) Modeling Contexts of Knowledge Sharing in an Online Community for Oral Medicine. In Bouquet, P. (ed.): CONTEXT'07 Doctorial Consortium Proceedings, Computer Science Research Report no. 118, Roskilde University, Denmark, October 2007, pp. 30–43.

I carried out the literature review, description of results of observations and the questionnaire, and provided initial ideas on how to incorporate context into SOMWeb. Results from the paper are included in Chapter 4 and informed the extended community resource ontology described in Section 5.3.2.

9 Falkman, G., Gustafsson, M., Jontell, M., Torgersson, O. (2007) Towards Pragmatic Patterns for Clinical Knowledge Management. In: Buckingham Shum, S. et al. (eds.): Proceedings ICPW'07: 2nd International Conference on the Pragmatic Web, 22–23 Oct. 2007, Tilburg: NL, vol. 280 of ACM International Conference Proceeding Series, pp. 65–74. ACM.

I provided descriptions of the ontological basis of SOMWeb, the description of the SOMWeb system and its use, and the potential use of context in SOMWeb. I carried out the questionnaire and also contributed to the ideas of the patterns, although these were mostly developed by the first named author. Results of the questionnaire are included in Chapter 7.

10 Falkman, G., Gustafsson, M., Jontell, M., Torgersson, O. (2008) Collaboration Patterns in an Online Community of Practice in Oral Medicine. In: Andersen, S.K. et al. (eds.): eHealth Beyond the Horizon – Get IT There. Proceedings of MIE2008. Studies in Health Technology and Informatics 136, pp. 175–180. IOS Press.

I provided input on the patterns described in the paper. Results from this paper are not included in the thesis.

11 Falkman, G., Gustafsson, M., Jontell, M., Torgersson, O. (2008) SOMWeb: A Semantic Web-Based System for Supporting Collaboration of Distributed Medical Communities of Practice. J Med Internet Res 2008;10(3):e25.

I contributed all the aspects related to ontology usage and the description of the SOMWeb system. I also carried out and analyzed all the observations and interviews described. Results included in Chapters 4 through 7.

12 Falkman, G., Gustafsson, M., Torgersson, T., Jontell, M. (2008) The Origin, Representation, and Use of Collaboration Patterns in a Medical Community of Practice. In: Lytras, M.D. et al. (eds.): Emerging Technologies and Information Systems for the Knowledge Society. Proceedings of the First World Summit, WSKS 2008, Athens, Greece, September 24–26, 2008, vol. 5288 of LNCS, pp. 403–412. Springer-Verlag.

I provided the description of the user model ontology and OWL descriptions of the patterns. These results are part of Section 5.3.

13 Gustafsson, M. (2008) Case Sharing and Ontology Structuring in an Online Oral Medicine Community. In: Siorpaes, K. et al. (eds.): Proceedings of INSEMTIVE 2008: 1st Workshop on Incentives for the Semantic Web.

The article contains initial thoughts on the case browser and the structuring of the value list ontology, see Section 5.2 and 6.6.4.

1.6 Thesis Overview

Following the introductory chapter, the thesis continues with a background chapter and a chapter discussing the research methodology. Five chapters subsequently outline the results of our work, each of which concludes with a discussion of the chapter's results. The final chapter presents conclusions. Figure 1.4 provides an overview of the the thesis chapters. A brief summary of each chapter follows:

Chapter 2: Background. The background chapter covers clinical collaboration and knowledge sharing as well as communities of practice, and technical means of supporting these. Further, Semantic Web technologies and ontologies are introduced, and more specifically RDF and OWL are described, as well as how these have been used in the life sciences and for supporting collaboration.

Chapter 3: Research Methodology. This methods chapter provides details on how the thesis research was carried out. The chapter describes how SOMNet's collaboration was studied, how the SOMWeb ontologies and system were developed, and how the SOMWeb system was evaluated.

Chapter 4: Collaboration and Knowledge Sharing in SOMNet. This chapter presents results of the interviews and observations in relation to how the members of SOMNet collaborate and share knowledge. These results are then related the theory of communities of practice.

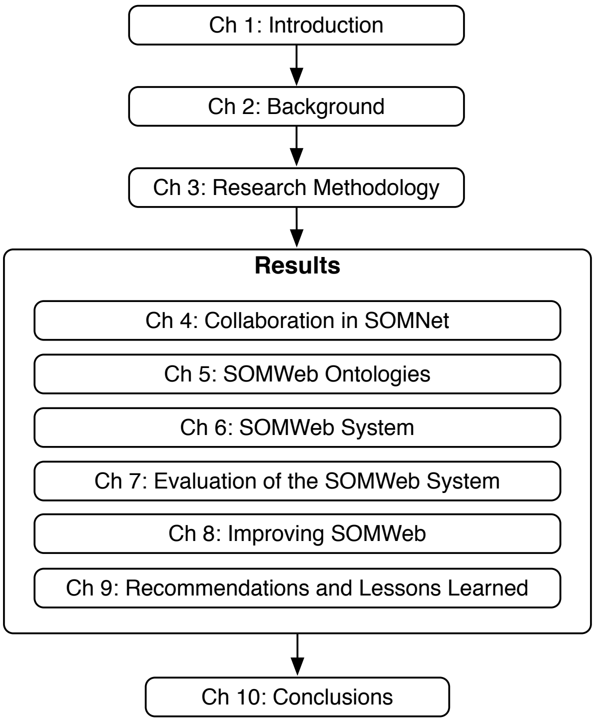


Figure 1.4: Overview of thesis chapters.

Chapter 5: SOMWeb Ontologies. This chapter presents requirements specified for developing the oral medicine ontology, and how this was carried out and formalized in OWL. The oral medicine ontology contains templates and value lists. A refined value list ontology and case browser ontology are also described, as well as the community resource ontology of SOMWeb.

Chapter 6: The SOMWeb System. This chapter presents the SOMWeb system: its design, functionality, and system architecture. This includes the description of how the system interacts with the OWL and RDF components described in the previous chapter.

Chapter 7: Evaluation of the SOMWeb System. This chapter presents an evaluation of SOMWeb based on a questionnaire, interviews, log analysis, and case analysis. The chapter also discusses the impacts of SOMWeb on the collaboration of SOMNet.

Chapter 8: Improving SOMWeb. This chapter details possible improvements to SOMWeb and gives a vision of a future SOMWeb.

Chapter 9: Recommendations and Lessons Learned. This chapter reports lessons learned and recommendations for prospective OWL developers and for developers of systems supporting clinical collaboration.

Chapter 10: Conclusions. The final chapter presents conclusions in relation to each of the thesis aims. Also, reflections on the research process are provided, and future work based on this research is presented.

Chapter 2

Background

The goal of this thesis is to investigate how distributed clinical collaboration and knowledge sharing can be carried out and technologically supported. In the context of the case studied in the thesis, SOMNet, the collaboration and knowledge sharing aims towards resolving cases, learning of the individual, and expanding the body of knowledge of the domain itself. As a group of people who share a common interest, focus on problem solving, and through this learn in a social context, SOMNet can be regarded as a community of practice. When the participants in a community of practice are not co-located but rather geographically distributed, some sort of technological support is necessary, and these often take the form of Web-based systems.

Regarding the topic of knowledge sharing, a distinction is often made between explicit and tacit knowledge, which Polayni [124] first noted and Nonaka and Takeuchi [105] popularized in knowledge managment circles. Explicit knowledge is that which can be transmitted through a systemic language, while tacit knowledge is personal, context specific, and thus hard to communicate and especially to formalize. Collaborating and sharing knowledge through a community of practice involves using and conveying both tacit and explicit knowledge, and therefore the design of any technology or social process should take this into account. In SOMNet, the use of telephone conferences provide a venue for the exchange of tacit knowledge. One way of supporting the use, transfer, and learning from explicit knowledge is through formal knowledge representation. Ontologies are a proposed means for this, and they are a component of Semantic Web technologies.

This chapter presents topics that the reader needs to be aware of to understand the results presented in the thesis, as well as identifies gaps in the current state of the art that this thesis aims to fill. The first topics of the chapter are clinical collaboration and knowledge sharing (Section 2.1) and communities of practice (Section 2.2). I then discuss how these can be supported by technological means (Section 2.3), before turning to the subject of the Semantic Web and ontologies (Section 2.4) and the application of these in supporting life sciences and collaboration (Section 2.5). The chapter ends with a short summary discussing the gaps that this thesis aims to fill (Section 2.6).

2.1 Clinical Collaboration and Knowledge Sharing

In studying medicine and dentistry, the learning of theoretical concepts aims towards the use of these in clinical practice. That is, the application of these concepts to make decisions regarding diagnosis and treatment of patients. However, learning to practice medicine and dentistry is also achieved in the clinic – a word which derives from the Greek word for bed, 'kline' – in addition to the theoretical backbone. Clinical decision-making and diagnostic work are key work areas in every field of medical practice, and clinical experience, knowledge and judgment are fundamental to health care management. One way of describing the clinical decision-making process is by three basic steps [33]: As presented in Section 1.2, evidence-based medicine holds that clinical decisions should be based on finding, evaluating, and using the latest research results [132]. While evidence-based medicine places much focus on the use of evidence gained from, for example, randomized clinical trials, proponents such as Sackett [135] have emphasized that research evidence should be integrated with clinical expertise.

In diagnosing and treating patients, the individual practitioner may need to consult the opinion of others, such as peers, experts, and researchers. This is the case in SOMNet. Clinical collaboration is also necessary when helping a patient requires a variety of professionals. While SOMNet is not multi-disciplinary, this is one area that clinical collaboration has been studied more in depth, as presented in Section 2.1.1. One reason for collaboration is knowledge sharing, and barriers related to this are discussed in Section 2.1.2. In addition to seeking knowledge from others, clinicians also consult external sources in the form of research articles. Findings related to actual use of such sources are presented in Section 2.1.3.

2.1.1 Clinical Collaboration

As with most useful concepts, collaboration can be defined in several different ways. A general definition states that collaboration is a process where two or more people or organizations work jointly to achieve common goals. A less general definition is provided by Wood and Gray [161]: "Collaboration occurs when a group of autonomous stakeholders of a problem domain engage in an interactive process, using shared rules, norms, and structures, to act or decide on issues related to that domain." Wood and Gray also identify general dimensions of interest when studying collaboration: the participants, the collaboration process itself, and collaboration outcomes. I return to these when describing SOMNet's collaboration in Chapter 4.

In clinical collaboration, the individual case is central. One way of characterizing the process of collaboration for case discussions is presented by Kane and Luz [78], who used ethnographic methods to investigate the structure of multidisciplinary medical team meetings (MDTM) in cancer treatment. They view the MDTM as a system, with associated processes, divided into pre-meeting, meeting, and post-meeting activities (see Figure 2.1), where pre-meeting activities include preparations, such as entering case data. Each meeting has an agenda, usually a list of cases. For each case presentation, four parts are identified: presentation of the results of investigations, discussion of these findings, recommendations

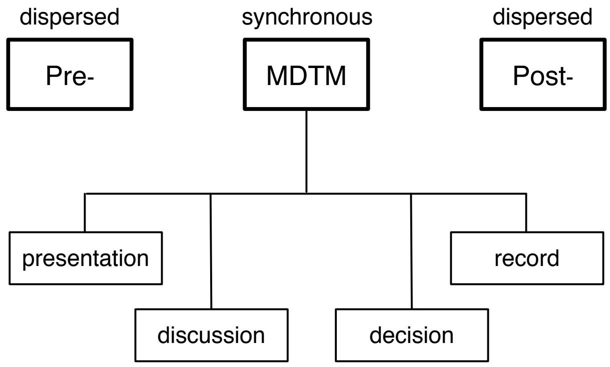


Figure 2.1: Activities of multidisciplinary medical team meetings, adapted from Kane and Luz [78].

for further patient management, and the clarification and recording of decisions. The decisions from the meeting are carried out as part of the post-meeting activities. Notice also that the pre- and post-meeting activities are dispersed and asynchronous, while the meeting is synchronous.

2.1.2 Barriers to Clinical Knowledge Sharing

One function of clinical collaboration is the sharing of knowledge. However, this sharing is not without barriers. Hinds and Pfeffer [67] identify motivational limitations to collaboration and knowledge sharing, where a person may be able to share knowledge but does not. Through reviews Hall [59] identifies issues of importance for encouraging knowledge-sharing: that knowledge-sharing should be seen as a key responsibility of staff, communities for knowledge sharing should be promoted, and experimentation should be encouraged. Factors that are important in community knowledge sharing include strong ties and social capital (for example, shared norms, obligations, trust and identity), where shared identity is particularly important. Encouraging experimentation concerns allowing risk taking, in order to discover new ideas.

Lin et al. [87] suggest that knowledge flow barriers in healthcare organizations can be associated with the knowledge source, knowledge receiver, knowledge transfer, knowledge flow context, and the organizational context. Barriers related to the knowledge source are retaining power and advantage, and not being trusted. Barriers related to the receiver are lack of absorptive capacity, lack of activity, and the ‘not invented here’ syndrome. Barriers related to knowledge transfer are identified as being due to tacitness, complexity, and uncertainty of knowledge, and that it is not evidence-based (both in that a clinician may not want to share knowledge if it is not based on evidence and in that the receiver may be skeptical about the knowledge if it is not evidence-based). Barriers related to knowledge flow context are lack of a mechanism and lack of relation between the knowledge source and receiver. The final set of barriers relates to the organizational context, and they are lack of reward system and leadership. As part of the discussion of SOMNet's knowledge sharing, we return to these barriers in Section 4.6.

2.1.3 Use of External Sources

In trying to ascertain the diagnosis and decide on treatment for a given case, a clinician may need seek information. In an evidence-based approach, attempting to find and use high quality external evidence is the aim. However, what do we know of the clinical reality? Dawes and Sampson [30] present results from a systematic review of studies of information seeking behavior of physicians. Text books were found to be the most frequent information source, followed by asking colleagues. Enabling factors were "convenience of access, habit, reliability, high quality, speed of use, and applicability." Barriers to information seeking were a lack of time, the vast amount of material, forgetfulness, believing that there is likely to be no answer, and a lack of urgency. Dawes and Sampson highlight the need to carefully plan information delivery to help physicians stay updated and for knowledge transfer to improve.

Gosling et al. [50] examined factors that influenced differences in clinicians' use of an online evidence retrieval system. They concluded that social and cultural factors could better explain variations in use than technical factors. Identified organizational, professional, and cultural factors included the presence of champions, support for evidence-based practices within the organizational culture, and the skills of the clinician in searching databases. This points towards a need to identify means for making external evidence available and accessible for clinicians, which is provided in this research through the study of external evidence use in SOMNet and support for this in SOMWeb.

2.2 Communities of Practice

A community of practice denotes a group of people sharing "a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" [159]. People participating in a community of practice have different levels of expertise, and as pointed out by Curran-Smith et al. [27], "collaboration in a community of practice is not a one-way traffic, namely knowledge flow from expert to novice. Rather, there are subtle gains for experts also in that by way of giving explanations they improve their own understanding of the domain."

Communities of practice can take a variety of forms. Wenger et al. [159] suggest dimensions of size, long-lived or short-lived, co-located or distributed, heterogenous or homogenous, spontaneous or intentional, as well as unrecognized or institutionalized. They also present a structural model for describing it, which derives from Wenger's earlier book [158], where a community of practice has a domain, community, and practice. The domain creates common ground and identity, the community is the group of people who care about the domain and who interact and learn together, and the practice is "a set of socially defined ways of doing things in a specific domain" [158], that can take the form of shared frameworks, tools, information, and language. The practice is continually maintained and developed by the community. The dimensions and model presented above are used in describing SOMNet in Section 4.5.

Below suggested principles for cultivating communities of practice are presented (Section 2.2.1), as well as the topic of distributed communities of practice (Section 2.2.2).

2.2.1 Cultivating Communities of Practice

Since communities of practice have been found conducive of high quality problem solving and knowledge sharing, it is of interest how these can be promoted. Wenger et al. [159] suggest seven principles for cultivating communities of practice:

1. Design for evolution: A community of practice often consists of fewer elements at the start than a more traditional organization design. Initially, it may consist of a core group holding regular meetings, without notes and without a defined plan. Eventually more structure emerges, such as Web sites, connections to other groups, and explicit strategies.

2. Open a dialogue between inside and outside perspectives: Only an insider of the domain knows where sharing knowledge matters and who potential members are. At the same time, somebody with an outside perspective may see solutions that the insider does not. Thus, both perspectives need to be involved.

3. Invite different levels of participation: Different members participate in a community of practice for different reasons. One might hope that all members will participate equally, but since there are different levels of interest, this is not a sustainable hope. Participants can often be divided into the groups of core, active, and peripheral. Many participants often belong to the last group, which mostly observes interactions between core and active members. Reasons for not participating may include the belief that their observations are not valuable enough or lack of time. Wenger et al. [159] hold that these peripheral activities are a very important part of communities of practice. Further, these peripheral members are not as passive as they might seem. They take in what is said, and may bring it up in private conversations. Members move back and forth between these levels of activity, depending, for example, on what is discussed. For the survival of a community of practice, it is important to build bleachers that the peripheral participants can sit on.

4. Develop both public and private community spaces: Public community events are necessary for members to tangibly feel they are part of the community and to obtain a sense of who the other members are. Such events also have concrete outputs. Meanwhile, private contacts among members, and between coordinators and other members, build the relationships that form the essence of the community. These informal discussions actually partly ensure useful public meetings.

5. Focus on value: As membership is voluntary, the interaction of the community needs to focus on topics that provide value to the members. However, the value of the community may change over time, and be found in aspects different than the ones

expected. With community growth, it becomes more important to have an easily accessed body of knowledge.

6. Combine familiarity and excitement: A maturing community often finds a pattern of interaction that suits it, and such familiarity can increase the comfort level of members to ask questions and share opinions. However, a lively community also provides excitement through workshops and encouraging diverging opinions.

7. Create a rhythm for the community: Our interactions often have a rhythm, where things happen at certain intervals. This applies to communities of practice as well. Meetings are held at regular intervals, which lead to a number of surrounding activities and the movement of members between different levels of participation.

Several of these are discussed in relation to SOMNet in Section 4.5.

2.2.2 Distributed Communities of Practice

As presented above, one of the dimensions for describing a community of practice, as suggested by Wenger et al. [159], is whether it is co-located or distributed. In this work, the focus is on distributed, sometimes referred to as virtual, communities of practice, where members are geographically dispersed and face-to-face meetings are rare. A distributed community of practice has at its disposal both traditional media, such as telephone, telephone conferences, and fax machines, as well as more recent technological tools, such as e-mail, common databases, Web sites, and online meeting spaces [36, 69]. Virtual communities of practice are not the same as the virtual or online communities in general. However, it may be the case that both co-located and distributed communities of practice are supported by an online community system.

Since the original community of practice concept was founded on situated learning in a co-located setting, some view distributed communities of practice as a misnomer. However, given the persistent growth of the Internet and globalization, it can be seen that such collaborations do take place [100, 61]. In this thesis, this is further exemplified through the presentation of SOMNet.

For distributed communities of practice, the facilitation of collaboration through IT becomes even more relevant than for co-located ones. This is one of the topics discussed in the following section.

2.3 Supporting Distributed Clinical Collaboration and Communities of Practice

Supporting distributed collaboration is part of the research field of computer supported cooperative work (CSCW), which Schmidt and Bannon [140] see as “an endeavor to understand the nature and requirements of cooperative work with the objective of designing computer-based technologies for cooperative work arrangements.” A common conceptualization, when describing CSCW systems, is the time/location matrix, first presented by Johansen [73]. This distinguishes between same time (synchronous) and different time (asynchronous), and between same location (face-to-face) and different location (distributed). The main focus of the thesis concerns supporting geographically distributed collaboration, which in this case is both synchronous (during the monthly one hour meetings) and asynchronous.

In designing and implementing IT support for collaboration, socio-technical aspects cannot be disregarded. For example, Obstfelder et al. [112] reviewed telemedicine applications and found that the interplay between technical and social factors during the process of implementation was important for reaching the goals of the application. The interaction between social and organizational factors and the technology used to support them is complicated, to say the least. On the one hand, technology needs to be aligned with the structure and processes of organizations, while on the other, technology will in turn affect how work is carried out and thus the organization itself.

Below, telemedicine and teleconsultations are presented (Section 2.3.1). Structured medical knowledge in the forms of electronic health records (EHRs) and terminologies can be seen as aids to clinical collaboration and knowledge sharing. Though this thesis does not directly aim to contribute to this field, they are related, and Section 2.3.2 provides a brief introduction. We then return to the topic of communities of practice, considering technological support for these (Section 2.3.3), followed by a general overview of Web-based collaboration (Section 2.3.4). Finally, examples of research on Web-based support for clinical collaboration are presented (Section 2.3.5).

2.3.1 Telemedicine and Teleconsultations

Telemedicine is, as the name indicates, medicine at a distance, where IT is used to transmit medical information for purposes of consultation and teaching. Telemedicine provides access to expertise that may not otherwise be available at a particular location, which helps avoid patient travel [162], for example. One area of telemedicine is teleconsultations; remote consultations carried out to aid clinical decision-making using, for example, teleconferences, videoconferences, or e-mail. In terms of knowledge sharing, Lundvoll Nilsen and Moen [90] point out that "telemedicine offers health-care providers the opportunity to access and share knowledge and experience with professionals at the same level or between different levels of care."

Differing from the approach of SOMNet, in the kind of teleconsultations described by, for example, Lundvoll Nilsen and Moen [90], the patient is often present and participates. Further, consultations often take place between a general practice and a specialist clinic. An exception may be seen in Boeddicker [13], which describes a telehealth network for oncology that holds case discussions using videoconferences. The hospitals meet twice a week, with two or three connected sites (out of six possible). The need for case discussions comes from smaller regional hospitals having to give up their local oncology activity, and thus rely on one hospital in the region for this expertise. No evaluation of the system is provided, and thus there is a lack analysis of what the challenges for the collaboration are, what forms systems to support can take, and what the system's impacts are, which are issues explicitly addressed in this thesis.

2.3.2 Structuring Medical Knowledge: Electronic Health Records and Terminologies

Structuring medical knowledge is one step in enabling clinical collaboration. Establishing an explicit structure aids participants in knowing what information to include and what to expect. Additionally, employing computers to enter information in a structured manner can facilitate use of clinical data to link patient records to decision support and knowledge management or to reuse information gathered in patient care for purposes of research, management, reimbursement, or quality assurance [127]. Efforts to this end include both electronic health records and terminologies.

The electronic health records is "a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting" [70]. They often include many components such as patients medical history, medicine and allergy lists and test results, and as reported by Hayrinen et al. [63] there is much variation in content. Electronic patient records have an advantage over their paper-based counterparts in that they can be displayed and searched in different ways. For example, they can be organized from perspectives such as time, source, or problem. It is hoped that improvements such as these will benefit decision making. Another appealing possibility is easier regrouping of data for clinical research and care evaluation [136], which is connected to the importance of clinical trials to evidence-based medicine. However, this is only possible if data is stored in a structured format (as opposed to free text).

The adoption of electronic health records in clinical practice is often problematic (see, for example,[33] and [72]), the reasons for which include the complexity of medical data and knowledge modeling, usability, security, privacy, and changing work patterns [33]. Interoperability is important to achieving the benefits of electronic health records, and several standard formats for structuring and exchanging electronic health records have been suggested, including the archetypes of the openEHR project [113], the related European standard EN13606 [77], and Health Level Seven (HL7) [64].

In addition to the structure of the health record, the terminology used when entering data is an issue. The medical terminology must be amalgamated in complex dictionaries to get semantic coherence within pieces of distributed records [24, 128]. Classification provides a framework for a systematic representation and codification of medical concepts. The International Classification of Diseases (ICD)[1] and the Systematized Nomenclature of Medicine – Clinical Terms (SNOMED-CT)[2] are two common classification systems. In the dental domain, the American Dental Association provides both a Current Dental Terminology (CDT),[3] which is updated regularly but limited to treatments and procedures, as well as a Systemized Nomenclature of Dentistry (SNODENT) [48], which is an effort to create a comprehensive dental vocabulary. However, it has been found that improvements are needed in content, quality of coding, and quality of ontological structure [48].

At the outset of the SOMWeb project, the status of terminologies and health record structures on a national level in Sweden were unclear. Over the time of the project this has

[1] `http://www.who.int/classifications/icd/`
[2] `http://www.ihtsdo.org/snomed-ct/`
[3] `http://www.ada.org/ada/prod/catalog/cdt/`

changed, so that that the Swedish National Board of Health and Welfare have begun work on translating SNOMED-CT into Swedish[4] and the Swedish Association of Local Authorities and Regions[5] is moving towards using EN13606. More consideration in relation to this is presented in Section 5.5.3.

2.3.3 Technology and Distributed Communities of Practice

Technology can be an enabler of both co-located and distributed communities of practice. However, when IT support for communities of practice is discussed in the literature, it is often done with little focus on the technology itself. For example, Lock Lee and Neff [89] present a study of communities of practice in two large global organizations and conclude that across the several hundred communities identified there is no single best tool. Rather, for all the support technologies, there are good examples of use, and these are based on different styles and cultures.

The social aspects of communities of practice, as discussed by Koch and Fusco [80], include their mission, structured activities, resources, and interactions among members. Technical structures include the online tools that support the communities of practice artifacts and communications. Thus, the social aspects of the community of practice affect what online tools are useful and effective, but the choice of tools will in turn affect the social components.

Technology has the potential to help communities of practice collaborate over distance. At the same time, there is evidence indicating that the establishment of community goals among the members is more important to its functioning than technology. For example, Akkerman et al. [1] describe experiences from attempting to initiate fifteen communities of practice in small and medium-sized tourist sector companies, where three eventually showed signs of self-sustainability. They conclude that coordinative systems have a secondary role to the groups' own definitions of how they are relevant to each other and what they want to achieve together. Further, Lock Lee and Neff [89] conclude that the introduction of new technologies needs a champion within the community.

In the literature, technologies presented to support distributed communities of practice are often listed, including discussion forums, e-mailing lists, and chat (see, for example, Demiris [34]). However, I believe that the multi-purpose communication tools are not the whole story, since communities of practice often have specific artifacts that are central to their problem-solving and learning. This suggests that further research is needed on what specific forms such support can take.

2.3.4 Web-based Collaboration

That clinicians and researchers are distributed is one reason why they may need IT-support for their collaboration. Collaborative software (also known as groupware) is created with the intention of helping a group of people solve a common task/reach a goal. Examples of collaborative software include e-mail, instant messaging, and project management systems.

[4] `http://www.socialstyrelsen.se/snomedct`
[5] `http://www.skl.se/`

However, in this thesis the focus is on Web-based approaches for collaboration, a selection of which is now reviewed.

A Web site is a collection of Web pages and other media, such as images, hosted on Web servers and accessed over the Internet. A content management system (CMS) can be used to create and manage the text and digital media of a Web site. The use of Web sites in collaboration goes under different names, indicative both of the form or purpose of the collaboration and the technology used (and to some extent these overlap). The term of online community was one of the first for such collaboration, and overlaps somewhat with the more recent concept of social software, which includes systems that provide communication through forums, wikis and blogs. Forums allow users to create discussions, linear or threaded, which may be organized into different topics. A wiki is a collection of Web pages where users can easily add and remove pages, as well as edit them using simplified markup languages. One of the best known wikis is the Wikipedia,[6] a collaborative encyclopedia. A blog, or web log, is a Web page that is regularly updated and often centered on a certain topic, such as a political topic, personal journal, or research. A blog can be created by an individual or a group.

An online community may include several such features, and is usually built around the main activities of the participants. In order to participate, membership in the community is usually required and, through the online community system, it is possible for members to find out more about each other. As mentioned in Section 2.2.2, a community of practice may use an online community system.

2.3.5 Supporting Clinical Collaboration on the Web

After the general overview of Web-based approaches for collaboration, some specific research projects for supporting clinical collaboration are considered. In Fearn et al. [41], the Caisis system is presented as a "web-based system for integrating clinical practice and research," where there is a separation between data entry and data presentation and a user-centered approach, with active involvement from clinicians. A lesson learned from the Caisis project is that "as the system becomes more complex and feature-rich with each iteration, the learning curve becomes higher."

Vega et al. [154] present "a cooperative working environment for sharing clinical experience over the Internet" in the field of radiology. The focus is on image data and "clinical sessions" where cases are discussed synchronously or asynchronously. Through a questionnaire the authors found a high degree of acceptance and that participation had affected their work habits. However, the impacts of the system on the collaboration itself was not addressed. An interdisciplinary computer-based information tool for palliative severe pain management is described by Kuziemsky et al. [83]. The tool development was centered on the needs of users and an in-depth study made of the domain and work processes of the users. However, the tool developed is a prototype that has not been used in practice, and thus its impact has not been assessed.

Berlingieri et al. [8] present a virtual consulting room, that aims to bridge the divide

[6] `http://en.wikipedia.org/wiki/Main_Page`

between primary and secondary care. The Web application contains modules for patient journeys, frequently asked questions, and specialist e-helpdesks. In the first two, the general practitioner interacts with system knowledge, while the latter provides e-mail contact with specialists. As with many telemedicine applications, the goal is to provide one-to-one contact, while SOMNet provides ties to a larger community. Further, the patient journeys contain generalized medical knowledge to help general practitioners make decisions, while SOMNet focuses on learning from individual cases. The two approaches can be seen as complementary.

2.4 The Semantic Web and Ontologies

One aim of the thesis is to apply Semantic Web technologies to support the collaboration and knowledge sharing of SOMNet. This section presents the Semantic Web initiative (Section 2.4.1), a key Semantic Web technology, namely ontologies (Section 2.4.2), as well as suggested forms of representing data and ontologies on the Semantic Web, namely RDF and OWL (Section 2.4.3).

2.4.1 The Semantic Web

The Semantic Web initiative is, to a large extent, defined by the World Wide Web Consortium (W3C), that state the following definition on their main Semantic Web page:[7]

> The Semantic Web provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries. It is a collaborative effort led by W3C with participation from a large number of researchers and industrial partners. It is based on the Resource Description Framework (RDF).

The Semantic Web vision is the product of many different ambitions and influences, and its aim is to make better use of the Web. Influences come from artificial intelligence, library science, and web services, among others. This leads to different visions of what the Semantic Web should be and achieve, such as providing a consistent structure by which people can access materials, building a globally distributed knowledge base that will be used by personal agents to collect and reason about information, and providing an infrastructure for the coordinated sharing of data and knowledge [93]. The Semantic Web, in its current conception, is mainly the brainchild of Sir Tim Berners-Lee. However, there are many visions of the Semantic Web. In the famous article by Berners-Lee et al. [10] in Scientific American, it was stated that "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." The article also provided an example of how the Semantic Web might one day be used by personal agents in scheduling appointments and other everyday things.

[7] `http://www.w3.org/2001/sw/`

Currently, there are two main strands of work, one focusing on linked data and the other one on ontologies. This has now appeared on the W3C's Semantic Web front page in the following wording:

> The Semantic Web is about two things. It is about common formats for integration and combination of data drawn from diverse sources, where on the original Web mainly concentrated on the interchange of documents. It is also about language for recording how the data relates to real world objects. That allows a person, or a machine, to start off in one database, and then move through an unending set of databases which are connected not by wires but by being about the same thing.

The first topic is often referred to as linked data, while the second is about ontologies. In this thesis, the focus is on the latter. The Semantic Web effort of the W3C centers on the development of specifications, the most well known of which are the Resource Description Framework (RDF) and the Web Ontology Language (OWL), which have both reached recommendation status.[8] Although RDF and OWL are the main recommendations of the W3C related to the Semantic Web, there are several other recommendations. In this thesis the focus is on RDF and OWL.

2.4.2 Ontologies

The word ontology is used in many different contexts, and has several different definitions. It originates in philosophy, where ontology is the science of describing the kinds of entities in the world and how they are related. A key aim of ontologies in the philosophical sense is a definitive and exhaustive classification of all entities [164]. One of the most commonly used definitions is that of Gruber [52]: an ontology is an "explicit specification of a conceptualization." This definition was modified slightly by Borst [15]: "Ontologies are defined as a formal specification of a shared conceptualization." If these definitions are combined, one gets that ontologies are formal in order to be machine-processable. The term explicit indicates that the kind of concepts used and any constraints on their usage are explicitly defined. Ontologies are shared in that they capture knowledge agreed-upon by a group and they can be communicated between computers. Finally, ontologies are conceptualizations in that they are an abstract model of some phenomenon in the world.

There are different motives for developing an ontology, such as to be able to [108]: share a common understanding of the structure of information among people and software agents, reuse domain knowledge, make domain assumptions explicit, separate domain knowledge from operational knowledge, and analyze domain knowledge. There are also differing motives and needs for using ontologies, ranging from large scale ontology development projects aiming at wide reuse to application developers who develop and reuse ontologies in order to provide specific system functionality. Thus the developed ontology might be a large-scale shared reference ontology (such as the Gene Ontology[9]), or small,

[8] A developing specification within the W3C goes through five steps: Working Draft, Last Call Working Draft, Candidate Recommendation (CR), Proposed Recommendation (PR), and W3C Recommendation (REC).

[9] `http://www.geneontology.org/`

specialist ontologies intended for particular use. There are also ontology users who need to augment or adjust existing ontologies for specific applications.

An ontology can be described by a 4-tuple $\langle$C, R, I, A$\rangle$, where C is a set of concepts, R a set of relations, I a set of instances, and A a set of axioms [157]. Concepts, also referred to as classes, represent sets of individuals with shared properties. Relations, sometimes called properties, express how individuals and classes can be related to each other. Instances, also known as individuals, are members of classes. Axioms are used to put constraints on classes and the types of relations that can hold between them. Taken together, these can be used by a reasoner to infer facts about classes and individuals.

Ontologies take different forms and serve different purposes; Guarino [54] refers to these as “the amount and type of structure of the conceptualization and the subject of the conceptualization.” In describing the amount and type of structure, ontologies may be referred to as lightweight or heavyweight, depending on factors such as whether mainly subclass relations are used or whether more complex axioms are included. Similarly, based on the extent to which concepts are specified by axioms, Sowa [145] suggests that there is a continuum between formal ontologies with detailed axiomatizations and terminological ontologies with little or no axiomatization. Regarding the subject of the ontology, there are several types [55]:

- Top-level ontologies: define very general concepts (such as space, time, and actions) which are highly reusable across several domains and applications.

- Domain and task ontologies: define the concepts of a given domain (such as mechanic, electronic, medical domains) or task (such as diagnostics).

- Application ontologies: specializes and adapts domain and task ontologies for use in specific contexts.

How then, are ontologies created? The question of ontology development is central to the active research field of ontology engineering. Topics in this field include overarching methodologies for ontology construction [42, 122], methods for automatic and semi-automatic ontology construction [12, 23], and methods for reusing previously existing ontologies [35, 116]. Related to the latter are methods for ontology alignment, mapping, and merging [31, 85]. During and after construction, an ontology may be evaluated, and methods for ontology evaluation [18, 45] are another a topic of research. Further, an ontology is an evolving artifact, which is why methods for ontology evolution and maintenance [11, 110] are being investigated. Other fields being explored are methods for estimating costs of ontology development [14], cognitive and sociological issues of ontology development [37], as well as contextualized and personalized ontologies [4, 17].

Before moving on to the W3C recommendations for representing ontologies, I want to discuss the above presented categorizations in relation to the ontologies of this thesis. These can be labeled as domain and application ontologies. Further, they can be placed on the terminological side of the ontology spectrum. Further, I take the view of Brewster et al. [21]:

> Good ontologies are the ones that serve their purpose. Complete ontologies are probably more than what most knowledge services require to function properly. The biggest impediment to ontology use is the cost of building them, and deploying "scruffy" ontologies that are cheap to build and easy to maintain might be a more practical and economical option.

2.4.3 RDF, RDF Schema, and OWL

In this thesis, the use the W3C recommendations of RDF and OWL are explored in the domains of oral medicine and collaboration support. Therefore, this section outlines the basic concepts of these recommendations. Essentially, RDF is a data-model, with a subject-attribute-object triple, called a statement, as its basic building block. These statements should be viewed as graphs, where subjects and objects are nodes connected by attributes as the arcs. An example of a triple is:

```
PeanutAllergy    rdf:type    somwebOntology#Allergy
```

Here `PeanutAllergy` (subject) is described as being of `rdf:type` (attribute) `Allergy` (value). The `rdf` in `rdf:type` should be interpreted as a namespace which would have been defined in an RDF file, and this is where we would find an ontology defining a meaning of type.

Fundamental concepts of RDF are resources, properties, and statements. Resources are the things we want to talk about, such as diagnoses, medications, and allergies. Every resource has a Universal Resource Identifier (URI), which can be a Unified Resource Locator (URL) or some other kind of unique identifier. Properties are special kinds of resources, describing relations between resources. The notion of using URIs to identify things and relations is central in providing a global naming scheme [3].

There are several ways to represent the abstract data model more concretely, one of which is the use of XML (eXtensible Markup Language) in the RDF/XML syntax [6]. The RDF/XML serialization is quite verbose, so in this thesis the Notation3 (N3) syntax [9] is used. The example above, about the `PeanutAllergy` resource, is represented as follows in N3, where an additional fact, an RDFS-label, has been added to the example to illustrate how several facts about one resource can be displayed:

```
PeanutAllergy
    rdf:type somwebOntology#Allergy ;
    rdfs:label "Allergi"^^xsd:string .
```

In order to define the vocabulary of RDF models, RDF Schema (RDFS) can be used. With RDFS we can also specify what properties apply to which kinds of objects and what values they can take, and also describe subclass relations between objects:

- Definitions of `Class` and using `rdfs:subClassOf` to organize these into hierarchies. Classes define individuals that can be grouped together because of shared properties. For example, Winnie the Pooh and Baloo are both members of the class of `Bear`, which can be declared a `rdfs:subClassOf` the class of `Mammal`.

- Properties can be defined, which are used to connect individuals to other individuals (`ObjectProperty`), or individuals to data values, with (`DatatypeProperty`). The `rdfs:subPropertyOf` construct can be used to create property hierarchies.

- For limiting the individuals to which a property can be applied, `rdfs:domain` can be used. Similarly, the individuals that a property can have as its value can be limited using `rdfs:range`. This means that if two individuals are related via a property and that property has a class as one of its domains, then the subject of that statement must be an instance of that class. If the property has a class as one of its range, then the object must be an instance of that class. Both `rdfs:domain` and `rdfs:range` are global properties.

- Definitions of `Individual`, which are instances of classes and can be connected through properties.

The definitions of an ontology can be used by a reasoner to infer facts not explicitly stated. For example, from the facts stated above, a reasoner can infer that Winnie the Pooh and Baloo are members of the class of `Mammal`. Also, if property `hasFriend` is provided with a `rdfs:range` definition of `Mammal`, then a reasoner can deduce that if Tigger is related to Winnie the Pooh via the `hasFriend` property (that is, Winne the Pooh `hasFriend` Tigger), then Tigger is a `Mammal`.

RDFS has some limitations, such as not being able to express a local scope on properties, disjointness of classes, or cardinality restrictions. In order to deal with these limitations and other requirements [66], OWL is designed to be the standardized and broadly accepted language for describing ontologies, allowing users to write explicit, formal conceptualizations of domain models. OWL builds on RDF and RDFS.[10] An OWL ontology can include descriptions of classes, properties and their instances. Given such an ontology, the OWL formal semantics specify how to derive its logical consequences, that is, facts not literally present in the ontology, but entailed by the semantics. Compared to RDFS, OWL has more vocabulary for describing properties and classes [94], including:

- Equality and inequality, through the constructs of `equivalentProperty`, `equivalentClass`, `sameAs`, `differentFrom`, and `AllDifferent`, with the latter three applying to individuals.

- Property characteristics, by employing the constructs `TransitiveProperty`, `SymmetricProperty`, `FunctionalProperty`, `InverseFunctionalProperty`, and `inverseOf`.

- Local restrictions on how properties can be used by instances of a class, using the constructs of `allValuesFrom` and `someValueFrom`.

- Cardinality restrictions, via the constructs `minCardinality`, `maxCardinality`, `cardinality`.

[10] It would have been preferable that OWL was an extension of RDF and RDFS, but such a layering cannot be realized in a straightforward manner [117].

- Enumerated classes, through the construct of `oneOf`.

Several syntaxes have been suggested for OWL. The one used in this thesis is the Abstract Syntax [118]. Ontology developers are provided with three increasingly expressive sublanguages of OWL:

- OWL Lite supports those who primarily need a classification hierarchy and simple constraint features.

- OWL DL (Description Logic) supports those who want the maximum expressiveness without losing computational completeness.

- OWL Full is for users who want maximum expressiveness with no computational guarantees.

The OWL DL sublanguage builds on experiences from Description Logic research, which studies subsets of first-order logic where the inference is restricted to classification and subsumption. Given a formula describing a class, the classifier will place it in a hierarchy, and given an instance description, the classifier will decide the most specific class to which it belongs. Description Logic research has been both in theoretical aspects and in implementing knowledge representation systems. This close interaction between theory and practice has been central in the research, where one important issue has been investigating the trade-off between the expressivity of DLs and the complexity of their inference problems [101].

OWL reached W3C recommendation status in 2004. OWL is still evolving and best practices are under investigation. This means that projects using OWL are pioneers exploring when and how to apply Semantic Web technologies, and therefore not a process without obstacles. To quote a project using OWL in the biomedical domain (for exchanging biological pathway information) [133]:

> In spite of the group's experience in biological knowledge representation, bioinformatics, software engineering, and database design, it encountered some challenging problems. We think problems similar to those described above will be common as more groups try to interact with the Semantic Web.

The reporting of such experiences help guide research related to Semantic Web technologies and serve to establish practices that can be conveyed to developers of end-user applications. The provision such experiences and lessons learned is one of the intentions of this thesis.

For example, through the application of OWL in academia and industry, additional features have been requested. Therefore, in 2007 a new W3C working group was formed with the intent of developing OWL 2. The updated version extends OWL with a small set of requested features, that tool developers are willing to support and for which effective reasoning algorithms are now available. The features include additional property and qualified cardinality constructors, extended datatype support, simple metamodeling, extended annotations, and extra syntactic sugar. In this thesis, OWL 2 is not used, since most ontology development took place prior to its release.

2.5 Applications of Semantic Web Technologies

This section presents examples of the application of Semantic Web technologies in fields related to the research of this thesis, life sciences and collaboration support.

2.5.1 The Life Sciences

The life sciences are often presented as an area that would benefit from the application of Semantic Web technologies. Indeed, the W3C has an interest group[11] devoted to the subject. Areas in which Semantic Web technologies can be applied include integration of heterogeneous data, locating relevant data sources and tools, retrieving relevant information, using inference to gather new insights, sharing formal annotations, creating rich and well-defined models of biological systems, and embedding models and semantics within online publications [102, 84]. Below are some examples of life science domains where Semantic Web technologies have been applied.

One potential use of Semantic Web technology is to support clinical practice. The use of OWL ontologies for intelligent patient modeling with the purpose of patient risk assessment is presented by Bouamrane et al. [16]. Another example of a clinical application is Mabotuwanaand and Warren [91], who describe an OWL-based approach for identifying non-adherence to prescribed medication in hypertensive patients.

The HealthFinland portal uses Semantic Web technologies to help citizens access health information, and to aid health organizations in creating and annotating it. The portal, presented by Suominen et al. [148], employs user-centric faceted search and specifically addresses the problem that indexing ontologies used in annotating resources are not a natural categorization for end-users. User-centric card sorting is used to create facets, which are then mapped onto the ontologies used in content description.

Another area of application is for integrative research. For example, Samwald and Cheung [137] describe how, for the area of neuroscience research, relational databases were converted into RDF and OWL, finding that using Semantic Web technologies improved integration of their databases with other neuroscientific data in a decentralized, flexible, and consistent way. Problems during the process related to a lack of mature and scalable open source software for editing expressive and complex ontologies.

For integrating scientific discourse in searching for a cure for Alzheimer disease, Gao et al. [46] describe the SWAN system, based on Semantic Web technologies. The idea is to represent, in a formal manner, scientific models that are potentially incompatible, while at the same time not forcing them to be incommensurable. This is achieved through allowing both public and private ontologies, where the ambition is that a researcher's private ontology will eventually be made common. In the SWAN Information Management Tool the ontologies used to represent the different steps in a scientific discovery process as well as keeping track of hypotheses and their supporting evidence, such as research documents, clinical tests, and results in the form of data and publications.

[11] `http://www.w3.org/2001/sw/hcls/`

2.5.2 Collaboration Support

Several of the projects presented above, under life sciences, can be regarded as aiming to support collaboration. Also, collaboration support using Semantic Web technologies includes adding semantic capabilities to well established concepts, such as portals, forums, and wikis. The creation of common ontologies for a domain can also be seen as a manner of supporting collaboration. In addition, ontologies have been specifically created for describing the components of collaborations, such as people and projects. Two ontologies of this kind are presented below, followed by examples of adding Semantic Web technology commonly known technologies, as well as work on modeling users and organizations.

When describing people, the Friend of a Friend (FOAF)[12] vocabulary is often used. FOAF as a project aims to create a Web of machine-readable homepages "describing people, the links between them and the things they create and do." Indeed, several initiatives for online Semantic Web communities use FOAF. The Semantic Web Research Community (SWRC) ontology [149] is an ontology that represents knowledge about researchers and research communities. Main concepts of this ontology are, among others, Organization, Project, Person, Topic, Publication, and Event.

The SWRC ontology is used and extended by several portals based on SEmantic portAL (SEAL) [147], which uses ontologies for dealing with the requirements of typical community web sites. Such requirements are information integration and Web site management. The system architecture of SEAL includes a knowledge warehouse and the Ontobroker [32] system for inferencing. Community users and software agents access the Ontobroker through modules for navigation, query, and templates for adding data.

Another approach to adding Semantic Web technology support for communities has been to enable the sharing of forum posts and other community objects between different communities, by defining a common format for these posts, which is being done in the Semantically Interlinked Online Communities (SIOC) [20]. Its goal is to interconnect online communities in helping to locate relevant and related information. The ontology and interface will let users searching in one forum find information on forums from other sites using a SIOC-based system architecture. The SIOC ontology outlines main classes, such as Site, Forum, Post, Event, Group, and User and properties of these. Mappings to FOAF, for example, are also provided.

As wikis have become popular, Semantic Web developers have also examined how these collaboration structures can be complemented with formal representation to be used in searching and browsing. Several projects have been created on this concept, see, for example, Völkel et al. [156] and Auer et al. [5], which include the addition of typed links and adding semantics to the Wikipedia template concept. It would have been interesting to investigate the use of this approach to support SOMNet. However, the SOMWeb system was already constructed when software for Semantic wikis became available.

Semantic Web Advanced Development for Europe (SWAD-Europe) presents how Semantic Web tools and standards can be used to build a decentralized information portal [131], as used in the Semantic Web Environmental Directory (SWED) demonstrator.

[12] `http://www.foaf-project.org/`

Each of the environmental organizations that want to be in the directory provides RDF descriptions of their organizations, constructed using a web-based data entry tool. The data is then hosted on the organization's own Web site (similar to FOAF).

In order to support collaboration, it is also relevant to model users and organizations. Kostkova et al. [82] discuss how user profiling can be used for semantic browsing of medical digital libraries, where the building of user profiles similar to those proposed above is suggested. For example, the profiles can contain information on profession, speciality, expertise area, and other areas of interest. Marchetti et al. [92] present a schematic figure for an ontology for health care organizations (HCO). Central to the model is the representation of an activity, which is seen as "the basic atomic action with which processes can be represented." The HCO ontology also includes goals, roles, and authority.

Thoughts on an ontology about communities of practice are presented by Vidou et al. [155]. They suggest that the central community concept includes individual members/actors with different roles, the performance of processes and activities, the production and use of resources (practices and tools) and lessons learnt. A collaboration concept is also introduced, where collaboration is defined by objectives, composed of activities, needs and produces resources, and implies actors. Further, a process/activity model is presented, in which a process is "a set of activities that need roles and resources in order to transform input objects into output objects, called outcome." Again, there is little elaboration on the elements in the ontology. This thesis seeks to provide community concepts relevant to SOMNet's collaboration.

2.6 Summary

This chapter has provided background information on the research areas of the thesis: clinical collaboration, communities of practice, technical support for clinical collaboration and communities of practice, as well as ontologies and Semantic Web technologies. However, there is a need to deepen the understanding of how distributed clinical collaboration that goes beyond one-to-one consultations function. What characterizes them and what challenges them? This ties into the need to investigate the functions of distributed communities of practice. Principles for communities of practice have been proposed, but how can they be seen at work?

In addition to social aspects, it has been suggested that knowledge formalization can help communities organize their knowledge through this advance their learning. Semantic Web technologies, and specifically OWL, have been proposed as standards for this purpose. However, there is a need for more knowledge on when using these is appropriate, as well as the identification of issues that enable and constrain their use and usefulness.

Given that much literature on IT support for communities of practice seems to be agnostic to the kind of technology that is actually used, more knowledge is needed on how support can be developed, what functions should be supported relative to the activities of the community of practice, and the impacts that the IT support can have on the collaboration.

The next chapter presents the methodology used to study these topics in this thesis.

Chapter 3

Research Methodology

The subject of this thesis is interdisciplinary. It spans from ontology construction and use to system development, and studying the system in use, as well as studying the collaboration that the system supports. While I believe that such interdisciplinarity is useful and required in order to provide a well-rounded view of the problem at hand, it also suggests a challenge since a wide variety of research methods from different disciplines have to be applied.

Investigative procedures of research can be divided into analytical and synthetical approaches. While analysis refers to the taking apart of a whole into components – the detailed examination of the structure of something, synthesis combines elements or components into a whole, such as a theory or system. Although the two approaches carry different values in different research communities (which may prefer one or the other, for example, physics is often associated with analytical methods and computer science with synthetic approaches), they also complement each other; synthesis builds on analysis and analysis builds on synthesis. This thesis contains both approaches. The objectives of the thesis, presented in Section 1.3, are now examined to illustrate the different methods applied in addressing each of them:

1. *Study the collaboration and knowledge sharing of geographically distributed healthcare professionals in oral medicine, as seen in SOMNet. This covers who participates, their collaboration process, and outcomes, as well as challenges to collaboration and knowledge sharing. Also included is the relation of these results to the theory of communities of practice.*
   This objective suggests an analytical approach that applies qualitative and quantitative methods of studying collaboration, and methods used are interviews, observations, and a questionnaire. The latter part of the objective also indicates the need for a synthesis of analytical results with theories from the literature.

2. *Employ Semantic Web technologies, OWL and RDF, to describe oral medicine knowledge and community resources. The oral medicine knowledge focuses on the formalization of examination templates and terminology applied when clinicians enter data about individual patients. Community resources are aspects of the collaboration related to users, meetings, and case metadata.*

This objective suggests an analysis of the domain and the collaboration and applying synthesis in the ontology creation. The first part of the objective takes the previous MedView representation as a starting point. For the development, I employ an adaptation of ISO/IEC 15288 [71] system life cycle processes. The second part includes central aspects of SOMNet's collaboration and consideration of how community resources can be modeled based on results from the first objective.

3. *Design and develop a Semantic Web-based system, SOMWeb, to support a community of practice of oral medicine in managing its meetings and cases. This includes design decisions and functionality, as well as technical aspects of the system architecture and how the ontologies resulting from the previous objective are used.*
   The third objective suggests the use of analysis to derive community requirements and a synthesis of these for the development of the SOMWeb system.

4. *Evaluate SOMWeb. This entails its general functionality, structured case-entry, how the system is used, as well as a comparison of cases before and after the introduction of SOMWeb. This also includes the identification of impacts of SOMWeb on SOMNet's collaboration.*
   This objective suggests the use of analysis to study the use and impacts of SOMWeb, where methods used are interviews, observations, a questionnaire, an analysis of system usage logs, and an analysis of cases submitted for discussion before and after SOMWeb's introduction.

5. *Extract recommendations for developers of Semantic Web-based systems and systems supporting clinical collaboration and knowledge sharing.*
   This objective suggests the use of a synthetical method in order to provide lessons learned, which may not be captured in the other objectives.

While different methods are applied in fulfilling the objectives, one important aspect is that this thesis focuses on a specific case, supporting SOMNet's collaboration and knowledge sharing. Therefore, this work can be regarded as using the methods of case study research, which according to Benbasat et al. [7] "examines a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or a few entities."

Above I have presented a view of the thesis organized by objectives and methods applied in addressing them. However, as an alternative perspective, in order to give an overview of the research process, Figure 3.1 shows a timeline of how the work presented in this thesis has been carried out. Through this figure, the iterative nature of the research can be seen, with, for example, repeated phases of ontology and system development. The grayness of the boxes indicate the extent to which work was done by myself. The grayest box, the first user study, indicates my non-involvement. The white boxes indicate work carried out by me. The dashed lines indicate that updates were performed to the SOMWeb system and literature was reviewed throughout the process.

Next, case study research in general is discussed (Section 3.1), as well as why it is appropriate in this study. Then, the method employed for ontology development is described (Sec-

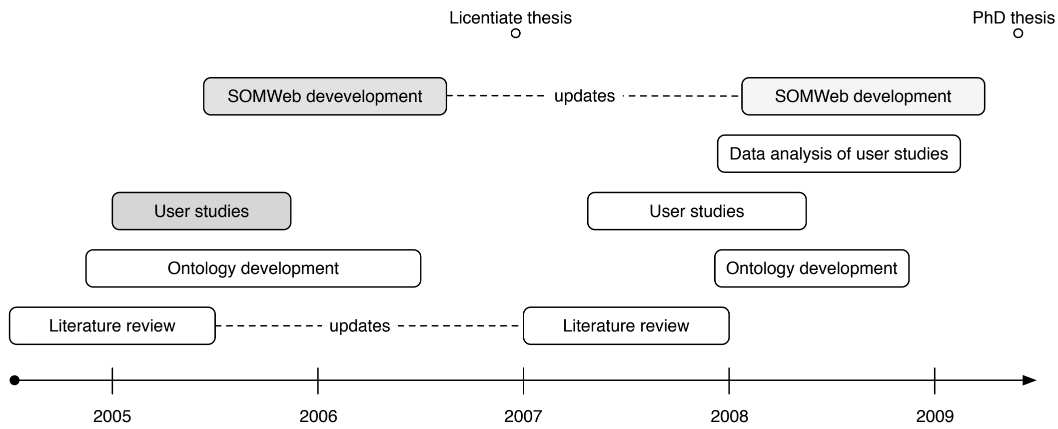


Figure 3.1: Research process timeline.

tion 3.2), followed by the system development approach (Section 3.3). A brief discussion of ethical considerations for SOMWeb is given (Section 3.4), followed by an overview of methods used in studying collaboration and system evaluation (Section 3.5). Finally, more detailed descriptions of each of these methods are provided: questionnaire (Sections 3.6), interviews (Sections 3.7), observations (Sections 3.8), log analysis (Sections 3.9), and case analysis (Sections 3.10). The chapter ends with a brief summary (Section 3.11).

3.1 Case Study Research

Case study methods imply an in-depth and longitudinal study of a single or a few instance(s). Benbasat et al. [7] give reasons for choosing the case research strategy: generating theory from practice, understanding the nature and complexity of processes taking place, and that few previous studies of a phenomenon exist. As Yin [163] puts it, a case study strategy is advantageous when “a ‘how’ or ‘why’ question is being asked about a contemporary set of events, over which the investigator has little or no control.” Since I have found no previous studies of collaborations such as SOMNet (though a few similar ones, see for example Kane and Luz [78]), I find a case study approach appropriate. Here I deal with a single-case study. Yin [163] proposes a single-case study is relevant if it is a revelatory case, if it is a critical case in testing a theory, or if it is an extreme or unique case. As discussed above, SOMNet is unique in the literature. According to our clinical contact, professor in oral medicine at the University of Gothenburg, within the field of odontology in Scandinavia, SOMNet is unique in providing regular and structured distance case discussions to a larger audience. However, it was found beyond the scope of this study to investigate whether similar practices exist in medical practice.

Research methods can be categorized according to levels of constraint, as described by Graziano and Raulin [51], where high constraint methods involve imposing limits and precisely defined measurement procedures and low-constraint methods are more flexible and appropriate when studying behavior in a natural context. The case study approach is a low constraint method. According to Graziano and Raulin, we can, from a case study, get a description of events, identify relationships between variables, lay groundwork for more constrained research, and make observations to negate general propositions. However, causal relationships cannot be drawn. Case studies cannot be generalized and replication is hard if the procedures have not been very explicit. The possibility of researcher bias is also greater than for more constrained research.

Thus, we should bear in mind that while using a case study approach can provide findings not accessible through other methods, using the method also has implications on generalizability. In the context of qualitative methods, the concept of transferability is often used instead of generalizability. According to Lincoln and Guba [88], whether conclusions made in one context are applicable in another context depends on the similarity of the two contexts. However, it is only the person in the second context, who wants to transfer the results, who knows the details of this context and can make such judgements. The role of the investigator of first situation is therefore to provide enough description for the second person to be able to establish whether their context fits the first.

In case study research, multiple methods of data collection are often used, and Yin [163] claims that the possibility of using several sources of evidence is one of the strengths of case studies, since employing multiple sources can be used in triangulation. Sources of evidence commonly used in case study research are documentation, archival records, interviews, direct observation, participant observation, and physical artifacts [163]. In line with the suggestion of using several sources, the SOMNet study employs, as briefly presented earlier in this chapter, archival records (in the form of cases e-mailed among participants before the system was introduced and those entered into the SOMWeb system, as well as other content of the system), interviews with members, and direct observation of meetings. In addition to this, logs of system use were analyzed and an electronic questionnaire was distributed. These methods are described in Sections 3.5 through 3.10.

3.2 Ontology Development

For SOMWeb, the oral medicine ontologies were developed to provide a formal conceptualization of the domain in order to enable reuse, querying, and inference based on collected case data. These ontologies were developed to expand on the knowledge representation and knowledge content of MedView. To move away from the previous representation, only used within the MedView research group, the W3C recommendations of OWL and RDF were chosen. The community resource ontology intended to explicate key community concepts and provide the potential for adapting the system based on classifications of users. Ontology elements related to community aspects were identified through the iterative modeling and development work of the SOMWeb system as well as the studies of SOMNet's collaboration.

Developing ontologies is a complex process which must address, among others, difficulties in knowledge acquisition, knowledge representation, and project management. Terminology in ontology engineering draws on software engineering, where the usually accepted stages through which an ontology is built are specification, conceptualization, formalization, implementation, and maintenance [122]. Several methodologies have been proposed for ontology development, such as the approach of Uschold and King [153], the method of Grüninger and Fox [53], and the Methontology approach [43].

For the development of the SOMWeb ontologies, an adaptation of ISO/IEC 15288 [71] system life cycle processes was employed. The ISO/IEC 15288 standard equips us with a domain independent way of understanding the nature and composition of man-made systems, as well as their movement through life cycles. The standard requires that a life cycle model be developed for each system-of-interest to which the standard is to be applied. In viewing ontologies as systems, techniques from systems thinking can be applied to structure the development and deployment of ontologies.

This adaptation of the ISO/IEC 15288 system life cycle processes for ontology development was performed by the author and inspired by methodologies such as those cited above. The adaptation is described in Gustafsson [57]. The standard describes twenty-five system life cycle processes divided into enterprise, agreement, project, and technical processes. A description of how different processes can be used during the ontology development and deployment life cycle is given in Section 5.1.3, when presenting the development process of the SOMWeb ontologies.

Using ISO/IEC 15288 for ontology development bears similarities to other methodologies for ontology construction, such as those described above, being most similar to the Methontology approach [43]. However, the applicability of the standard to a wide range of system related activities brings about a desirable level of adaptability to different ontology development configurations. An ontology will usually not exist in isolation, but will be part of a larger system, composed of both software components and people. Since ISO/IEC 15288 can be applied to all levels of the encompassing system, it makes sense to also apply it at the ontology-level. It is therefore a drawback that it has not been used for system development in this project.

For reading and writing OWL and RDF from Java, the Jena [130] application programming interface (API) was used, since it provides means for interacting with both OWL and RDF (as opposed to only OWL), and because it is a widely used API for this purpose.

3.3 System Development

System development is a complex process, and several methodologies have been proposed to facilitate the process and help ensure a successful outcome. However, there is to date no great consensus on what the optimal methodology is, and it has been speculated that the choice is dependent on the kind of system to be developed. It is not uncommon to have problems with user acceptance due to insufficient user involvement during development, as noted by, for example, Koch [81]. One way to alleviate this is to employ a user-centered approach [106]. Another way to ensure that a system meets user expectations is to develop it iteratively: initially constructing a smaller system and incrementally adding more features and improving those already included.

For these reasons, the development of SOMWeb followed an iterative, user-centered design approach, which means that a selected group of users were involved in the design process already from the start. These users took active part in the establishment of initial requirements, and have continuously provided feedback on developed prototypes.

The initial forms of collaboration and SOMNet's opinions of these were investigated by observing the meetings and through informal interviews with selected participants and the secretary coordinating the meetings. Also, an online questionnaire regarding the forms of participation in SOMNet was made available to all members of SOMS, which received twenty replies. Through this questionnaire, six members willing to participate in the development of SOMWeb were also identified. It should be noted that the questionnaire, observations, and interviews were not the same as those presented later in this chapter. The investigation resulted in the identification of problems with the former support for their collaboration, presented in Section 6.1. The design decisions for the SOMWeb system, found in Section 6.2, were informed by these initial observations and interviews. Then prototypes were developed: first paper prototypes, since these are an efficient means of providing the initial presentation of a system to users; followed by an interactive HTML prototype that was testable but did not contain real functionality. Section 6.3 describes the prototypes used in development.

The design rationales are to provide simplicity of interaction as well as a clean and aesthetically attractive user interface design. This was in order to avoid the often-reported problems of medical information systems not having compelling and useful interfaces for the user [165, 74]. It was also the MedView group's experience from previous work that the IT-literacy among the clinicians is not very high. Thus, to ensure simplicity, only basic functionality is initially available to the user. In order to have full access to all parts of the system, the users must make an active choice by changing their individual preferences.

The development of SOMWeb, described above, began in the spring of 2005 and the system was introduced to all SOMNet members in May 2006. In August 2006, all SOMNet participants at the time were invited to answer a Web-based questionnaire intended to further examine their needs and wishes regarding system functionality. Eight members replied and the results served as a basis for further iterations of system development.

Our primary contact was the clinic for oral medicine at Sahlgrenska Academy at the University of Gothenburg. The requirements elicitation, design of the system architecture and user interface, as well as coding was performed by Fredrik Lindahl, Chalmers University of Technology. I implemented the parts of the system that use Semantic Web technologies. After the clinicians began using SOMWeb for their meetings in mid 2006, the development of SOMWeb was continued by Daniel Roth, Chalmers University of Technology, Andreas Argirakis, University of Gothenburg, and myself. Administrators, clinicians, and developers suggested features that were initially not present, either due to lack of time or because the need was not identified. New features were added when finished, and when relevant, the members were informed on the SOMWeb news page. Since December 2006, I managed the updates to the system.

3.4 Ethical Considerations for SOMWeb

All users need an individual user name and password in order to access the system. No information is available in SOMWeb that will reveal the identity of the patient in the presented cases. The case data that each presenter provides does not contain any personal information, except age, gender, and country of birth. En face images are prohibited and intraoral images do not disclose any identity. All members of SOMNet have signed a professional secrecy agreement as part of their clinical assignment. It is the individual submitter's responsibility to ascertain the patient's approval for discussion of their case at SOMNet's meetings. A written consent form for this purpose is made available on the instruction page of SOMWeb. SOMNet also suggests that a note should be made in the patient record that this has been done.

3.5 Overview of Methods for Studying Collaboration and System Evaluation

After the launch of the SOMWeb system, there were parallel investigations of the collaboration of SOMNet and evaluation of the system, addressing Objectives 1 and 4. As mentioned above, a variety of methods were used: an online questionnaire, interviews with participants, observations of teleconference meetings, logs of system usage, and examining the cases submitted for discussion. Results from all methods were used to inform the evaluation, while the first three were used for the study of SOMNet's collaboration. The methods complement each other. For example, according to Patton [120] interviews are helpful to "access the perspectives of the person being interviewed" while observations supplement this by giving insights into the studied setting, its activities, and participants. With the questionnaire, more users could be reached in a time efficient manner, while not giving as in depth responses as the interviews. To learn how SOMWeb is used, system logs and cases were analyzed.

Table 3.1 summarizes figures related to the methods used, such as number of respondents and cases. Figure 3.2 provides a timeline of when the data gathering of the observations, interviews, and the questionnaire was carried out. The timeline begins when SOMWeb is first introduced in May of 2006 and concludes in April 2008, when the last observation was carried out. All meetings in this time period are indicated, and whether or not they were observed. Furthermore, the location of the observer is reported for those meetings that were observed, with only the primary contact, the clinic of oral medicine at the Sahlgenska Academy indicated by name. This is to preserve the anonymity of interviewed persons at the other clinics. The questionnaire was distributed in April 2007.

Before describing the methods used, a short discussion of bias is in place. Since all data gathering and analysis was carried out by one of the developers of the SOMWeb system, there is the possibility for bias in more readily seeing results that confirm the intent and proper functioning of the system. Further, the behavior of those observed and those interviewed could have been affected by them knowing that I had taken part in the development of SOMWeb. Brender [19] describes pitfalls and biases related to the use of questionnaires

Table 3.1: Summary of figures for the data gathering methods.

Method	Information
Questionnaire	24 respondents
Interviews	9 members
Observations	10 meetings at 5 clinics
System data	May 2006 – Dec 2008
System logs	Aug – Dec 2008
Pre-SOMWeb cases	232 cases, from Jan 2001– Apr 2006
SOMWeb cases	122 cases, from May 2006 – Dec 2008

and interviews. These include psychological factors leading to unwillingness to answer questions due to, for example, prestige, differences between personal opinions and the official account, and mood at the time of responding. Evaluations pose difficulties in that there is often disparity between what people think, what they say, and what they do. Further, the Hawthorne effect indicates that the act of evaluation changes the activity studied.

The following sections provides details on data gathering and analysis for the methods used for studying SOMNet's collaboration and the SOMWeb systems evaluation.

3.6 Questionnaire

The online questionnaire contained both open-ended and closed questions (see Appendix B) formulated by myself and my collaborators. These were checked by our clinical contact previous to distribution. The questionnaire was made available for about one month in the spring of 2007. Requests to complete it were made at a telephone conference, on the news page of the system, and by e-mail to approximately 60 members, which was all of the members at the time. In total, 24 completed the questionnaire. Of these, thirteen worked in dental units in hospitals, six in specialist clinics, three in public dental care, and two i private practice. Eighteen had worked as dentists twenty years or more, four for ten to twenty years, one for five to ten years, and one for zero to five years. Seven reported that they had submitted cases to SOMWeb. The average age of the respondents was 51, with thirteen women and eleven men.

3.7 Interviews

The interviews were intended to identify processes that are part of SOMNet functioning as a distributed community of practice, as well as to give a greater understanding of how SOMWeb is used and how the system has affected SOMNet. A semi-structured interview format was chosen in order to obtain the flexibility to adapt the interview to the issues raised by the interviewee. The interviews were thus guided by an interview guide (see Ap-

2006	May	Meeting	SOMWeb introduced at meeting	
	June	Meeting	SOMWeb first used in meeting	
	September	Meeting	Unobserved meetings	
	October	Meeting		
	November	Meeting		
	December	Meeting		
2007	February	Meeting	Observed at Sahlgrenska	
	March	Meeting	Observed at Sahlgrenska	
	April	Meeting	Observed at Sahlgrenska	Questionnaire distributed
	May	Meeting	Unobserved	
	June	Meeting	Observed at Clinic 2	
	September	Meeting	Unobserved	
	October	Meeting	Observed at Sahlgrenska	
	November	Meeting	Observed at Clinic 3 4 members interviewed (3 different locations)	
	December	Meeting	Observed at Sahlgrenska	
2008	January		1 member interviewed	
	February	Meeting	Observed at Clinic 4 1 member interviewed	
	March	Meeting	Observed at Clinic 5 3 members interviewed (2 different locations)	
	April	Meeting	Observed at Sahlgrenska	
	(meetings continue, but are not observed)			

Figure 3.2: Timeline showing of data gathering for the observations, interviews, and questionnaire.

pendix A), which included parts about submitting cases, meeting participation and preparation, knowledge needs and benefits of SOMNet, and use of the SOMWeb system outside of meetings. The interviewees were also encouraged to discuss anything that was not brought up in the questions. The questions were not always raised in the same order.

The interviewees were selected in order to get respondents from different clinics and with different lengths of SOMNet membership, while retaining some convenience with respect to travel time. In the interviewee selection process, I asked for the names of persons available after a meeting which I observed in the autumn of 2007, and received eight names. Five of these persons were contacted, and two suggested additional members for participation in the interview (who were then interviewed together). One person, not present at the meeting at which names were collected, was contacted due to geographical convenience. In terms of sampling strategies, as described by Patton [120], this is a combination of maximum variation sampling (with respect to location and membership length) and snowball sampling (where interviewees suggested other persons to interview, though this was not initially intended), with elements of convenience sampling (in geography and in getting participants).

I interviewed nine members of SOMNet. Five were interviewed individually, and two interviews were carried out with two members at a time. The first interview was carried out in November 2007 and the last in March 2008. Each interview lasted between 35 and 85 minutes. Three of the interviewees have been members of SOMNet from the mid 1990's, three have been members for at least four years, and three have joined more recently. Thus, views of members with varying lengths of membership were captured. Two of the respondents are oral pathologists and do not see patients themselves. The other seven all work at hospitals, and two of these have a research background. This is representative of those with a high level of participation in SOMNet. Of the interviewed, six were men and three women. The average age of the dentists was 55 and they had been practicing for an average of 31 years. Three weaknesses in the selection of interviewees are that no interviews have been carried out with general practitioner dentists, whose membership in SOMWeb has increased since its introduction, as well as that no interviews were done with those who had joined very recently nor those who have been dentists for a shorter time period.

The interviews were recorded, and in addition to this, on the same day as the interview, I wrote down all impressions of the interview and any question responses that I recalled. This was especially helpful because due to a technical malfunction the recording of one interview was lost. I transcribed all the recordings from the interviews. Patterns in the interview data were identified and coded through content analysis, as described by Patton [120]. The interview questions were used as initial themes for coding the interviews, but matters that came up spontaneously during the interviews were also included in the coding. I carried out all the coding, first by writing the codes and highlighting key phrases on printed transcripts, and then responses from interviewees were collected by theme on a spreadsheet. This compilation was used to compare and count interviewee opinions on different themes. However, due to the qualitative nature of the study and the open-ended responses, a deeper quantitative analysis was not appropriate.

3.8 Observations

Observations were carried out by sitting at one of the clinics during a telephone conference. The purposes of the observations were to elucidate how cases are presented during telephone conference meetings, how clinicians behave locally during these meetings, and how the SOMWeb system is used locally during meetings. I conducted all observations, taking notes both of what was said during the telephone conference as a whole, and what the participants said and did locally.

Since the meetings are telephone conferences, being present at one site gives access to all that is said globally during the meetings. However, I also wanted to find out what differences there were in the way meeting participation was carried out in different locations. Ten meetings were observed: six at the clinic for oral medicine at the Sahlgrenska Academy in Gothenburg, and four at four other clinics in Sweden. Meetings were observed at Sahlgrenska due to geographical convenience and, since it is our primary contact, it meant that fewer arrangements had to be made. Three of the meetings observed at other clinics were in conjunction with interviews. The first meeting was observed in February 2007 and the last in April 2008.

In analyzing the data, descriptions of meeting procedure and case presentations were generalized from my observations and notes. However, no content analysis of what was said at the meetings was carried out.

3.9 Logs of System Use

To investigate system usage, user activity in the SOMWeb system was logged during the fall of 2008. Members of SOMNet were informed of this via the news page of the system, which all users reach upon logging in. The logs were internally created by a system, and each log line consists of the date and time, user name, as well as the page requested, for example, a certain meeting page, the form to enter a new case, or the presentation of a specific case. The log file was programmatically converted to a comma separated value (CSV) file, imported into a mySQL database for querying.

Some limitations of analysis of user activity bear mentioning. One problematic aspect of the log analysis in general is that users frequently use the back button in their Web browser, and this activity does not appear in the log. For example, Tauscher and Greenberg [152] found that thirty percent of the browsing activity was performed using the back button. There is also a problem in determining the length of a visit. It is, for example, not possible to know how long users stay after the last page view, how they are mentally processing the content of a Web page, or if they are interrupted.

3.10 Case Analysis: Before and After Introduction of SOMWeb

Cases from before and after the introduction of the system were analyzed to examine how the SOMWeb system and its structured case entry have affected the information entered for cases submitted for discussion at meetings, as well as the distribution of submitting clinics. I have access to the cases presented at SOMNet from approximately 2000 until the introduction of SOMWeb in May 2006, as well as those contained within SOMWeb. The analysis of cases thus consists of two parts: analyzing the cases prior to the introduction of the SOMWeb system (approximately 230 cases) and analyzing those contained in SOMWeb (approximately 120 cases at the time of analysis).

The same information is not available in both the old and new cases. In addition, while some information can be extracted automatically from the new cases, the old ones were analyzed manually, thus, a detailed analysis was not performed for all cases. To be able to compare the distribution of submitting clinics, data on the name of the submitter and their clinic were noted for all pre-SOMWeb cases, where possible. For the SOMWeb cases, this can be automatically extracted.

To compare the content and structure of the cases, twenty pre-SOMWeb cases were randomly selected for further analysis of headings used in the presentation and any use of structured information (as opposed to free text). For all SOMWeb cases, data was extracted on the number of values filled in for each of the attributes of the template, and the length of the free text entry.

A drawback the case analysis being carried out by myself is that I have limited medical and dental knowledge. Especially for the pre-SOMWeb cases, it is possible that, for example, a dentist might have made other observations.

3.11 Summary

This research methodology chapter has presented how the thesis objectives were addressed and the process through which the research was carried out. I also elaborated on the appropriateness of a case study, given that SOMNet is, to my knowledge, a unique collaboration within dentistry in Scandinavia. Further, the processes used for ontology and system development were described, as well ass how an online questionnaire, meeting observations, interviews, log analysis, and case analysis were used to study SOMNet's collaboration and the evaluation of SOMWeb.

Chapters describing the results of these investigations follow, beginning with the collaboration of SOMNet.

Chapter 4

Collaboration and Knowledge Sharing in SOMNet

This chapter presents results related to Objective 1, as presented in the introductory chapter. It involves the study of the collaboration and knowledge sharing of distributed healthcare professionals in oral medicine, including the relation of these results to the theory of communities of practice. The methods used in studying SOMNet's collaboration are a questionnaire (Section 3.6), interviews (Section 3.7), and observations of meetings (Section 3.8). Table 3.1 on page 42 summarizes important figures for each of these.

The results presented in this chapter relate to the more general aspects of SOMNet's collaboration and knowledge sharing, while those presented in Chapter 7 relate to aspects of how the users perceive SOMWeb and how SOMWeb has affected their collaboration. The results presented here are intended to reflect the behaviors and motivations of the participants. Knowing how SOMNet functions furthers the research community's insights into the ways in which distributed communities of practice work which can be used to inform the development of systems built to support such collaboration. However, since the studies that inform this chapter were made after the introduction of the SOMWeb system, the conclusions of this chapter did not inform the initial development of SOMWeb.

In the chapter, an attempt has been made to do this without reference to the system used for support and how it is used. This is both because I believe that there are characteristics of SOMNet's collaboration that are not closely linked to this support, and because SOMWeb has not yet been described. However, since the studies were carried out after the SOMWeb system was introduced, some reference to system behavior is made.

The chapter contains direct quotations from the interviews to illustrate findings and variations in viewpoints. Since the interviews were carried out in Swedish, these quotations have been translated. In carrying out this translation, I have tried to stay as close as possible to the original wording. After each quotation, an indication is given of the interviewee's position. Further, the respondents are numbered so that it is possible to follow which statements are made by the same person.

In Section 2.1.1, dimensions of collaboration and clinical collaboration are presented, and the corresponding results from the SOMNet study are now described. The participants and what organizations they belong to are presented (Section 4.1). The process through which collaboration takes place, in SOMNet's case the meetings, is described (Section 4.2). The scenario presented at the beginning of the introductory chapter also illustrates how SOMNet collaborates. Outcomes of SOMNet's collaboration, in terms of benefits for the participants, the impacts on knowledge seeking, and outreach activity, are presented (Section 4.3). Furthermore, challenges in collaboration and knowledge sharing in SOMNet are identified (Section 4.4) followed by a characterization of SOMNet as a community of practice (Section 4.5). The chapter ends with a discussion of the results (Section 4.6) and followed by a brief summary and conclusions (Section 4.7).

4.1 Participants and Participation

The members of SOMNet are mainly dentists with an interest in oral medicine and they are distributed throughout Sweden. Among the participants are general practitioner dentists, hospital dentists, specialists in oral surgery and oral medicine, professors, and several oral pathologists. Both public clinics and private practices are represented among the general practitioners. Some, but not all, of the participants have been certified by SOMS.

All the members do not participate in each meeting, and there are participants of meetings that are not members. In the latter case, a person does not have a login to SOMWeb or, with the previous approach, did not directly receive e-mailed PowerPoint-presentations, but somebody else at their clinic accesses the cases. When the interviewees were asked about the frequency of their participation in telephone conference meetings, all stated that they participate as often as possible. They are generally able to set aside time from their work, but sometimes prior engagements interfere. One questionnaire respondent said they could never participate, as the meeting time does not suit them.

Since May 2008, ten to fifteen clinics join each meeting. At each of these, the organizers estimate that there are between one and ten participants, with an average of three. Where the participants of a local clinic congregate for a teleconference meeting depends on the number of participants. If the number is small, they usually sit in front of a computer in an office. If more than two or three participate, then usually a meeting room with a projector is used.

4.2 Collaboration Process – SOMNet's Meetings

The collaboration process of SOMNet is mainly carried out through the meetings. These meetings have several functions: patient consultation, a means for continuing education, and as a forum of discussion. When the questionnaire respondents were asked which of these they viewed as the primary purpose of SOMNet, 15 replied a forum of discussion, seven an instrument of continuing education, and two a means for patient consultations.

In this section, the structure of the meetings and the activities involved are presented (Section 4.2.1), followed by how the participants prepare for the meetings (Section 4.2.2). Then case submission is discussed (Section 4.2.3), which includes why participants submit cases and why they refrain from doing so.

4.2.1 Meeting Structure and Activities

The SOMNet distance consultations are held once a month (four times in the spring and four in the fall) by telephone conference in conjunction with case presentations, previously as PowerPoint presentations and later with the SOMWeb system. The time scheduled for each meeting is one hour, during which three to six cases are introduced for the first time, and up to three follow-up cases are presented. A chairperson leads the meeting by, for example, guiding the transition between case presentations as well as heading and summing up discussions.

During case presentation, the submitter usually tells the story of his or her meetings with the patient, the treatments attempted, and their results. After, and sometimes during, this short presentation, the other participants ask questions of clarification. Depending on the kind of case presented and the clinician's purpose for discussing it, the participants will suggest possible diagnoses and treatments. Similar cases or general treatment strategies will sometimes accompany the suggestions. A broader discussion may ensue, for example, about reported side effects of medications or whether a certain treatment is suitable in general. The chairperson usually starts summarizing when several options have been put forth, and suggestions are given to the presenter.

SOMNet has much experience with teleconferences and there is a flow in the conversation even though participants cannot see each other. Most identify themselves before giving their comments. However, if several members at one of the clinics choose to have a small, whispered, local discussion among themselves, the flow in conversation is quicker and more interactive.

Few participants, apart from the chairperson, take notes at the meetings that were observed. The issue of note-taking came up in several interviews, but not all. Two of the interviewees reported that they regularly take notes. As seen Quotation 1, one of these used the feature of SOMWeb for making private comments on cases during meetings. The quotation also indicates the value the respondent finds in the participation of experts.

> **Quotation 1:** When [name of senior member] says something, then I write a lot in my comment box: 'oh that and that, 60 mg Prednisolone...' (Hospital dentist 1)

Another respondent said that she took notes on paper and had intended to enter them into SOMWeb but had not gotten to it. As for those who said they did not take notes, one commented that they usually sit and listen, but take notes when given suggestions for action on their own case.

4.2.2 Meeting Preparations

Participants can prepare for the meeting by looking at case descriptions and images prior to the meeting. While reviewing the cases they try to form their own opinion of them which they find increases the benefit of participation, as seen in Quotation 2. It was also indicated that there is an obligation towards the case submitter to review the case before the meeting. Quotation 3 conveys this other aspect of preparation which is not directed at the individual's learning but the needs of the case submitter and community.

Quotation 2: I usually want [go through the cases before the meeting], because otherwise I think it is hard to follow. You have to get a picture of what it is. It isn't always that the case title says what it is. Sometimes you have to look at the pictures and read lists of medications and such to get a feel for what it is. And it isn't certain that you get that either, for that matter. Some of the cases are really hard. (Hospital dentist 2)

Quotation 3: I usually want to look through the cases that will be brought up and look if I have something similar and if there is something I might be able to add. (Hospital dentist 3)

To what extent do members prepare for meetings? Of the twenty-four questionnaire respondents, six replied that they always prepared, eleven that they sometimes did, three seldom, and one never (three respondents, who had not taken part in any meetings, did not answer the question). All the interviewees replied that they usually go through the cases before the meeting, either the same day or the night before.

A more thorough review of the meeting's cases is carried out by the designated chairperson. This involves searching for applicable research literature as well as recollecting similar cases of their own. As seen in Quotation 4, consideration is also given to more closely understand what kind of help the case submitter needs and how to lead the discussion of it.

Quotation 4: You look at a case for maybe five to ten minutes. Sometimes it is self-evident. And sometimes you ask yourself 'What is this?'. And then you look at it longer. The case of [name of member] for today's meeting I looked at for maybe two minutes, just to understand what the question was. And then how to handle it, that I spent more time on. How to introduce it at the meeting. But that I wouldn't have spent time on if I wasn't chairing the meeting. (Hospital dentist 4; has research background)

The reason the interviewees reported for often preparing close to the meeting time is that cases are often not submitted until then. This can make it difficult for members, especially the chairperson, to prepare. Quotation 5 shows the consequences of this. The same respondent suggested that earlier case submission could be promoted through the rotation of leadership should help, as being chairperson means you believe receiving cases early is important.

Quotation 5: Well, I started already last week to look at cases, because we had decided that cases should be submitted at least a week before the meeting, so we have time to prepare. But when I looked a week ago there were only two cases. And those two were the only cases yesterday. So I added one. (Hospital dentist 3)

4.2.3 Case Submission

In order to learn more about how SOMNet functions, it is also interesting to know the purposes for submitting cases and why members might refrain from submitting cases.

Purposes for Submitting Cases

In general, the interview responses and the observations indicated three main purposes for presenting cases: seeking advice regarding diagnosis or treatment, sharing a case of unusual character, and wanting to raise an issue for discussion. The most common reason given was seeking advice, due to being “stuck”, as several interviewees put it, though a presenter may have several motives for bringing a case to the meeting. Examples of recurring discussions include how to monitor patients with pre-cancerous disorders and reporting medication side effects. For the most experienced members, considerations is also given to what the submitted case will contribute to the community as a whole, as illustrated by Quotations 6 and 7. The context of the latter quotation is a chairperson considering what cases to add to the meeting.

> **Quotation 6:** I like to add cases that are original and of current interest. That is, cases where there could be something new. But I also bring up typical cases, but maybe with some new angle on diagnostics or treatment that we may not have considered before. Or cases that have been brought up previously that I can illuminate with a new case. [...] There could be many purposes, but mainly consultation. You want to know what the colleagues say about this. But it could also be that you are aware of something that they may not know about. And then there is a bit of teaching and informing too. (Hospital dentist 5; research background)

> **Quotation 7:** So today I added one case that is for the curiosity cabinet. One where the diagnostics are interesting, how you ascertain the diagnosis. There I want the pathologist to tell us what to do to give the diagnosis, Myelom. What can the pathologist help with? [...] Then I have a case where you can question whether I have the right diagnosis. The same patient, two aspects. What is this really? Have I reasoned the right way? So I’ve tried to include different things. (Hospital dentist 4; research background)

Sharing is another factor in the submission of cases, for example when having found a rare case, something for the curiosity cabinet as mentioned in above in Quotation 7. New treatment strategies can also be shared, where there is a usual manner of treatment that didn’t work, and where the submitter successfully tried something different. This kind of submission can be seen as reputation building, as can the rare cases, as the interviewee indicates in Quotation 8.

> **Quotation 8:** Of course, it is always more fun to find something that nobody else has seen before. It is like collecting stamps. If you have a ‘three skilling banco’, then you want to show it off. So there is a little bit of vanity in it. (Hospital dentist 5; research background)

Interviewees also addressed the problem of experienced members showing off cases, giving junior members the sentiment that only very unusual cases are interesting. The issue of what kind of cases that the community as a whole should seek to address, on the spectrum of typicality, is reflected on in Quotation 9.

> **Quotation 9:** I think that we sometimes get things that are really incredible things for the curiosity cabinet [...] You know that you will never see it again and if you are to recognize it the patient needs a sign around his neck that says what it is. But I think that it can be just as good to discuss regular, quite banal changes. Things that take a lot of time in the clinic, where you have many cases. ‘Should we follow them, should we not follow them.’ And try to form a common opinion about this. (Hospital dentist 4; research background)

Refraining from Submitting

As with many enterprises, one may intend to do something but in the end refrain from doing so. In the questionnaire, 16 responded that they had thought about adding a case to SOMWeb but had not done so, while four had not. One person did not reply to the question. In response to an open-ended follow-up question on why the case had not been added, five gave reasons related to missing images and data, four indicated a lack of time, and two said that the case felt too banal. The questionnaire also asked what, in general, would motivate the respondent to submit more cases. Fourteen persons gave some response to the question, with eight of them mentioning more time. Other responses were only mentioned by one person and included getting started with continuous education, finding unusual cases, and and the meeting being at a different time.

4.3 Outcomes

The outcomes of SOMNet's collaboration were investigated through interview questions of the perceived benefits of participation (Section 4.3.1) and the effect on knowledge seeking (Section 4.3.2). SOMNet's function as a general outreach activity for oral medicine is also discussed (Section 4.3.3).

4.3.1 Benefits of Participating

The value of SOMNet for the majority of participants is access to external expertise and ultimately better care for patients, as well as a means of continuing education, as illustrated by Quotations 10, 11, and 12. One interviewee, see Quotation 13, found that participation in SOMNet benefited more than attending a course. Quotation 14 highlights that oral medicine has many diseases with low prevalence, making case focused collaboration especially valuable.

> **Quotation 10:** It is the exchange of experience. There are always new changes that you haven't seen before. Listening to others' problems and new treatment methods. It is great. It is like working at a very big clinic. (Hospital dentist 3)

> **Quotation 11:** I have never sent in a case for discussion. But I can say that over the years I have participated I have acquired knowledge that helps me solve cases that come in today. (Hospital dentist 2)

> **Quotation 12:** Even if I don't have a case you benefit from hearing about others' cases, experiences, patients. Of course. That's what's fun, looking at the cases that are added for every meeting. Then I try to think about what I would have done. (Hospital dentist 6)

> **Quotation 13:** The first time we did this I said that if you go to a regular course, or a convention or something then half of what is said during those two days, I already know, and 25-30 percent I have some idea of... But then you get those things, 20 percent, that I had no clue about, 'this was exciting, glad someone told me'. But during the one hour of SOMNet, you can get lots of interesting information. There are

really good colleagues out there that have rich clinical experience. [...] So I think that even if you don't say anything... you can take part in the debate, and understand that 'this you can do, this you can't'. (Hospital dentist 4; research background)

Quotation 14: We often have rare diseases, so everybody doesn't have experience with everything. I still see first cases, after 40 years. And that means it is a big advantage with SOMNet that here we have 30-40 experienced people where there is always somebody who has seen something similar. We have had cases which nobody has seen before. I know that [name of clinician] has one now and [name of another clinician] does... So sure, all of a sudden a similar one shows up in my everyday work, and then I will remember it. (Hospital dentist 5; research background)

Effects on practice touched upon by interviewees were having clearer conception of treatment models, which impacts how medications are administered. Meanwhile, the pathologists, with no patients of their own, bring up the social aspects SOMNet provides, in addition to a more complete clinical picture of patients than they usually get. In addition to the advantages for the individual in joining the discussions, the collective knowledge increases when the community is able to systematically consider how to handle complex patients.

Interviewees were asked about concrete examples of when they benefited from diagnosis and treatment discussions at meetings, both from their own cases and from the discussions of others'. Examples of replies included one respondent describing how a special kind of plastic guard described at the meeting had been constructed and used with good results. Another interviewee reported that a dentist at a non-participating clinic had heard about the plastic guard technique from a participant, and had later applied it, which demonstrates that knowledge shared in SOMNet can spread outside of those directly taking part. A third respondent vividly retold the lengthy discussion generated by a difficult case where the symptoms could be construed to have three different causes. Even though the more experienced members to a great extent participate to share their knowledge, they still get useful advice, as illustrated by Quotation 15.

Quotation 15: I had a case, not long ago. We had a so called lichenoid reaction that [names of two participants] had published on. [...] What they concluded was that you could use Chlorhexidine and so on. That helped me directly with a case that I had. So, sure, even if you are, like I like to think I am, experienced, you can surely get good treatment suggestions. (Hospital dentist 5; research background)

The help sought for a case, and the benefit for the clinician, can also be to discuss different treatment alternatives or paths of inquiry. The submitter wants to find out how the others handle the advantages and drawbacks of an action. Such discussions also fill a need for corroboration, as elaborated on in Quotation 16.

Quotation 16: Sometimes you just need corroboration. We discuss how long we should follow different kinds of patients. There are a lot of difficult diagnoses, bordering on cancer and so on. You can get a bit worried about making a mistake. We don't have that many of these patients. If I decide to see this patient every six months, is that too often or too seldom? So then it can make a big difference to bring up such a case and hear 'that is okay, what you have done is right' or 'I would also have done like that'. (Hospital dentist 3)

Finally, SOMNet can also be seen as a way of making the experts more approachable and known to non-experts, as indicated in Quotation 17, by one of the more experienced members.

> **Quotation 17:** After meetings it isn't uncommon that I have consultations with colleagues, especially regarding treatments and such. That is, I have contact via e-mail or telephone within just a few minutes. (Hospital dentist 5; research background)

4.3.2 Impact on Knowledge Seeking and Use of External Sources

While participating in SOMNet is one way of attaining external input on cases, research literature is an important source of external evidence. Increasing the use of such sources in clinical practice could be achieved through SOMNet: For the cases submitted for discussion, the chairperson searches for relevant research findings, which helps bring a sense of closure to the discussions, as emphasized in Quotation 18.

> **Quotation 18:** It is very interesting to sit and listen, if somebody is knowledgeable and has prepared: 'I looked at this and that article and read this about that' and I feel 'God, that is good' and then we get the answer. (Hospital dentist 1)

Further, participants from research institutions use SOMNet to make practitioners aware of new research findings. As described in Quotation 19, this means that members who do not use research findings as part of their everyday work still get exposed to key developments.

> **Quotation 19:** Before we thought that dysplasias were important, that it was important to judge the degree of dysplasia from a malignity standpoint. Now there is data that shows that this does not have significance at all. And that data is only a few months old. And that isn't very easy to find on the Web if you're not out there as often as we are. (Hospital dentist 5; research background)

To explore SOMNet's effect on the clinicians' use of external evidence in their everyday work, the interviewees were asked if participating in SOMNet has changed the way they seek knowledge. This question was not always quite understood by all interviewees, perhaps because some of them do not actively think about this issue. In general, it may be difficult to know if your behavior has changed and to clearly be able to ascertain the reason for this change. Only one person explicitly responded that they were more active. The other responses were either along the lines of already using literature on a regular basis, or that they saw themselves as primarily clinicians, as illustrated by Quotations 20 and 21.

> **Quotation 20:** I am not [more active]. I am still primarily a clinician, and not so theoretical. I go for that which is recommended to me, but I don't really search in my everyday work. (Hospital dentist 7)

> **Quotation 21:** I try to read as much as I can. You see that pile there, with articles I haven't had time to read? [...] But we are more of clinicians, we aren't that research oriented. So most of our time is spent in the clinic. But sure, it is important to stay updated. (Hospital dentist 6)

That is, it seems that searching for and reading research literature is something that the clinicians see as a natural part of the researchers' work, but not their own.

4.3.3 Outreach Activity

SOMNet also serves as a means for outreach regarding oral medicine, even outside of the community's members. For example, members at teaching institutions have included participation in SOMNet as a part of the curricula of some of their courses. One member works at a regional competency center for public dental clinics where they try to raise interest and awareness for oral medicine issues by providing a standing invitation to clinicians to participate in SOMNet's meetings via the local teleconference meeting room.

4.4 Challenges

Four challenges for SOMNet's collaboration and knowledge sharing are accommodating varying levels of expertise (Section 4.4.1), encouraging participation (Section 4.4.2), the clinician's perceived lack of time (Section 4.4.3), and access to journal articles (Section 4.4.4). These issues to some extent limit the output of SOMNet. At the same time, however, the issues can be viewed as pervasive in collaboration and learning in healthcare organizations as a whole. In this light, SOMNet can be viewed as a means of relieving these tensions.

4.4.1 Accommodating Varying Levels of Expertise

As indicated in Section 4.3.1, the interviewees identified several benefits to participating in SOMNet, most pertaining directly or indirectly to knowledge sharing and learning. Further, the case discussions of SOMNet provide opportunities for learning for its members, even though they may have differing levels of expertise. The role of the member probably affects the kind of learning. For a case submitter, there are direct diagnosis and treatment suggestions. While the "difficulty" of the case may vary with the submitters expertise, the outcome is similar. For members listening to the discussion of others, there is an opportunity to assimilate different strategies and viewpoints in a social setting. Less experienced members are exposed to the reasoning and knowledge of the experts, and through community of practice processes of legitimate peripheral participation they may progress toward becoming more experienced members. The expert members obtain access to new findings, maintain their enthusiasm, and get the opportunity to share their knowledge. Further, members chairing meetings have a reason to further their knowledge through literature searches, something which many indicated a wish for but seldom are able to take the time to do.

However, the different levels of expertise affect the extent to which participants learn from discussions, as illustrated by Quotation 22.

> **Quotation 22:** You have to have a certain level [of knowledge] to learn from it [SOMNet] otherwise it like goes over your head and you can't follow. Then maybe it is rather to get help with a case. (Hospital dentist 2)

If in fact those less experienced in oral medicine learn mostly from help on cases they submit, it is problematic that case submission are primarily made by experts. As will be presented in Section 7.5, both before and after the introduction of the SOMWeb system, there are a few specialist clinics that submit most of the cases. The most active members are aware of this, as indicated by Quotation 23.

> **Quotation 23:** It is a few people who supply... and that is a pity because if you look at who submits cases it may be those that need the least help. [...] I think what scares people is that the top names submit a lot of cool cases and there are a lot of treatments and lengthy discussions about these at the meetings. And then there is somebody at a small clinic who doesn't know much about oral medicine and who has found something strange and doesn't know what to do. I think they may be a bit inhibited then. The thing is that you could submit something that for many participants is a very banal change... but for this person it isn't... and to then dare to present it and say 'what could this be, I've never seen it before'. And then there are twenty other people listening who have seen such a change during the past week. But that is how it has to be. (Hospital dentist 1)

This quote is in line with others who have speculated that one issue concerns revealing gaps in one's knowledge. Some replies in the questionnaire, to the question if they had ever considered adding a case but had not, indicated their worry that it was not "advanced enough". When this was brought up in the interviews with the more active participants, several said that meeting discussions about what appeared to be straightforward cases to them often actually turned into very interesting discussions.

At the same time, the interviewees acknowledged that the fact that only a few clinics had many cases is due to them seeing more patients with specifically oral medicine conditions, as seen in Quotation 24.

> **Quotation 24:** But sometimes I feel that, we are a few clinics that see a lot of patients, and then we have a certain responsibility to submit cases. But the risk is, and this I want to avoid... I want everybody to add cases! I was so happy, there was somebody from a public clinic in Stockholm who [added a case]. 'What was this?' It was a really nice discussion, it was really difficult. So we sat there and scratched our heads. [...] But you have to dare to submit. Because I think that is the threshold you have to cross. That it is really good if you add a banal change, and discuss it. To raise your own level of knowledge, to hear what your colleagues think, and not be afraid to be wrong. But how to reach that, I don't know. (Hospital dentist 4; research background)

4.4.2 Encouraging Participation

There is an awareness among senior members of SOMNet of a skewed distribution of submitters and that many participants do not speak at meetings. Several interviewees discussed how to increase the participation of smaller clinics can, both with regard to adding cases and participating verbally in the meetings. Quotations 25 and 26 also bring up the role of the individual in this, in daring to speak even when others are more experienced. All of the interviewees find that encouraging participation from a wide variety of clinics and clinicians is important. One interviewee reflected after the meeting that that it is four or five people who discuss most at meetings, and suggested that all meeting participants could be encourage to talk by explicitly asking them what they think

> **Quotation 25:** You have to be allowed to be stupid. I am several times a day. When you don't understand. But you have to dedramatize this. (Hospital dentist 4; research background)

> **Quotation 26:** Everybody can add a case. You just have to have the courage... It is always a bit nervous in the beginning, when you speak, that you don't know enough. A lot of them are really good. (Hospital dentist 6)

When one of the more experienced members was asked what cases should be discussed, the reply was that he wanted SOMNet to discuss routine cases in addition to "specials". I asked how you got more routine cases, and the reply was that you just add them. I suggested that this was maybe easier for the experts to do, that others might not think it was interesting enough. However, as indicated by Quotation 27, this member found all cases could lead to interesting discussions.

> **Quotation 27:** No, that is as it is, but according to me it is a misunderstanding. To me there isn't one case that isn't interesting enough. [...] I think that you can take the most typical case and you can always discuss it. (Hospital dentist 5; research background)

In relation to this, it was suggested by several of the interviewees that one way of alleviating concerns regarding junior members adding routine cases is for more senior members to submit such cases also. The need for more routine cases was also raised by an interviewee who mainly uses SOMNet as an educational tool, to "open doors" to awareness of changes in the oral mucosa.

4.4.3 Shortage of Time

The interviewees often raised the issue of lack of time, due to a heavy load of patients or teaching. One interviewee mentioned the differences he felt existed between his work place, where oral medicine is a only small part of the overall activities and there is no research connection, and research institutions which specialize in oral medicine. He found that it was not possible to set aside office hours to search for and read relevant literature. Fortunately, there was no problem setting aside an hour for the meeting.

4.4.4 Access to Journal Articles

While interviewees at research institutions and some hospitals have access to online articles, smaller hospitals and general practitioners often lack such access. This difference was demonstrated when one of the senior interviewees mentioned that he had two "fantastic" librarians who often impressed him in what they could find. Knowledge about the availability of such resources, if they are available, should not be underestimated, especially when considering that for several interviewees access to journals was problematic. One respondent worked in a place that did not have subscriptions to the desired journals. Another thought that they could get access, but had not gotten around to doing so. This correlates with interviewees who mainly see patients stating that they do not read literature as much as they would like because, again, time is the main barrier. Two interviewees stated that they read articles mainly outside of work hours.

4.5 SOMNet as a Community of Practice

Communities of practice are groups of people who interact regularly in order to improve their practice of a common passion or concern, as presented in Section 2.2. In this section I discuss how SOMNet can be characterized as a community of practice and how principles for cultivating these are seen at work.

In Section 2.2, ways of characterizing a community of practice, as presented by Wenger et al. [159], are listed. SOMNet is a long-lived, distributed, homogeneous, and intentional community of practice. Further, on the spectra between unrecognized and institutionalize, it is legitimized by the work-place organizations, but not institutionalized. SOMNet has a clear domain, oral medicine. The community is formed mainly by clinicians, as well as some researchers, who have a special interest in oral medicine. The practice is centered on distributed case consultations, focused on generating ideas for diagnosis and treatment, and with an intent to include more external evidence as the basis of decisions. The products of SOMNet, its shared repertoire, includes tacit as well as explicit elements, where the former includes the diagnosis methods and treatment models shared by participants and the latter include the case descriptions that serve as a basis for discussion.

The common purpose in participating is better patient care, achieved through access to external expertise and the continuing education that is provided through the collaboration. However, depending on the level of expertise of the participant, there may be more focus on teaching or on learning. The relationships formed through SOMNet's extended collaboration can be seen as a way of building trust and identity in the profession. There is also a narrative aspect to this process, where stories of successful or unsuccessful patient encounters are told. SOMNet can be seen as a reasonably formal community of practice, in that it is a named entity in which participants may have explicit membership. Since its inception SOMNet, has evolved into having a clear set of work practices and including more members. This has also led to an evolution in technological support, as discussed below.

Also in Section 2.2.1, several principles for cultivating communities of practice are presented, as identified by Wenger et al. [159]. These principles can also be read as characteristics present in a successful community of practice. I now discuss several of these, prominent in SOMNet's collaboration: an evolution of support, different levels of participation, focusing on value, and community rhythm.

The need to design for evolution in supporting communities of practice emerges from the fact that they often begin as preexisting personal networks, and that the level of designed support will grow and change as the community grows and changes. In the matter of SOMNet, this is very much the case: In the beginning, a handful of participants e-mailed case presentations to one another, which were then put into PowerPoint presentations. The number of participants grew, and case presentations were put in a Web-repository, and eventually the need for SOMWeb arose. That is, SOMNet began with a simple technical solution, which has successively become more advanced and adjusted to the work processes of its members. One can also argue that it was necessary for the users to get used to the system functionality before they identified the need for new features, which is in line with results in Moehr et al. [97].

Encouraging different levels of participation reflects the idea that while it is appealing that all members participate equally this is not a realistic expectation since different members participate for different reasons. It is also part of the important community of practice concept of legitimate peripheral participation, that novices become familiar with activities, terminology, and policies of a community by taking part peripherally. Wenger et al. [159] find that the participants of a community of practice can often be divided into three groups: core, active, and peripheral. The core group consists of members that take on leadership roles and set the agenda for the group. The active group's members are regular participants in the community's events and sometimes participate in discussions, but without the intensity or regularity of the core group. A large portion of the participants often belongs to the group of peripheral users, who mostly observe interactions between core and active members. Reasons for not participating may be that they do not believe their comments are valuable enough or that they do not have enough time. Wenger et al. [159] hold that these peripheral members are a very important part of the community of practice, and that they are not as passive as they might seem. They take in what is said, and may bring it up in private conversations. The different levels of member participation are clearly discernable in SOMNet. The core members chair meetings, contribute most cases, and are very involved in the discussions. The active members participate in most meetings, sometimes contribute comments and provide some cases. Finally, there is a large group of peripheral members, who do not submitted cases and rarely or never make comments.

The centrality of cases to the practice of SOMNet is part in ensuring a focus on value. As seen in Section 4.3.1, SOMNet's members value the community for several reasons, such as continued learning, help on cases, and the opportunity to reach out with new findings. However, as Section 4.4.1 indicates, the value of participation varies with the member's position.

A community of practice has a rhythm, consisting of regular meetings, informal conversations, Web site activity, and so on. It can be too fast, overwhelming participants, or too slow, giving the air of inactivity. In the case of SOMNet, the most prevalent rhythm is the monthly teleconferences. These affect when cases are entered and when members log in to the system. A system where members submit cases with a request for advice and other members could reply at any time would probably not work in this situation. This conclusion is supported by the observations made in Moehr et al. [97].

In discussions of communities of practice, other terms are sometimes used, to distinguish between different but similar forms of collaboration, as discussed in the background chapter. One of these is networks of practice, where the connections between members are construed to be less close than in a community. One way of looking at it is that early on SOMNet could, to a larger extent, be characterized as a community of practice, but as the number of members grows, it becomes more of a network of practice.

4.6 Discussion

What distinguishes SOMNet from many other telemedicine initiatives (such as [90] and [13]) is that SOMNet's collaboration includes many locations and many peripheral participants. In other telemedicine consultations, the participants are usually one specialist (or hospital) and one general practitioner (or a primary care unit). In SOMNet, however, the submitter, gets access to a panel of experts and peers. Further, there is a greater possibility for learning as clinicians other than the submitter and experts take part in the discussion.

The structure of SOMNet's meetings bears similarity to the multidisciplinary medical team meetings described by Kane and Luz [78] (see Section 2.1.1) in that members meet regularly to review patient cases, establish a diagnosis, and decide on the most appropriate treatment plan for the patient. It should be noted that SOMNet's participants do not fit the multidisciplinary profile, though a pathologist is present. As I have shown, a SOMNet meeting contains the same set of processes, though the recording of outcomes was not done before SOMWeb and is still problematic after its introduction, as discussed in Section 7.7.4. It would be interesting to see how the MDTM structure could aid in the design of future versions of SOMWeb, adding possibilities for cueing chairpersons and participants in the discussions and securing that decisions are being made, supported by relevant external evidence.

The lack of time suggested by the interviewees stems from clinicians being busy and task-oriented people. What can be done to get members to prioritize meetings and be up to date with new articles and treatments, which in the end will benefit their patients? It is partly habit, since it is probably easier to participate in meetings at a clinic where several people regularly join. Another is priorities, and here the organization can probably play a role in encouraging the reading of articles, participating in SOMNet's meetings, and using sources of evidence, such as SOMWeb. Since there is a shortage of time, the ease of use of tools is also important.

The interviews showed that many members did not have time to read articles or had problems in accessing external resources. The time issue is in line with the findings of Dawes and Sampson [30] (see Section 2.1.3). This can be coupled to the conclusion of Gosling et al. [50] (also Section 2.1.3) that social and cultural factors affect variations in use of external evidence. The view of several interviewees that they see themselves primarily as clinicians, as expressed in Section 4.3.2, is an indication that these factors play a large role in inhibiting the use of external sources by oral medicine practitioners. While this points to SOMNet being able to play an important role in increasing the use of external evidence, at the same time, SOMNet is only a small part of the clinicians professional life, and thus the culture of the work place probably plays a larger role.

Related to the knowledge flow barriers in healthcare organizations identified by Lin et al. [87] (see Section 2.1.1), I suggest that clinical communities of practice such as SOMNet can play a vital role in overcoming barriers related to knowledge flow context, by connecting the knowledge sources and receivers. Further, SOMNet, as well as the SOMWeb system, act as a mechanism through which this knowledge transfer can happen. Within SOMNet one can still discern barriers both related to the source and the receiver. However, the barriers related to the knowledge source are not perceived to be those identified by Lin et al., retaining power and advantage, but rather that the rare cases and level of discussion of the experts are not relevant to the knowledge sources. These less experienced participants of SOMNet may have difficulty following the discussion, which could be due to what Lin et al. term lack of absorptive capacity. Further, lack of activity could be coupled with meeting participation and case submission. A submitting clinician probably learns more, as they are involved in the case. While the barriers to knowledge flow identified by Lin et al. can be seen in SOMNet, they also present what I see as a problematic view on knowledge sharing by dividing participants into sources and receivers. In the collaborative practice of SOMNet there may be individuals that more often share knowledge and experience, but learning seems to take place for all participants.

4.7 Summary and Conclusions

This chapter portrays how SOMNet collaborates and characterizes it as a distributed community of practice. The regular teleconference meetings focused on case discussions provide a rhythm for the community. Further, the centrality of cases means that there is an immediate benefit for the submitting clinician while the community as a whole is provided with an authentic context for continued learning. Thus, it can be surmised that support for SOMNet should focus on cases and meetings. SOMNet has also been found to provide opportunities for help and learning for varied levels of expertise, though the benefits varies depending on oral medicine knowledge and involvement in the collaboration. However, there is still a challenge in accommodating varying levels of expertise and encouraging those less experience to participate, both by submitting cases and speaking at meetings. Another identified challenge is the clinician's shortage of time, which may prevent case submission, shorten meeting preparations, and hinder the reading of research literature. In developing support for such collaborations, case entry and meeting preparation should thus be eased. Further, to increase the exposure of clinician's to research literature, support systems should aid the dissemination of relevant findings by those members with research interests.

Conclusions related to the collaboration of SOMNet are elaborated in Section 10.1.1. The next chapter changes focus, as we turn to the use of ontologies to formalize oral medicine knowledge and community resources.

Chapter 5

Ontologies for Oral Medicine and Community Resources

This chapter presents results related to Objective 2, presented in the introductory chapter, and involves the use of Semantic Web technologies to describe oral medicine knowledge and community resources. An overview of the SOMWeb ontologies is given in Figure 5.1. This includes the templates that provide the structure for the individual examination records, as well as the value list, or the terminology, that provide the values used in the records. The case browser ontology defines classes used to classify the individual examinations by, for example, diagnosis. The structure of the templates and the values of the terminology are used in defining the case browser classes. Finally, the community resources ontology defines classes pertaining to the central functions of SOMNet.

The chapter begins with a presentation of the SOMWeb oral medicine ontologies, which cover examination templates and value lists (Section 5.1). Included in this presentation is the knowledge representation of MedView, which provides the basis for the SOMWeb ontologies, the structure of the ontologies and elaborations of the design decisions made in their development. The value lists produced by this initial iteration of ontology development had very little structure, and their extension, to be used in the SOMWeb system's case browser, is subsequently presented (Section 5.2), along with the case browser classes. SOMWeb's ontology for community resources ends the presentation of ontologies (Section 5.3). This is followed by providing data pertaining to the evaluation of the ontologies (Section 5.4) and a discussion of the chapter's results (Section 5.5).

OWL examples are provided in the OWL Abstract Syntax [118] and RDF examples in the N3 syntax [9]. In the running text, OWL constructs and named entities in the SOMWeb ontologies are monospaced type.

5.1 Oral Medicine Ontologies

This section begins with a description of MedView and its knowledge representation (Section 5.1.1). Based on the MedView experience, requirements for an oral medicine ontology are set forth (Section 5.1.2). The development process for the oral medicine ontologies is

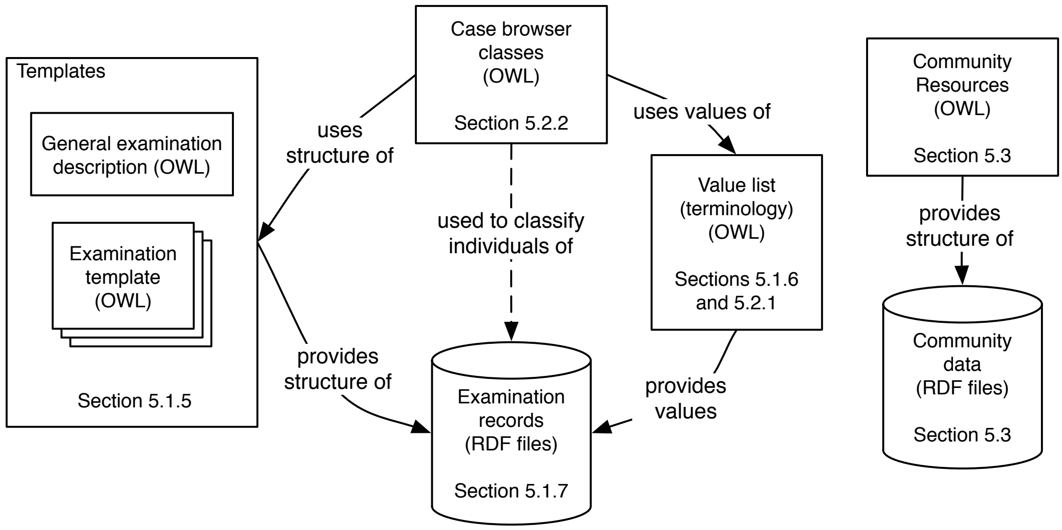


Figure 5.1: Overview of the SOMWeb ontologies for templates, terminology, case browser, and community resources, as well as the relations between them.

then presented (Section 5.1.3), followed by an overview of the relation between the structures of MedView and SOMWeb (Section 5.1.4). I subsequently describe the structure and the design decisions made for the examination template ontology (Section 5.1.5) and the value list ontology (Section 5.1.6). The representation of individual examinations (Section 5.1.7) and value aggregates (Section 5.1.8) follows. Finally, the results are considered in relation to the requirements set forth (Section 5.1.9).

I refer to the original approach as the MedView representation, and the new OWL- and RDF-based representation as the SOMWeb representation. In the running text, named entities in the MedView representation are in italics.

5.1.1 MedView and its Knowledge Representation

Since its inception in 1995, the main goal of the MedView project has been to support evidence-based oral medicine. This includes developing models, methods, and tools to aid clinicians in their daily work and research. The central research question of the project is how computer technology can be used to aid clinicians in systematically learning from the gathered clinical data. As described in Falkman and Torgersson [40], the approach of MedView is to combine formal knowledge representation of clinical concepts with the design of flexible and user-friendly tools that are quickly brought into everyday practice. The knowledge representation is a declarative model based on the assumption that definitions are central tools in all attempts to provide a precise and formalized representation of knowledge [60]. The clinical knowledge used in MedView is divided into examination templates, value lists, and aggregates (also referred to as value classes).

Within MedView a suite of tools have been developed to support the activities involved in this learning. In the following list of activities, the name of the supporting software is given in parenthesis. The clinicians specify what data to gather in a clinical examination by defining an examination template along with lists of values that can be used in examination record (mForm). These templates are then used to gather data in, for example, an application for creating and viewing examination records (MedRecords) and in an online tool for collecting data (mForm). The clinicians can then visualize and analyze the collected patient data (mVisualizer). Natural language summaries of examination records can also be generated (MedSummary). The knowledge base built in the project currently contains data from over 25,000 examination records.

The main clinical contact for the project is the clinic of Oral Medicine, faculty of Odontology, University of Gothenburg, where the MedView tools are used in addition to the dental patient record system. Clinicians use MedView because the other system does not fulfill the needs of the oral medicine practitioners and does not support learning from clinical data. Given the template based approach of MedView, it can be used in other domains as well. For example, it is used to collect data by a research project investigating what causes dental fear in children. However, the system does not have widespread use in Sweden.

Below is an explanation of how the definitional approach has been realized in MedView, followed by a description of how templates and value lists are stored. A description of the use of the tree file format to store individual examinations is followed by a presentation of value aggregates, created and used when analyzing data from the examination records.

A Definitional Approach

Clinical data in MedView has thus far been seen as definitions of clinical terms, where a definition is regarded as a collection of equations, and the left-hand sides (atoms) are defined in terms of the right-hand sides (conditions). In the case of MedView examination templates, the atomic data unit is an examination. Each examination is a set of terms, and a term is defined either as a set of other terms or as a set of values. In this way, abstract clinical concepts, such as examination, diagnosis, and patient data, are given using definitions of collections of specific clinical terms. An example of this is given in Figure 5.2, where the *Examination* term is defined by the terms *Patient-data* and *Anamnesis* and *Diagnosis*. The terms *Patient-data* and *Anamnesis* are then defined by sets of other terms. Among the terms used in defining *Patient-data* is the term *Age*, which in this examination is defined by the value 37.

Progressing from an examination template to an individual patient record, the definitions that the template provided are elaborated on by filling in values for terms. For example, the terms status, direct, mucos and palpation are all part of the general template that defines a particular clinical examination protocol. A concrete instance of an examination template—an examination record—is given by defining terms like *Mucos-site* and *Mucos-color* in terms of observed values, for example, *{l12}* and *{white, brown}* respectively.

The knowledge base also contains knowledge structures describing general domain knowledge. Values for the terms defined in templates are taken from formalized lists of valid values. These value lists are given as value definitions, which are stored in the knowledge base along with the examination records and templates.

Term		Definition
Examination	=	Patient-data
Examination	=	Anamnesis
Examination	=	Diagnosis
Patient-data	=	Patient-code
Patient-data	=	Age
Patient-data	=	Born
Patient-data	=	...
Anamnesis	=	Medication
Anamnesis	=	Allergies
Anamnesis	=	...
Patient-code	=	1234567890
Age	=	37
Born	=	Sweden
⋮		⋮

Figure 5.2: A sample examination in MedView, using the definitional approach.

Storing Templates and Values

The structure of the examination template is stored as XML. The general structure of the template is:

```
EXAMINATION
             FORMINFO
                        AUTHOR
                        TITLE
                        ...
             CATEGORY
                        INPUT
                        INPUT
                        ...
             CATEGORY
                        INPUT
                        ....
             ...
```

An example XML template is given in Appendix C.1, on page 185. The example template is for a meeting consultation, and records data from teleconference meetings. In terms of XML, the root of the template is an examination element, which contains several category elements. Each of these category elements contains a name, a description, and several inputs. In addition, each input has several attributes, such as type and whether it is required, its name, description, and an instruction to be displayed to the clinician entering patient data. An input in the template could be:

```
<input type="multi" free="true">
```

```
      <name>Treat-sugg</name>
      <description>Suggested action/treatment</description>
 </input>
```

Type here indicates how the values can be chosen for the input. These types include:

- single value – only one value can be chosen (for example, country of birth)
- multiple values – more than one value can be chosen (such as medications)
- text – free text (for example, a note field)
- incomplete value– a composite answer, where the value list specifies possible units, for example for smoking habits. For these, an amount is entered and units are chosen from the list.
- VAS – a number between zero and ten. Visual Analog Scale (VAS) is a method to measure pain intensity, where the patient is shown a 10 cm line, with "no pain" at one end and "worst possible pain" at the other, and is asked to put a mark on the line signifying their experience.[1]

The value lists of MedView hold to the terminology used in filling in individual examinations. These are not based on an external classification system, such as SNOMED, though ICD codes are included in some diagnostic values. Values are described using two files; *termDefinitions* gives the possible types of values for each term, while *termValues* gives the actual possible values (for example, a list of countries for the term Born). An entry in the termDefinitions file corresponding to the input example above could be:

```
$Born single
```

The term's entry in termValues file could be:

```
$Born
Australia
Bolivia
Bosnia
Bulgaria
Chile
Denmark
...
```

Tree Files

One way of representing definitions is as tree files. This is how individual examinations, created as a result of a patient encounter, are stored in MedView applications. The individual

[1]The VAS input type was not originally in the MedView model. The main purpose for distinguishing it from a single value is that the input interface generated is different: a line scale from zero to ten.

examination is created by filling in values in the definition given by the template. This can be described as a tree, where the defining concepts and values are seen as children, so that for the example in Figure 5.2, the root node *Examination* has as its children *Patient-data*, *Anamnesis*, and *Diagnosis*. The specific values entered at a patient encounter become leaf nodes.

Value Aggregates

As the knowledge base grows, it becomes increasingly important to be able to group related values into classes in a hierarchical manner. For example, diseases such as Herpes labialis, Herpetic gingivostomatis, and Shingles can be classified into viral diseases. The ability to categorize values into different classes (or groups) has proven very useful in data analysis because they reduce the complexity of the data set, facilitating the detection of interesting patterns in the data. Value classes can also be useful for concept formation, such as differentiating between two different forms of a diagnosis. Value classes are constructed using class definitions, which are stored in the knowledge base for future use. As an example, the following class definition S groups smoking habits into three classes:

$$S \begin{cases} \text{1 cigarette without filter/day} & = < \text{10 cigarettes/day} \\ \text{5 cigarettes without filter/day} & = < \text{10 cigarettes/day} \\ \text{10–15 filter cigarettes/day} & = > \text{10 cigarettes/day} \\ \text{20 filter cigarettes/day} & = > \text{10 cigarettes/day} \\ \text{Occasionally} & = \text{Non-smoking} \\ \text{No} & = \text{Non-smoking} \end{cases}$$

5.1.2 Requirements for an Ontology of Oral Medicine

In deciding to revise the knowledge model of MedView, requirements for an ontology of oral medicine were collected. These are based on the ten years of experience of developers and domain experts of the MedView project:

- The utilizing external sources of knowledge, such as taxonomies of diseases and medications as well as general medical vocabularies, should be made possible. Faster sharing of information is a prerequisite for effective evidence-based medicine [95].
- The relation between the conceptual models of fundamental clinical concepts, for example, examination templates, lists of approved values for terms and groups of related terms, and their corresponding concrete entities, must be formally examined.
- Relations and interactions between different parts of the examination template ontology should be captured, for example, that a certain answer to a specific question in an examination template triggers another question.[2] By limiting the amount of questions to be answered, a potential barrier to clinicians entering the relevant information is diminished.

[2] This requirement is fulfilled in mForm, but it still needs to be fulfilled in the new context.

- A strong typing of elements is needed. It must be enforceable that a given term only has values that are, for example, numeric or a certain enumerated domain.
- It must be possible to capture different kinds of meta-data, for example, identifying the creator of a specific examination template and the purpose (scientific or clinical) of the introduction of a specific examination template.
- There needs to be a way to differentiate between different 'views' of the underlying data, for example, a patient, time or diagnosis oriented view.
- The localization of data must be addressed. How can different versions templates, terms, and values be provided based on language? This is important since the transparent transition between language borders is a presumption of evidence-based medicine and knowledge sharing at a global level.
- An increasingly larger portion of medical data has its origin in images. The enormous amount of information obtainable from images is, however, difficult to grasp for the unaided human mind [25]. Thus, information contained in images, for example, photos taken during the examination of patients, must be captured and represented.

Following the presentation of the oral medicine ontologies, these requirements are discussed again in Section 5.1.9.

5.1.3 Development Process

As introduced in Section 3.2, I employed an adaptation of ISO/IEC 15288 [71] system life cycle processes for the development of the SOMWeb ontologies. In the following I describe the different stages of the development of the SOMWeb oral medicine ontologies. Each stage includes one or more processes, and for each of these I give a general description of the stage as well as what was done in relation to the SOMWeb ontologies. While some design decisions are described, more details on these are presented in Section 5.1.5 and Section 5.1.6.

First, a short note on the considerations between a manual and an automatic approach. Initially, the MedView knowledge representation and its content were used as inspiration for, more or less, constructing the examination template by hand using Protégé. However, given the number of terms and term values in the most commonly used template and term-value file, a conversion program was written. Java classes in MedView are used to read templates, term values, and term definitions, and from the internal Java representation of these, the Jena API is used to create OWL constructs based on the structure and design decisions described below.

1. ***Concept stage***

   Stakeholder Requirements Definition Process: *Identify stakeholders, such as domain experts, ontology developers, maintainers, and users. Capture motivating scenarios. Use these to identify the purpose and scope of the ontology and to enumerate important terms.*

Stakeholders identified were clinicians and IT personnel at the clinic of oral medicine (domain experts, users, and maintainers), and persons from computer science departments (ontology developers and maintainers). A motivating scenario was using the ontology as a schema to represent examinations in oral medicine in RDF for the SOMWeb online community. The purpose of the ontology is to represent concepts relevant to examinations in oral medicine, and the scope of the ontology is to be able to represent at least that which can be represented with MedView's previous knowledge representation. Important terms are foremost those already enumerated by the previous representation; different parts of examinations and properties associated with these, as well as value lists for the properties.

2. ***Feasibility stage***

   Acquisition Process: *Identify possible ontologies for reuse, using the list of important terms as a starting point; evaluate the identified ontologies according to criteria defined in the Stakeholder Requirements Definition Process. Decide whether any of the external ontologies fulfill the particular need, and to what extent internal adaptations is needed. Also, consider if there are sources suitable for semi-automatic ontology construction, which might be used to bootstrap the ontology.*
   Unfortunately, there were few ontologies which could accommodate the domain-specific needs and none available in Swedish. Since the use of the W3C standards was decided on early in this work, I searched for medical and dental ontologies which could be considered relevant and which were represented in OWL. No relevant domain-specific OWL ontologies were found, although some had fragments translated into OWL. The ontology identified for reuse, Dublin Core,[3] represents metadata. Automatic or semi-automatic ontology construction was not considered outside the use of MedView's knowledge content.

3. ***Development stage*** – In this stage it is decided what classes, properties, constraints, and instances should be included in our ontology. This is done informally, that is, not in a representation language.

   Acquisition Process: *For the ontologies selected for reuse, carry out a more detailed analysis of what concepts are to be reused and what concepts need to be represented in the internal ontology.*
   It was decided that translating the larger medical ontologies, not in OWL, into OWL, was beyond the scope of this ontology development project. The ontology identified for reuse, Dublin Core, is small and already in OWL, thus no adaptions were made.

   Architectural Design Process: *Both manual and semi-automatic ontology learning should be considered for defining the architecture of the ontology. Define the classes and the class hierarchy. Possible approaches for developing a class hierarchy are top-down, bottom-up, or a combination of the two. Define the properties of the classes, which describe the internal structure of concepts. Define constraints, which describe or limit the set of possible values of properties. The constraints can deal*

[3] http://dublincore.org/

with cardinality, value type, as well as domain and range. Identify instances of the classes. Defining an individual instance of a class requires choosing a class, creating an individual instance of that class, and assigning properties. Consider using ontology design patterns [150] to help solve design problems for the domain classes and properties that make up the ontology.
The list compiled from the Stakeholder Requirement Process in the Concept stage was used to decide what should be represented as classes, properties, and instances. It was decided that the different parts of the examination, such as *general anamnesis*[4] and *diagnosis*, should be represented as classes. Associated with each of these are properties, such as *hasAllergy* and *hasTentativeDiagnosis*. These properties can take values from instances of corresponding value classes, such as *Allergy* and *Diagnosis*, respectively.

Implementation Process: *Decide how to encode the classes, properties, and constraints identified in the Architectural Design Process.*
It was decided that OWL DL should be used, due to being an W3C recommendations, which hopefully will make it easier to integrate SOMWeb's collected data with data from other sources, and give access to a greater range of tools developed in accordance with the recommendations. The sublanguage of OWL DL was chosen as there was a potential need for cardinality constraints more advanced than those offered by OWL Lite, and OWL Full was not an option since computational guarantees are required.

4. ***Production stage*** – This stage entails encoding the classes, properties, constraints, and instances identified in the Development stage using an ontology representation language. The result is more formal than that of the Development stage, but the degree of detail and formality will still vary depending on the purpose of the ontology.

   Implementation Process: *Encode the classes, properties, and constraints, identified in the Development stage, in the representational form decided upon. In this process, identified best practices should be used. For OWL, see for example the W3C Semantic Web Best Practices and Deployment Working Group [151].*
   The identified classes, properties, and instances were encoded in OWL using Protégé and Jena. A prototype was made more or less manually using Protégé. The final ontology was created programmatically using Jena by reading the examination templates in the old MedView format and creating OWL classes, properties, and instances according to the earlier design decisions.

   Maintenance Process: *Establish criteria for further changes to the ontology and adapt an ontology versioning policy.*
   The importance of end-user development means that it should be possible for the users to add instances to the ontology, but metadata should be added to show who has created a concept and ideally for what purpose. In SOMWeb, the purpose for adding an instance is because it is needed in an examination record. A versioning policy has not yet been established.

[4]The general anamnesis is the medical history of the patient.

5. ***Utilization stage***

   Operation Process: *Use the ontology as part of an ontology-supported application.* The oral medicine ontologies are intended for use in the SOMWeb system.

   Supply Process: *Make the ontology available and known to others by, for example, adding it to ontology repositories.*
   The ontologies are available at: `http://www.somweb.se/ontologies/`.
   However, the instance data from examinations cannot be publicly available. The examination instances entered in the online community are available online through member login, but when the clinicians view the cases, they will see natural language representations rather than the RDF.

5.1.4 Comparison between Structures of MedView and SOMWeb

As indicated above, the SOMWeb ontologies are based on the MedView representation, presented in Section 5.1.1. Figure 5.3 shows how the structures of the SOMWeb representation can be mapped to the ones of MedView. The most general aspects of examination templates are described in a DTD in the MedView version, and in OWL in SOMWeb. The examination templates previously described using XML are now described using OWL. There can be many different examination templates, corresponding to different examination situations. The terms and values that are used by the examination templates and in the individual examinations are, in the MedView representation, kept in a termValues and corresponding termDefinitions file, which are stored in text files of a specific format. These are now stored as classes and instances in an OWL file. Just as there could be different sets of termValues and termDefinitions files, it is possible to have different value list OWL files. Aggregates were previously stored in a specific format for aggregate definitions, in separate files. They are now represented in OWL. Finally, the examination records that were previously stored as tree files are stored as RDF files.

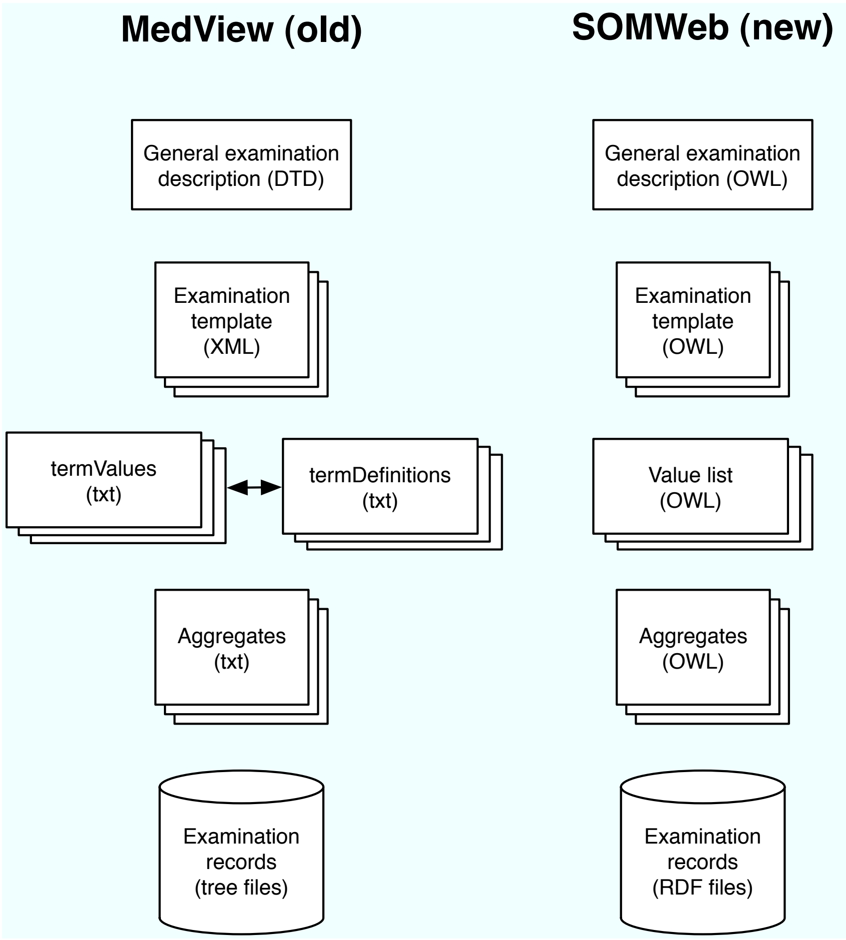


Figure 5.3: Comparison of the structure of MedView and SOMWeb components for describing examinations.

5.1.5 The Examination Template Ontology

An examination template describes what should be included in an examination record. It is used both to construct the form-based user interfaces and to structure the actual record. The structure of the ontologies describing examinations is presented, followed by some design decisions related to this structure and other features of the examination ontologies.

All named entities are referred to by a URI, so all classes, properties, and instances in the SOMWeb examination template and value list ontologies are assigned URIs. The general examination description OWL file has its own namespace. In the examples that follow, if no namespace is indicated, it is assumed to be the examination namespace.

Structure of the Examination Template Ontology

Templates consist of categories with associated questions (also called inputs). When filling out a form, values for each input may be chosen from a specified class of the value list. Each template is stored in an OWL file. Additionally, classes and properties common to all templates are defined in a separate OWL file. A template defines categories (subsections of the examination) that can or need to be included in a consultation constructed from that template and each category has a set of inputs (properties).

The general examination ontology, shown in Figure 5.4, contains elements common to all examinations. It describes general entities: classes such as `Examination`, `ExaminationCategory`, and a property `hasExaminationCategory` to connect an `Examination` instance to `ExaminationCategory` instances. The input types of the old MedView templates, such as `MultipleExaminationProperty`, and `VASExaminationProperty`, are represented as either object or datatype properties. The reason for explicitly representing matters that could be handled using cardinality constraints in OWL is to allow for easier integration with the existing code base. Until those modules can be rewritten, both cardinality constraints and the explicit properties such as `SingleExaminationProperty` are used. There are also various annotation properties associated with the inputs, such as `instructionProperty` and `descriptionProperty`.

All individual examination templates refer to this general examination ontology. In SOMWeb, one template describes what to enter when first entering the case into the system. Other templates are for consultations from the teleconference meetings and for consultations performed after the initial examination data is entered. An example template is found in Appendix C.2, on page 187. An examination template contains definitions of the categories that can or need to be included in an examination constructed from that template. Examples of subclasses of `ExaminationCategory` in current use are `PatientData`, `GeneralAnamnesis`, and `MucosChangeAnamnesis`. Each examination template also includes inputs associated with the template, such as `medicationInput`, as subproperties of the properties described in the general examination description OWL file, such as `MultipleExaminationProperty`. For each property, there are annotation properties pertaining to description and instructions to be shown to the user. Any relevant cardinality constraints are described, as well as the ordering of the categories and the properties

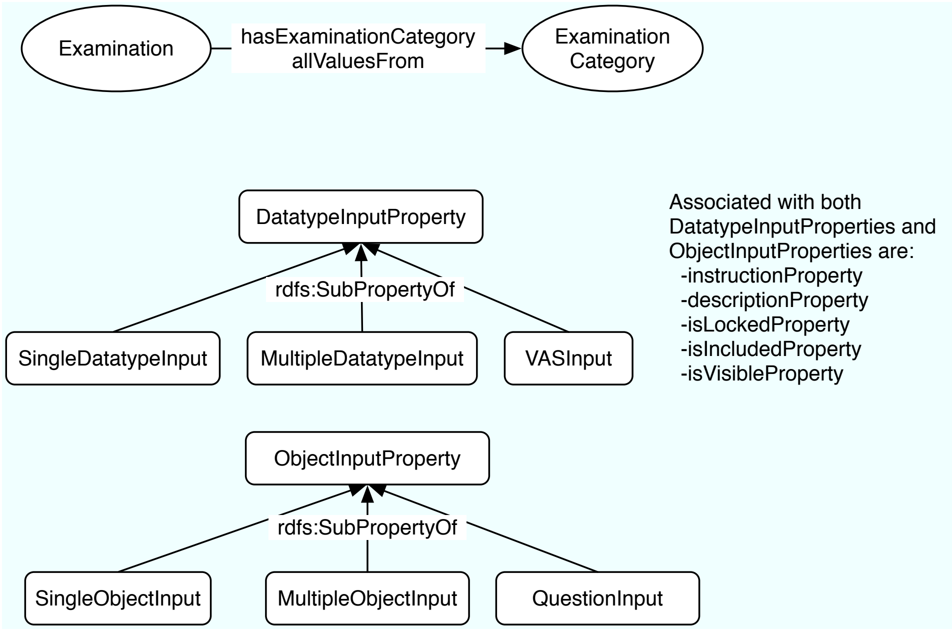


Figure 5.4: Contents of the general examination ontology, referred to by specific examination templates.

within the categories, using `rdf:list`. For each `ExaminationCategory` subclass, the relevant inputs and corresponding value classes are connected using `owl:allValues-From` restrictions. Figure 5.5 shows the structure of an example `ExaminationCategory`, `GeneralAnamnesis`, and how it relates to the common examination description and the value list ontologies. The boxes indicate which OWL files contain the classes and properties. The properties used by `GeneralAnamnesis` are in the caseExam.owl file, which also contains restrictions. For example, an instance of `GeneralAnamnesis` has only instances of the class `Diseases` as values of the property `dis-nowInput`. The `Smoke_Relation` and `Alcohol_Relation` classes are described under 'MedView's Incomplete Value Inputs' in Section 5.1.5.

Design Choices

Now that the general structure of the SOMWeb examination ontologies has been presented, more detail is provided for some of the design choices made. Considerations about whether or not to use the constructs of domain and range are discussed. In addition, how and whether the order of categories and properties should be included in the examination template description is considered. Also, the issue of properties reflecting MedView term types is discussed. Finally, the representation of incomplete value inputs using n-ary relations is presented.

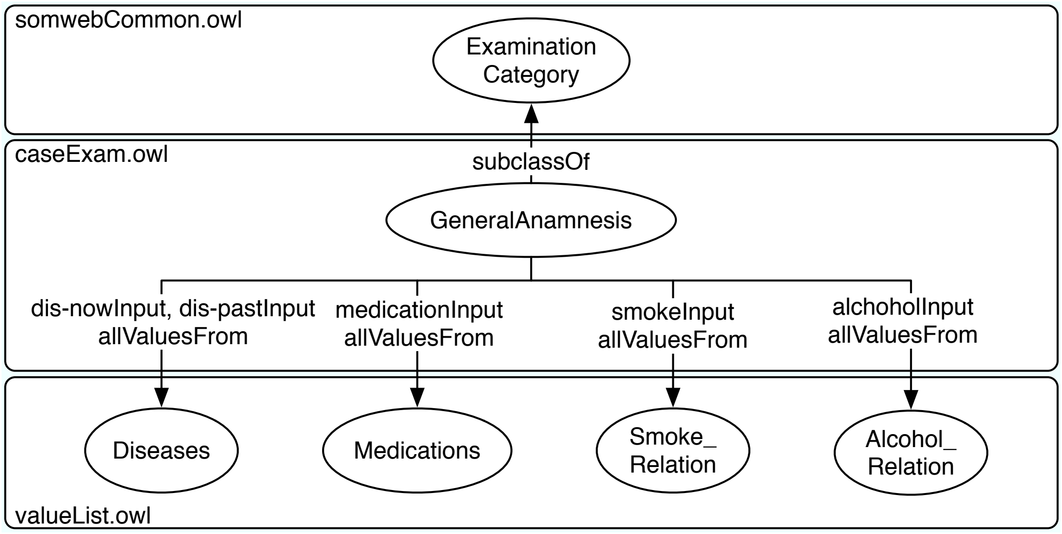


Figure 5.5: The structure of a subclass of `ExaminationCategory`, `General-Anamnesis`.

Domain and range For each `ExaminationCategory`, the inputs that should be included and what types of values these inputs can take need to be specified. This can be done using `rdfs:domain` and `rdfs:range` or using restrictions such as `owl:allValuesFrom` and `owl:someValuesFrom`. It was initially expected that using domain and range would provide constraint checking, but in OWL the constructs are used to infer additional information about individuals. Another consequence of using `rdfs:domain` and `rdfs:range` is that they apply globally to the property, while `allValuesFrom` and `someValuesFrom` restrictions are local to the class to which they apply. This led to using the latter constructs rather than `domain` and `range` in the SOMWeb oral medicine ontologies.

Representing order An examination template has an implicit order. For example, a general anamnesis normally comes before a diagnosis. Whether or not this order is intrinsic to the examination, or part of the *presentation* of the examination remains an open question. However, OWL and RDF, being graphs, have no order. In the SOMWeb examination templates the `rdf:list` construct is used to represent the order of categories and inputs. However, using `rdf:list` brings us into OWL Full. Since the order of `ExaminationCategories` is not used in reasoning, `rdf:list` is used in the examination templates. Was such reasoning needed (for example, in dependency relations between different categories), one possibility is representing lists as N-ary relations, as suggested by the W3C Working Group Note on N-ary relations [109].

Properties Reflecting MedView Term Types In order to make the OWL templates easier to understand for those used to the old representation, as well as making it easier to use old MedView Java code to read and write SOMWeb examinations, it was found necessary to have properties for each term grouping that exists in MedView today – such as single, multi, and VAS – which suggest properties that can take only one value, many values, or values on a VAS scale. Corresponding OWL properties include `SingleDatatypeProperty`, `MultiObjectProperty`, and `VASProperty`. However, the old groupings did not always apply to the new SOMWeb model, and needed to be subgrouped further. For example, each multi and single had to be further subgrouped into object property and datatype property. Further, some of these groupings can be easily represented using cardinality constrains in OWL, such as the single and multi groupings. It would be easy to determine what grouping the MedView program should use for these, from the cardinality constraints. However, for others, such as the `VASProperty`, it is more complicated. Rather than using this subproperty construct for only some of the properties, I decided to use it for all, even though some information might be redundant.

MedView's Incomplete Value Inputs One type of input in MedView is incomplete value inputs. This is used, for example, to specify how long a patient has had a certain problem (value + time unit), or smoking habits (value + tobacco category + time unit). In the MedView term values file this is represented as:

```
$Smoke
? cigarettes no filter/day
? cigarilles/day
? cigarrs/day
? filter cigarettes/day
? pipe tobacco packet/week
Not daily
No
```

The lack of relation between the time units makes this approach problematic. These 'incomplete values' can be represented using the W3C OWL Best Practices Proposal for Representing N-ary Relations [109]. In the case of examinations in MedView, the 'n' will most often be two or three. In the case of two, there is a value and a unit. In the case of three, there is a value, then a category, then a time unit. Figure 5.6 depicts how this pattern can be used at the instance level for the case of smoking. The `Smoking_Relation_1` instance connects `Anamn-gen_123`, an instance of the class general anamnesis, with appropriate properties and values to describe the smoking habit of a patient: the number of tobacco products used, the type of tobacco product, and the time period of usage. The description of such a relation in the examination template is given in OWL in Figure 5.7.

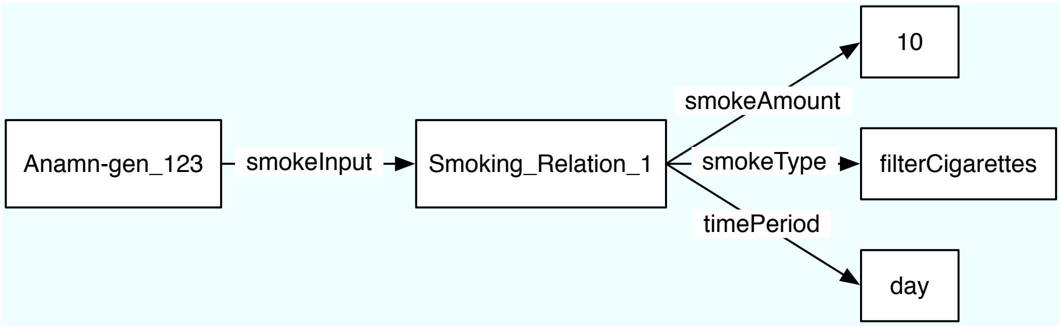


Figure 5.6: A depiction of the use of a separate class for representing n-ary relations, here the `Smoking_Relation`, at the level of individuals.

```
Class (Smoking_Relation complete
restriction (smokeAmount someValuesFrom (XMLSchema:int))
restriction (smokeAmount allValuesFrom (XMLSchema:int))
restriction (smokeType someValuesFrom (Smoking_category))
restriction (smokeType allValuesFrom (Smoking_category))
restriction (timePeriod someValuesFrom (TimeUnit))
restriction (timePeriod allValuesFrom (TimeUnit)))

ObjectProperty (timePeriod
Functional)

DatatypeProperty (smokeAmount
Functional)

ObjectProperty (smokeType
Functional)

Class (Anamn-gen complete
restriction (smokeInput someValuesFrom(Smoking_Relation))
restriction (smokeInput allValuesFrom(Smoking_Relation)))
```

Figure 5.7: Use of the n-ary relation pattern to represent a smoking habit in the examination template.

5.1.6 The Value List Ontology

The value list ontology describes classes of values that are used to fill in an examination record. This section begins with a description of its structure, and is followed by the related design decisions.

Structure of the Value List Ontology

All of the MedView terms are represented as OWL classes, and their values are instances of these classes. Thus, the term *Allergy* becomes the class `Allergy`, and the values of the *Allergy* term become instances of the `Allergy` class. Since the structure of the terms and values in MedView is flat, no subclasses were initially created (Section 5.2.1 describes the addition of subclasses). For the classes and their instances, meta-information about who has added it can be supplied. For the examples given below, and from the initial ontology, all values were created from the MedView termValues list, but when in use in SOMWeb the name of the clinician adding it can be automatically included. The Dublin Core `creator` is used to include this information. The following is an example of the class `Allergy`, which has “MedView termValues” as its creator, to indicate that it is a translation from the older format:

```
Class (somwebValueList:Allergy
    annotation(dc:creator "MedView termValues")
)
```

Individuals of these classes are created for each of the values of a term in the term values file. If the name of the value contains symbols not allowed in URIs, such as spaces and Swedish letters, the URI is made by removing these. The `rdfs:label` is used to represent the original name of the value. Because language information can be attached, labels can be provided for as many languages as needed:

```
somwebValueList:Chemicals
   rdf:type somwebValueList:Allergy ;
   rdfs:label "Kemikalier" @sv ;
   rdfs:label "Chemicals" @en ;
   dc:creator "MedView termValues" .
```

The somwebValueList.owl file, created from the term definitions and term values currently used in the SOMWeb community, contains only these two kinds of statements. They are in no particular order since RDF has no order. An excerpt is shown in Appendix C.3, page 189.

Some of the values in the current value lists contain extra information in the value name. For example, the diagnosis values have an International Classification Diseases (ICD) code concatenated to them: *Gingivit - plackinducerad K051* (gingivitis - plaque induced). In the value list ontology such extra information is extracted from the name:

```
somwebValueList:gingivit-plackinducerad
   rdf:type somwebValueList:Diagnosis ;
   somwebValueList:icdCode "K051"^^xsd:string ;
   rdfs:label "Gingivit - plackinducerad" @sv ;
   dc:creator "MedView termValues" .
```

Design Choices

Apart from the more general decisions presented above, more specific questions that were under consideration during development are now discussed. These are the use of instances rather than classes for the values, the naming of instances, as well as the reuse of ontologies developed by others.

Using Instances The term values of MedView are represented as instances, rather than classes, in the SOMWeb ontologies. A major reason for this is that in OWL DL classes cannot be treated as instances. This means that a class cannot be the object of a statement. Thus, if `DogAllergy` is a class and we want to remain within OWL DL, it cannot be stated that:`Patient123 hasAllergy DogAllergy`. This is why, in the SOMWeb value list ontology, `DogAllergy` would be an instance of the class `Allergy`. When seeking advice on how to make the decision between using classes or instances, it became apparent that the choice is to some extent a matter of taste, and that the W3C intends to provide guidance on this issue. In the W3C Best Practice Working Group note on N-ary relations [109], they state in passing, when discussing how to represent a diagnosis, that: "For simplicity, we represent each disease as an individual. This decision may not always be appropriate, and we refer the reader to a different note (to be written)." Such a note has yet to be made available.

However, the representation of `DogAllergy` as an instance can be seen as problematic. If this instance is used in two different examinations of two different people, does this mean that they have the same allergy to dogs, in the sense that the chemical reaction in their bodies resulting from an exposure to dogs is identical, or at least the same kind of reaction? One approach to get around this would be to have each kind of allergy as a subclass of the class `Allergy`, and then create instances, such as `DogAllergyOfPatient123`, of these subclasses for each patient's allergy. However, this would mean creating a large number of instances, thereby adding complexity in terms of application code and memory requirements. It was decided that this added complexity was not compensated by the benefit of staying closer to the real world meaning.

Such an approach would be similar to the system for referent tracking suggested by Ceusters and Smith [22]. In the referent tracking paradigm, all concrete individual entities relevant to the correct description of a patient's condition, therapies, and outcomes should be referable explicitly through the use of unique identifiers. Not only does the patient receive such an identifier, but so does the patient's particular fracture, the particular bone that is fractured, and so on. However, referent tracking systems are still under development and considered beyond the scope of this work.

URIs The URIs used for the values are based on the current term values, which are in Swedish. If the name of the Swedish value contains symbols not allowed in URIs, such as Swedish letters, the URI is made by replacing these with an allowed symbol (International Resource Identifiers were not considered.). Before deciding to base the URIs on the Swedish values, the use of English names or an identifier scheme not containing the value names was considered. Using English names was decided against, as many of the terms needed are not in a common dictionary, and a manual translation would be time-consuming. If the decision is made to use URIs based on English instead, it can be declared that the new, English URIs refer to the same thing as the old, Swedish ones.

Having URIs with an identifier scheme not based on the value name and having the Swedish name only in the `rdfs:label`, was also considered. However, with this approach, the RDF-file describing the examination is less readable and contains less information since you need to consult the ontology description of the value to find its Swedish name. Related to the question of URIs and naming are Life Science Identifiers (LSID), designed to be location-independent, stable, and resolvable identifiers for entities on the Semantic Web for the life sciences [26]. However, these were found to be beyond the scope of this work.

Reuse Creating the SOMWeb ontology led me to conclude that reuse is perhaps more difficult than creating an ontology from scratch. Further, finding a good ontology, in OWL, to reuse, that suits SOMWeb's needs, was not possible. This may have become easier during the past five years of this project. The ontology to reuse must, for example, have concepts of interest and be of 'good' quality. More importantly, a Swedish translation of the value would have to be provided. For example, although earlier versions of the SOMWeb value list ontology did reuse an ontology of countries, the lack of a Swedish translation meant that it was easier to use an OWL version of the old value list of countries, though this contains less semantics.

One feature of the MedView applications is that it has been easy for users to add values to the value lists, as they saw fit. If instances of another ontology are reused, this would mean that new instances of the classes of that ontology would be added 'locally', and kept separate from the 'original' instance list. This might not be a problem in itself, and can perhaps rather be seen as a feature of using Semantic Web technology, but it does make the management of the value lists more complex.

It thus appears that if the SOMWeb ontologies are to attain the benefit of interoperability from ontology reuse, such will have to be added later, when and if appropriate ontologies appear. This can either be done by declaring a SOMWeb class a subclass of some external class, or by using `owl:sameAs` or `owl:equivalentClasses`, as appropriate.

5.1.7 Representing Individual Examinations

An examination generated by the SOMWeb community is exemplified in Appendix C.4, on page 190. Note that the examination in the Appendix is in RDF/XML format, rather than N3, which the examples in the main text are in. This is because SOMWeb's examinations are in RDF/XML and because though I find N3 very useful for small examples, for larger data models the ease of reading is not improved. Another example of an examination is visualized in Figure 5.8. It shows an instance (`Examination_123`) of the `Examination` subclass defined in an examination template. This instance has several categories associated with it, `PatientData_123`, `Anamn-gen_123`, and so on, which are instances of `ExaminationCategory` subclasses, also defined in the examination template. Also shown are the properties (inputs) associated with these categories. If these properties are object properties, they point to instances found in the value list ontology, valueList.owl. In the example, `age` is a datatype property, and thus refers to an integer.

The original intent of the SOMWeb examination templates were to take a RDF description of an examination instance and check that it fulfills all the requirements of the corresponding OWL examination template description. However, given OWL's open world assumption and the no unique names assumption, this is not inherently available. In this case, since the examination data in SOMWeb is generated from an input form based on the ontology template, the values for the inputs are from the appropriate classes. However, if examination data from several sources would to be brought together, such validation might be needed. One tool that could be of use is Eyeball,[5] a library and command-line tool which makes closed world assumptions for checking common problems of RDF models.

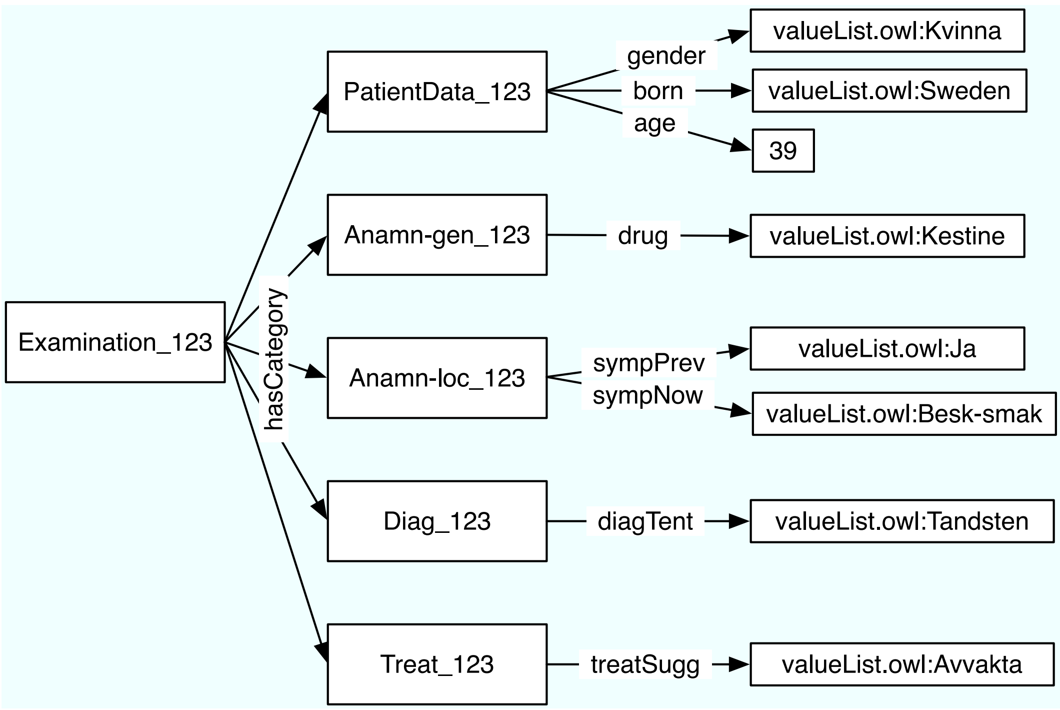


Figure 5.8: A fictive example of an individual examination.

[5] `http://jena.sourceforge.net/Eyeball/`

5.1.8 Representing Aggregates

In keeping with the allergy example, it may be of value to group the different allergies into different categories to see if there is any relation between these categories and certain mucous membrane changes in the mouth. In the MedView representation, such value classes were seen as an abstraction of values, but which are in themselves values. In the SOMWeb representation, this is mainly done by subclassing the values in the value list ontology, and making the appropriate individual values instances of this subclass. This is what what has been done in the refined value ontology, described in Section 5.2.1.

5.1.9 Results in Relation to the Requirements

This section returns to the requirements presented in Section 5.1.2, to discuss the extent to which the OWL-based oral medicine ontologies fulfills them.

Utilization of External Sources. I found it difficult to locate relevant ontologies to reuse, partly due to a lack of ontologies fitting SOMWeb's needs and partly because there was a lack of appropriate services[6] for finding ontologies of use. One part of the problem may be in the naming of concepts, where ontologies fitting SOMWeb's needs exist but name important concepts differently. Another problem is that a relevant ontology may become available after the initial search is done. Further, in the case of the SOMWeb community, the users want to have a high level of control over what kind of data they collect. How can this need be balanced with the possibilities of interoperability that may be gained from reuse? The problems of reuse are widely known (see, for example, [116]), and while in the development of the SOMWeb ontologies, problems arose partly from not finding relevant ontologies in OWL to reuse, they might not be alleviated by more published ontologies. As noted by Noy [107], with more ontologies available, more effort is required to evaluate them, and few objective measures to determine ontology quality are available.

Relations Between Conceptual Models of Clinical Concepts. The remodeling work had value in itself, as it meant that many of the structures of the knowledge model had to be thought through further. Indeed, one reason for developing an ontology is to elaborate on a common conceptual model, as suggested by Noy and McGuiness [108].

Capturing Interactions Between Different Parts of the Template Ontology. This requirement, where for example, one examination question depends on the response given for another question, has not been studied within this work. One way of doing this in OWL would be to include restrictions that for an input to be activated the values chosen for a previous input have to be in a given set.

Stronger Typing of Elements. In this matter there is a benefit from working within a larger framework, where the semantics are externally defined. However, the consequences of the open world assumption on validation mean the expected validation is not present.

[6]Though services exist, such as Swoogle (`http://swoogle.umbc.edu/`).

Capturing Examination Template Meta-data. Using Semantic Web technologies provides possibilities for capturing meta-data regarding creators and the purpose of different examination templates.

Localization of Data. It is possible to provide different language-based versions of the examination template parts and the values that can be used, by utilizing the `xml:lang` of `rdfs:label`. However, such translations have not yet been provided.

Differentiating between different views of the underlying data. Through the case browser classes, viewing the SOMWeb cases based on diagnosis and treatment has been made possible.

Representing Image Information. While there are Semantic Web initiative for representing image information (for example, [146] and [58]), this has not yet been addressed within SOMWeb.

Representing Data Ranges. Though not listed as a requirement, the possibility of defining data ranges would have been useful, for example, to represent values on a scale from 1 to 10. There is currently no support for this in OWL, which was not something that was anticipated when the development of the SOMWeb ontologies in OWL began. However, in the proposed OWL 2, support for value ranges is included.

It can be concluded that several of the requirements go unmet, which can be attributed both to the capabilities of OWL and prioritizations made during development. Given the centrality of images to SOMWeb, in retrospect it seems especially unfortunate that the annotation of images was not further investigated. The appropriateness in using OWL for the oral medicine ontologies is discussed in Section 5.5.1.

5.2 Adapting the Ontologies for use in the Case Browser

A benefit of SOMWeb users entering the cases in a structured manner is the use of this structure for browsing data. It is thus possible to view cases from the aspect of, for example, diagnosis or treatment. In the interviews with SOMWeb users, the overall results of which are described in Chapter 4 and 7, several interviewees found that as the number of cases in the system increases, more advanced methods of browsing and searching the cases are needed.

The addition of the SOMWeb case browser is intended to fill this need. The development of the case browser includes adding more detail to the value list ontology, presented in Section 5.2.1, as well as the definition of case browser classes, described in Section 5.2.2. SOMWeb's case browser functionality is presented in Section 6.4.3 and the implementation of it using the ontologies detailed below is described in Section 6.6.4.

5.2.1 Refined Value List Ontology

The original value list ontology contained no subclasses of, for example, `Diagnosis`. The MedView group's previous work to support oral medicine practitioners, has included the development of a data analysis tool in which the user may create aggregates of values to be used in grouping data, for example, diagnosis categories. These aggregates were taken as a starting point for a more finely grained ontology for use in the case browser. The refinement of the value list ontology was carried out programmatically, after the relevant aggregates had been identified.

The aggregates obtained had the following diagnosis groupings: afte, cancer, candida, candida associated diagnoses, lichen, lichenoid contact reaction, lingua geographica, and snuff related diagnoses. In the aggregates, a number of values from the MedView style value list was associated with each of these. In creating the refined value list ontology, the groupings listed above are added as subclasses of `Diagnosis`. For the values associated with the grouping, a statement is added that they are instances of the new subclass. If the value is not already part of the value list ontology, it is added. Thus, for example, a class `Afte` is created and made a subclass of `Diagnosis`. For each value associated with afte in the aggregate, whether or not it is already part of the value list ontology is checked. If it is, it gains an `rdf:type` of class `Afte`, and if it is not, it is created, using the same procedure as in creating the value list ontology from the previous format, and then adding the `rdf:type`. For example, *Aftös ulceration - major K120B* is matched against `aftos_ulceration-major` and gains an `rdf:type` of class `Afte`.

One of the `Diagnosis` subclasses, `Lichen`, could be further subclassed from the aggregate information. Thus, the class `Lichen` is specified to have two subclasses, `OLPeu` and `OLPrpp`, which group related types of oral lichen planus.[7] Figure 5.9 depicts part of the refined value list ontology. It shows the `Diagnosis` class with some of its subclasses, as well as the associated values from the aggregate that matched instances in the value list ontology, for which `rdf:type` relations are added.

5.2.2 Case Browser Classes

The purpose of the SOMWeb case browser is to display cases associated with the subclasses of `Diagnosis` and `Treatment`. These classes were selected for browsing in collaboration with our clinical contacts. A case browser ontology is created that includes the classes `BrowserCase`, `DiagnosisCase` and `TreatmentCase`, where the latter two are subclasses of the first. `DiagnosisCase` and `TreatmentCase` have subclasses that group sets of diagnoses and treatments using the refined value list ontology. Figure 5.10 depicts some of these relations. For example, `AfteCase` and `SnuffChangeCase` are subclasses of `DianosisCase`.

The definition of the class `AfteCase`, a subclass of the class `DiagnosisCases`, is seen in Figure 5.11. It is defined as a case that `hasSomeValuesFrom` the class of `Afte` for the inputs `Diag-tentInput` (tentative diagnosis) or `Diag-defInput` (definitive diagnosis). These are properties used in individual examinations. Since several value list individuals are defined to be instances of the `Afte` subclass (see Figure 5.9), this definition can be used to infer which cases are instances of `AfteCase`. For example, if in an examination in SOMWeb, there is a case with a `Diag-tentInput` of

[7] OLPeu groups oral lichen diagnoses for erosive and ulcerating types. OLPrpp groups those of types reticular, plaque, and papular.

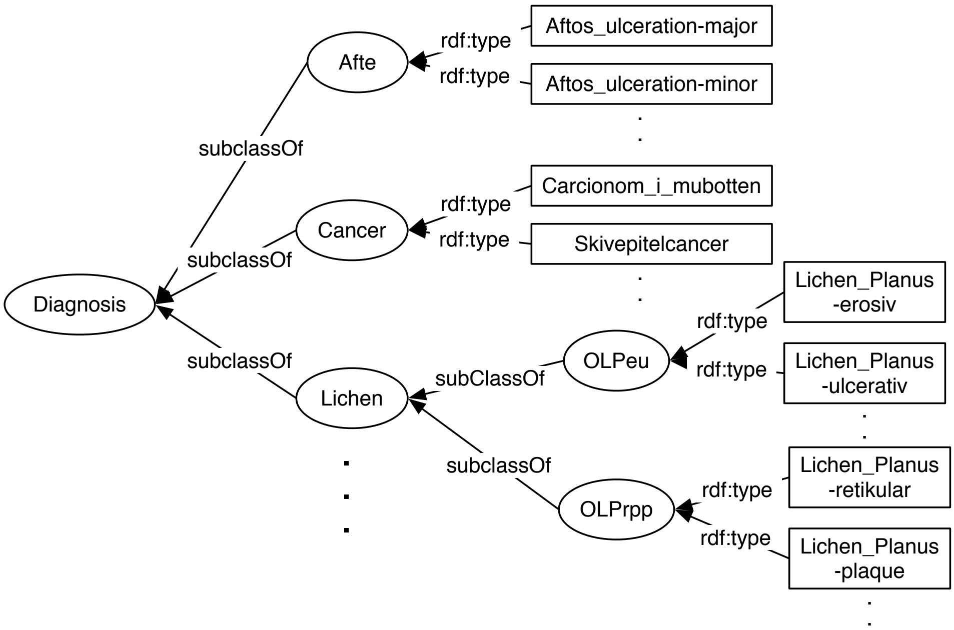


Figure 5.9: Part of the refined value list ontology showing subclasses are added to the `Diagnosis` class.

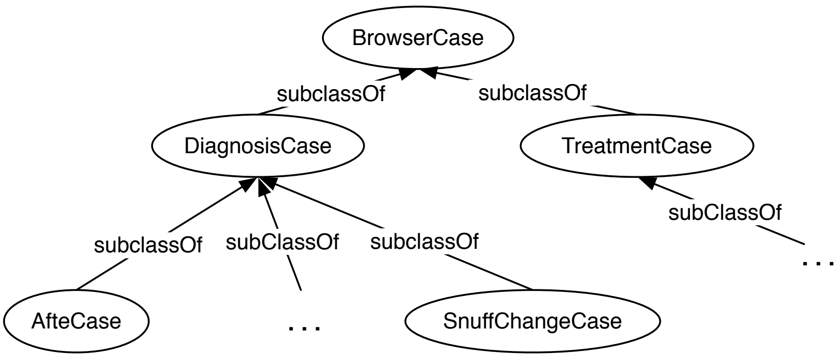


Figure 5.10: Class hierarchy related to `BrowserCase`, with subclasses `DiagnosisCase` and `TreatmentCase`, which are then further subclassed.

aftos_ulceration-major, it will be classified as an instance of AfteCase and displayed under this heading in the case browser.

```
EquivalentClasses(AfteCase
    restriction (caseForm:Diag-tentInput
                   someValuesFrom (somwebInstances:Afte)))
EquivalentClasses(AfteCase
    restriction (caseForm:Diag-defInput
                   someValuesFrom (somwebInstances:Afte)))
SubClassOf(AfteCase DiagnosisCase)
```

Figure 5.11: Definition of AfteCase used in case browser.

5.3 Ontology of Community Resources

Chapter 4 describes the collaboration and communication of SOMNet. The collaboration can be said to consist of the community's resources, which for SOMNet are its members, meetings and cases. In line with the use of Semantic Web technologies to represent oral medicine knowledge, Section 5.3.1 presents the ontology over community resources as it is currently being used in SOMWeb.

Another reason for this modeling is the potential to update SOMWeb to adapt to different users, usages, and cases. Section 5.3.2 outlines how the ontology of Section 5.3.1 is extended, in order to take more information about the members into account and to use concepts from communities of practice. While the extended ontology is not used in the system, ideas on how it may be used in adapting the system are found in Sections 8.1.2 and 8.1.3.

5.3.1 Community Resources Ontology

The members of SOMNet are instances of the SOMNetMember class, a subclass of Person. Other subclasses of Person are Guest, Student, and Admin. Contact information is specified for each Person, and consists of telephone and fax numbers, as well as e-mail address. Additionally, each SOMNetMember also has an associatedClinic Clinic, and each of these has contact information, as well as their city and country. A member may own cases in the system, but information about this is stored with the case. Some of the user-descriptions are related to relevant FOAF-classes and properties.

The SOMNetMeeting class collects all information about a SOMNet meeting. This includes its date and chairperson, who is a SOMNet member. The meeting also has cases associated with it, but information about which meetings a case is discussed at is stored with the case. Meeting-descriptions make use of classes and properties of the Semantic Web Research Community (SWRC) ontology [149].

Another central concept is the SOMNetCase class, depicted in Figure 5.12. For each case, information is recorded about its owner and at what meeting it is presented. The content of a case is a set of consultations and optional support material, both of which have further subclasses. The `Consultation` class has three subclasses:

- `InitialExamination` – First entry about a case, containing a general anamnesis, mucous membrane anamnesis, and information about treatments and tentative diagnosis. It also contains a free text entry and references to images.
- `FollowUpExamination` – Data about any subsequent patient visits.
- `MeetingConsultation` – Records the decisions and suggestions of a meeting.

The `SupportMaterial` class has three subclasses:

- `Article` – A reference to an article, with information about title, authors, publication, an URL indicating where the article can be found, and a free text entry where the person adding the article may explain its relevance.
- `SOMNetCase` – A pointer to another case in the SOMWeb database that is of relevance to the given case.
- `NonSOMNetCase` – Free text and image description of a case external to SOMWeb, but which is related to the given case.

Each type of consultation and support material has an associated template, in the manner described in Section 5.1.5, that is used to fill in data from a specific consultation occasion.

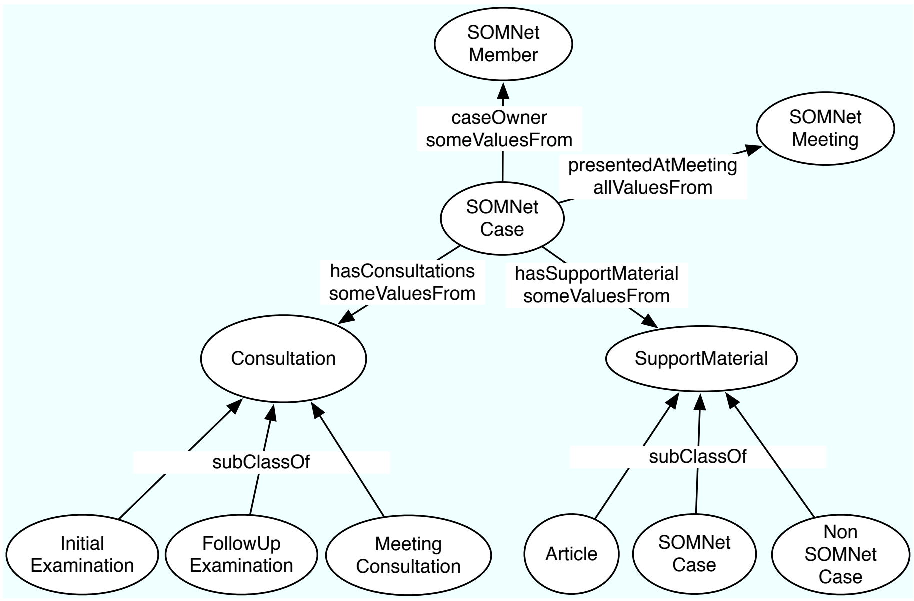


Figure 5.12: The `SOMNetCase` class.

In addition to the community resources described above, the ontology also includes a news concept, which are information items to be shown to all community members. News items have a submitter, date, title, and message.

The classes described above are used to store data in the SOMWeb system, using separate RDF files for users, meetings, cases, and news.

5.3.2 Extended Community Resource Ontology

The ontology for community resources described in the previous section has been extended to include more information about the members and their organization, as well as concepts from the theory of communities of practice. How SOMNet can be seen as a community of practice is discussed in Section 4.5. The extended community resource ontology includes concepts related to both the SOMNet organization and the workplace organizations of the members. Thus, the class `Organization` has subclasses `Community-OfPractice` (of which SOMNet is an instance) and `FormalOrganization`, which has subclasses `PrimaryDentalCare`, `PrivateDentalCare`, `HospitalDental-Care`, and `UniversityDepartment`.

In the extended ontology, each `Person hasEducation` of `EducationType`. Subclasses of `EducationType` are `AcademicTitles`, `Certification`, and `FormalDentalEducation`. Instances of these classes are the types of education relevant to SOMNet's members. Significantly, an instance of `Certification`, `SOMSCertification`, refers to a certification provided by SOMS, and indicates that a member has more in-depth knowledge of oral medicine, and the class `SOMNetMemberWithSOMSCertification` defines those SOMNet members who `hasEducation hasValue SOMS-certification`. Each member also has a workplace, which is a `FormalOrganization`, as described below, and a property `numberOfYearsOfExperience`. Also included are `hasInterests` and `hasExpertise`, which, for example, take values from diagnosis and treatment classes of the oral medicine ontology.

As discussed in Section 2.2, Wenger et al. [159] propose that the members of a community of practice have different levels of participation, and that they can be divided into groups of core, active, and peripheral members. As described in Section 4.5, a similar division can be discerned within SOMNet, and these concepts are therefore included in the extended ontology. However, how to define these classes in terms of information available in the system is an open question. In the case of SOMNet, a `CoreMember` can be defined as a member with SOMS certification or one who has chaired at least one meeting, see Figure 5.13. An `ActiveMember` can be defined as a member who has added at least one case, also in Figure 5.13, while a `PeripheralMember` is a one who is not entailed by the definition of `CoreMember` or `ActiveMember`.

Although the extended ontologies are not yet used in SOMWeb, their potential use is included in Section 8.1, which discusses improvements to SOMWeb.

```
Class(CoreMember complete
     unionOf(SOMNet-member-with-SOMS-certification
             SOMNet_member_has_Chaired_Meeting))
Class(SOMNet-member-with-SOMS-certification complete
     restriction(educationType value(SOMS-certification))
     SOMNetMember)
Class(SOMNet_member_has_Chaired_Meeting complete
     restriction(chairpersonForMeeting minCardinality(1))
     SOMNetMember)

Class(ActiveMember complete
     SOMNet_member_has_added_cases)
Class(SOMNet_member_has_added_cases complete
     restriction(hasCases minCardinality(1))
     SOMNetMember)
```

Figure 5.13: OWL classes for Core and Active Members.

5.4 Evaluation of the SOMWeb Ontologies

Ontology evaluation plays several roles in the construction and research of applications that use ontologies. When selecting an ontology for reuse, we want to know its properties in general and its suitability for a given project, and thus need to either perform an evaluation or have access to accurate evaluation results. For the SOMWeb ontologies, an evaluation is necessary as part of the research process and to provide data for enabling reuse by others. Approaches to ontology evaluation include, as listed by Brank et al. [18]: comparing the ontology to a 'golden standard'; using it in an application of which the results are evaluated; comparing it with a source of data relevant to the domain; or by humans assessing it according to predefined criteria. Gangemi et al. [45] propose several measures relating to the structure of the ontology, including depth, breadth, tangledness, and density.

The evaluation of the SOMWeb ontologies was done by indicating their structural properties using metrics from Gangemi et al. and an application-based evaluation relating to their use in the SOMWeb system. Table 5.1 details of the number of classes and properties, and where appropriate, individuals, for each of the ontologies presented above. Information on average depth and average branching is also provided. These figures were collected through the SWOOP[8] application, and are of use when comparing the SOMWeb ontologies to other ontologies. As is to be expected given the purpose of the different ontologies, the templates contain mostly properties, while the value list consists of classes and individuals. The refined value list ontology only contains classes and individuals related to diagnosis and treatment, and has larger average depth and smaller average breadth than the original value list, due to the addition of subclasses.

Apart from the users' involvement in the knowledge elicitation of MedView, the users have not been involved in the direct evaluation of the SOMWeb ontologies. As part of an

[8] http://code.google.com/p/swoop/

Table 5.1: Evaluation of the SOMWeb ontologies.

	templates	value list	refined value list	case browser	community
classes	11	114	16	39	37
obj. prop.	21	0	0	0	25
data prop.	24	3	0	0	30
individuals	0	3136	225	0	12
avg. depth	1.3	0	1.6	2.6	2.0
avg. branch	8.3	25	5.6	3.8	4.5

application-based evaluation, the use of the ontologies in the SOMWeb system is presented in Section 6.6 of the next chapter. Application-based evaluation has several drawbacks as identified by Brank et al [18]: one can say something about how an ontology works when employed in a specific way for a particular task, but this may be difficult to generalize; the ontology is only one component in the application, and its effect on the outcome may be small or indirect; and it is only possible to compare different ontologies if they can be used in the same application. At the same time, for the individual team developing an ontology for use in an application, it is the evaluation through such use that is most important, where it can be seen, for example, that the correct inferences are drawn from a larger set of instance data than is practical to load into an ontology editor.

5.5 Discussion

This section discusses the oral medicine ontologies (Section 5.5.1), the benefits and constraints of starting from an existing model (Section 5.5.2), SNOMED and openEHR (Section 5.5.3), the community resource ontologies (Section 5.5.4), and finally application-based ontology evaluation (Section 5.5.5).

5.5.1 The Oral Medicine Ontologies

The oral medicine ontologies take the knowledge content of MedView as a starting point. That is, oral medicine knowledge as seen through MedView is modeled, which means that the individual examination is seen as central and that detailed definition of, for example, symptoms and diagnoses, are not included in the ontology. Also, much of the knowledge elicitation had already been carried out which meant that the end-user involvement in the development of the SOMWeb ontologies was limited. Since it was decided to translate the old term values to OWL, the SOMWeb ontologies still contain problematic entries from the old value lists, such as duplicate entries and misspellings.

Since the MedView knowledge model includes both terminological knowledge and models for patient records, the remodeling work presented here asks if OWL can handle both. The use of OWL to represent the terminological knowledge was less of an issue than using OWL to represent templates for patient records. Initially, there was an expectation that it could be possible to specify a schema, which would be used to validate examination records, in addition to being able to give more elaborate definitions of what to include in an examination. However, it became apparent that this kind of validation is not available without making several assumptions, such as a closed world assumption. This could be made clearer to newcomers to OWL. Further, I see a need to be able to provide schema functionality within the Semantic Web framework. Defining new restrictions for this purpose, such as `makeSenseForTypeKnownToBe`, `canOnlyBeKnownType`, and `mustBeAtLeastOneKnown`, as suggested by Ruttenberg et al. [134], could be a step in this direction. Other suggestions are briefly described by Rector and Stevens [129]: treating domain and range restrictions as integrity constraints (as described by Motik et al. [98]) and having the option of using a template mechanism similar to "slot attachment" in frames.

As described in Section 5.1.6, the aim of the initial attempts at remodeling was to add subclass structure to the term values right away. Using OWL gave the possibility of postponing this addition; it was carried out in a later iteration, as described in Section 5.2.1, for use in the case browser. The oral medicine ontologies can be considered lightweight, since they contain, as defined by Gómez-Pérez and Corcho [49], only concepts and the taxonomic relations between them, relations, and instances, and few or no axioms. I believe that such light weight ontologies provide value to the applications that use them, and the case browser ontologies demonstrate the use of OWL for reasoning based on the individual examinations and the refined value list, clearly showing the applicability of OWL for aiding in the viewing of cases from different perspectives.

5.5.2 Benefits and Constraints of Starting from an Existing Model

The development of the SOMWeb ontologies was strongly based on the knowledge model of MedView. This includes the structure of the examination templates, the structure and content of the value lists, as well as the naming of these structures. In addition to being influenced by the previous representation, the created ontologies were also affected by the organization of the existing code base, such as how and where the templates, term definitions, and term values are processed. For example, the different input types were represented explicitly in the examination template ontologies, as this greatly simplified the processing of the templates within the MedView code.

Taking a previous representation as a starting point for ontology creation simplifies the development, as part of the knowledge acquisition has already been carried out, and consideration has already been given to the structuring of this knowledge. At the same time, it means that the ontology is developed within certain constraints, and cannot entirely adhere to the new representation paradigm. Further, by developing within an existing code base, we get access to software functions that the newly developed ontologies can be used in and users are accustomed to. At the same time, previous code design decisions may then lead to compromises in the developed ontology.

5.5.3 SNOMED and openEHR

For both information models and medical terminologies there has been extensive international work (see Section 2.3.2 for a brief overview). In retrospect, this work would have benefited from to a larger extent attempting to utilize these. Several barriers to such utilization are now discussed, which fall into the general categories of availability in Swedish, coverage of oral medicine concepts, and availability in OWL. One of the main candidates when it comes to terminologies is SNOMED. Over the past years the Swedish National Board of Health and Welfare have begun work on translating SNOMED into Swedish with the intent of introducing it in Swedish health care. However, this work was started after the initial modeling of the SOMWeb ontologies had been completed. Another issue is the coverage of SNOMED with regard to oral medicine, where our clinical contacts have previously found them lacking in coverage. However, this issue can be more rigorously investigated. Finally, while SNOMED is based on Description Logic, there is no official version available in OWL.

When it comes to coverage of oral medicine concepts, standardized nomenclatures for dentistry were considered. In the dental domain, the America Dental Association provides the Current Dental Terminology (CTD), which is updated regularly, but limited to treatments and procedures, as well as the Systemized Nomenclature of Dentistry (SNODENT), which is an effort to create a comprehensive dental vocabulary. However, it has been found that it needs improvements in content, quality of coding, and quality of ontological structure [48]. Again, there is no version in Swedish nor in OWL.

This, coupled with earlier decisions to investigate the use of OWL and the somewhat daunting task of integration the content of the local knowledge model with an external terminology, led to not basing this work on any of these larger initiatives. In the MedView representation, ICD codes are included in some of the names of diagnosis values. In the SOMWeb representation, such codes can be included as properties of instances of the Diagnosis class (see example in Section 5.1.6). Preferably, ICD as a whole could have been reused, but it is not available in OWL. The approach used here has the advantage of only providing the subset of values that SOMWeb's users are interested in. A similar approach could be taken to map the SOMWeb ontologies to SNOMED concepts.

In addition to terminology initiatives, standardized approaches to representing patient records are being developed (again, see Section 2.3.2). Given that OWL was not entirely satisfactory in representing templates and recent developments where the Swedish Association of Local Authorities and Regions support the use of EN13606 and the archetypes of the openEHR project, the latter would be a good choice for SOMWeb. This also suggests the enticing possibility of easing the data entry of the clinicians who participate in the project, if more EHR systems in Sweden start being based on the standard.

5.5.4 Community Resource Ontology

In creating the SOMWeb community resource ontology, I attempted to identify relevant concepts from external ontologies. Therefore, the SOMWeb ontology imports concepts from FOAF and SWRC. While it is good practice to reuse concepts from other ontologies, it is doubtful that anything was gained in this case. While the reuse of external ontologies may, for example, bring greater data interoperability and a shorter process of knowledge elicitation, in the case of SOMWeb, integration with external data was not foreseen (see Section 6.7.2 for more discussion of this). Further, the resource ontology relates fairly specifically to SOMNet's collaboration and is not very large, which may also indicate that reuse is of less value. The definition of the classes for the levels of participation of the SOMWeb users is an open problem. One way of doing this is through some machine learning algorithm, partitioning the users into groups based on the system data of their cases and data in the logs.

The SOMWeb ontologies for community resources are related to work on user and organization modeling ontologies, such as Kostkova et al. [82], Marchetti et al. [92], and Vidou et al. [155]. While the model of Marchetti et al. [92] served as an inspiration for the SOMWeb community resource ontology, the level of detail was low. In addition, there are differences between a regular HCO and a community of practice. In the case of a community of practice, the aspect of authority is less clear than in a more traditional HCO. Another difference between the HCO ontology and the SOMWeb community resource ontology is that, in the latter, the case is more prominent than the patient.

5.5.5 Application-based Evaluation

Evaluation of ontologies is difficult, as is the evaluation of the SOMWeb ontologies. One means of evaluation is through their use in applications. However, what does it tell us to know that it is possible to use an ontology in an application? As a developer, one can make any number of code-based adoptions to make this possible. While application-based evaluation of ontologies may be one of the best measures, I conclude from this research that there is a need a need to present guidelines for what factors to examine in such evaluations, especially with indications of appropriateness based on level of formalization and content. Further, in ontology evaluation, a distinction needs to be made between evaluation for the purpose of deciding between different ontologies to reuse and for the purpose of ascertaining whether using ontologies is appropriate in a given situation and whether the developed ontology fulfills the requirements.

5.6 Summary and Conclusions

This chapter has presented ontologies for oral medicine and community resources. For the oral medicine ontologies, OWL is used for examination templates as well as value lists (or terminology). In designing these, several decisions were given lengthier consideration, related to taking a previous representation as a starting point, the appropriate use of OWL, as well as ontology develoment in general and the proposed open nature of the Semantic Web. One aim of this chapter is to determine the applicability of OWL for the different components. I find that OWL is least fitting for representing examination templates, due to a lack of integrity constraints. Since many applications need templates, there is a need for such a mechanism within the Semantic Web framework. OWL is more appropriate for representing the value lists, which mostly contain taxonomic relations. Further, OWL gives the opportunity to add more detailed class descriptions after initial development, as demonstrated with the refined value list ontology. Concepts from the template and refined value list ontologies were used in defining case browser classes, which are used to classify individual examinations. This demonstrates the use of the formal definitions to enable reasoning.

Conclusions regarding the use of Semantic Web technologies are expanded on in Section 10.1.2. The next chapter presents the SOMWeb system. Related to the current chapter, Section 6.6 presents how the ontologies of this chapter are employed in the system. In Chapter 9, I return to issues dealt with in this chapter when presenting lessons learned and recommendations regarding the use of OWL.

Chapter 6

The SOMWeb System

This chapter presents results related to Objective 3, as given in the introductory chapter. It involves the design and development of a Semantic Web-based system, SOMWeb, to support a community of practice of oral medicine in managing its meetings and cases. First, I describe previous IT-support of SOMNet, and drawbacks of these (Section 6.1). A presentation of design decisions for the SOMWeb system (Section 6.2) is followed by the prototypes used in the design process (Section 6.3) and details on the functionality of the system (Section 6.4). We then turn to more technical aspects, with a description of the system architecture (Section 6.5) and how Semantic Web technologies are used within SOMWeb (Section 6.6). The chapter ends with a discussion (Section 6.7) followed by a brief summary and conclusions (Section 6.8).

6.1 Previous IT Support for SOMNet's Collaboration

As seen in Section 1.1, before the SOMWeb initiative, the submission of cases was handled by e-mailing PowerPoint presentations to the meeting coordinator, who then e-mailed the submitted cases to the clinics intending to participate. During the teleconference meeting, each clinic opened its local copy of the case presentation file. At the meetings, no collective written notes were taken, and there was no central repository of handled cases.

The described procedure had several major problems: (1) Relevant information could be lacking in the case presentation, as there was no agreed upon template of what had to be included. What text and image information to include was entirely at the discretion of the individual submitting the case. (2) It was difficult to review previously discussed cases, as there was no shared record of treated cases. (3) The opportunities for collective and individual learning were limited by the lack of shared written notes from the meetings. (3) It was difficult to go back and check previously discussed cases, as there was no shared record of treated cases. (4) There were recurring problems of cases that could not be opened by all attendees, due to differences in versions of the software and platform used to produce the presentations.

Learning from earlier meetings was thus hindered by the lack of access to and reviews of previous cases, as well as difficulties in a structured comparison of different cases. Even with these problems, the participating clinicians found enough value in the opportunity of sharing experiences with other experts in the field to keep taking part in the meetings, both by submitting cases and joining discussions.

The introduction of a common Web-based repository was a first step towards improving the IT-support of the SOMNet meetings. In this repository, the presentations were stored as HTML documents rather than PowerPoint presentations. The new practice made administration simpler and provided a common bank of cases. From early 2004, when the clinicians first started using the repository, to May 2006 when the SOMWeb system was introduced, eighty-four cases from seventeen SOMNet meetings were added.

A Web-based questionnaire was distributed to all SOMNet participants to further examine the needs and wishes of the users. The results indicated that the participants considered SOMNet valuable and wanted it to continue in a similar way; as a forum for the most part dedicated to the discussion of submitted cases. Approximately 75 % of the respondents also said that they wanted to be able to have access to the collection of treated cases. The ability to share cases and treatment methods, as well as papers, directly with other clinicians was of interest to a majority of the respondents. When the questionnaire was discussed at a later meeting, the participants agreed that it was important to introduce a system that would allow the community to follow up previously discussed cases in a more organized manner. They also emphasized the importance of a means of searching the case database.

6.2 Design Decisions

In Section 5.1.2, the requirements for an oral medicine ontology for SOMWeb are listed. Based on these requirements an ontology for examinations in oral medicine was designed in OWL. Individual examination instances are encoded in RDF. Given that the examinations are an important part of the oral medicine community, and that these have Semantic Web representations, using such technologies for other relevant community concepts seems natural. Based on this, along with the analysis given in Section 6.1, the following design choices were made:

- The community should be constructed in cooperation with its users, foremost in order to adapt it to the users' needs, but also because the development of the online community can be seen as part of a learning process for the SOMNet users.

- The examinations should have a central role in the community and be represented in RDF, motivations for which are given above.

- The examinations to be presented at meetings should be entered online, using forms created from user-defined examination templates, represented in OWL.

- Community data should be stored in RDF, to allow interaction with, for example, examination data and hopefully other related online communities in medicine.

- Community data will be stored centrally, rather than be distributed as in, for example, [131], since the member clinicians and clinics cannot be expected to have access to local hosting.

- Where possible, existing ontologies for representing community data should be reused.
- In order to allow integration with the existing tools of the MedView project, Java technologies should be used in constructing the system.
- The constructed community should allow for browsing and searching of cases.
- In order to adapt to the needs of the users, the community should have basic user modeling support, with the long-term goal of providing a more intelligent user interface.

It was also decided to not develop SOMWeb based on an off-the-shelf system, such as a Content Management System (CMS), which is software that facilitates collaborative creation and organization of documents and other content. While using a CMS would have given a framework that would have enabled the rapid development of some aspects of our system, other aspects, such as generating case entry forms from templates, would still have had to be custom-made from scratch. Furthermore, the thesis aim to investigate the use of Semantic Web technologies also pointed away from using a CMS in favor of using a lower-level framework with greater flexibility and control.

6.3 Design Process

As presented in Section 3.3, the SOMWeb system was developed in collaboration with the end-users employing an iterative and prototype-based approach. Figure 6.1 displays one of the paper prototypes for SOMWeb. It shows a text-based search function, restricted to a specified clinic and clinician, which results in a list of cases with associated photos shown as thumbnails, with the option of viewing and editing case data.

Based on discussions with the user group about the paper prototype, an interactive HTML-prototype was developed. This prototype, while not containing any real functionality, was fully testable and provided the opportunity to try out what it would be like to work with the system. Figure 6.2 shows such a prototype: a meeting page with new cases to be discussed for the first time and cases that are follow-ups from previous meetings. For each case, the associated set of photos is displayed as a row of thumbnails

The presentation of the prototypes led to deep and lengthy discussions with the user group concerning the exact details of what to include in the system, how cases should be presented and entered, how follow-up cases should be handled, and so on. Once initial consensus was reached, based on the prototypes, development of the first version of the system began. According to the iterative development method, only the basic functionality of adding cases and managing these at meetings was initially implemented. In a subsequent iteration, secondary features, such as e-mail messaging and a discussion forum, were added to the system.

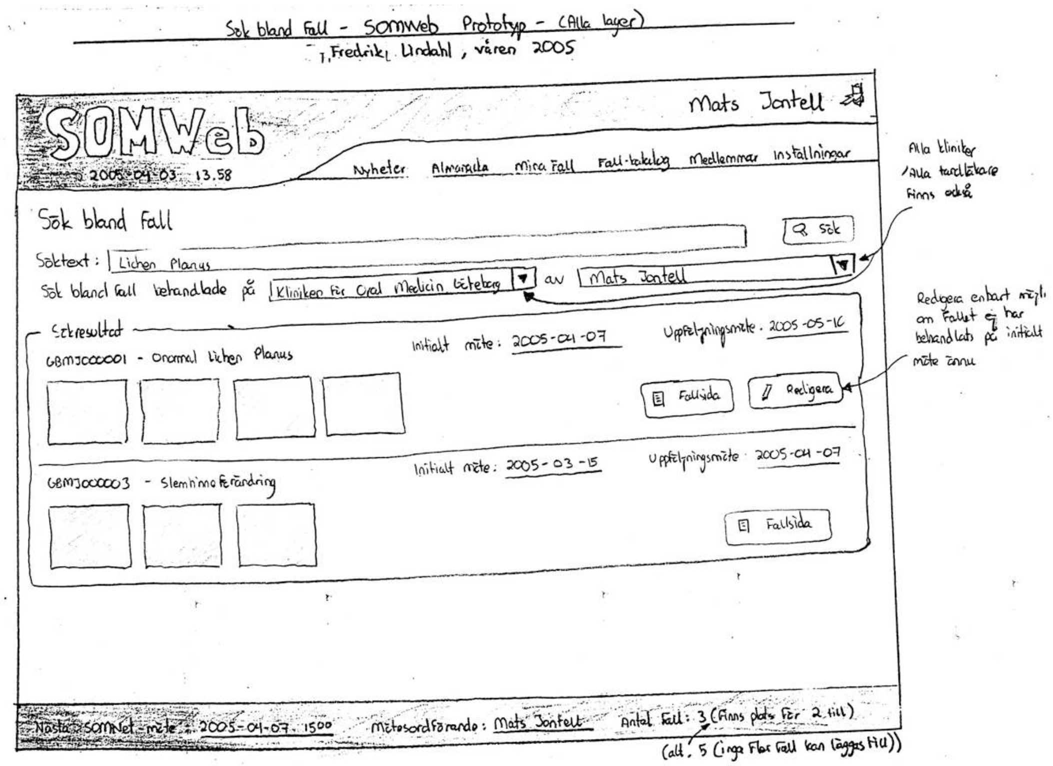


Figure 6.1: One of the paper prototypes of SOMWeb. Design by Fredrik Lindahl, Chalmers University of Technology.

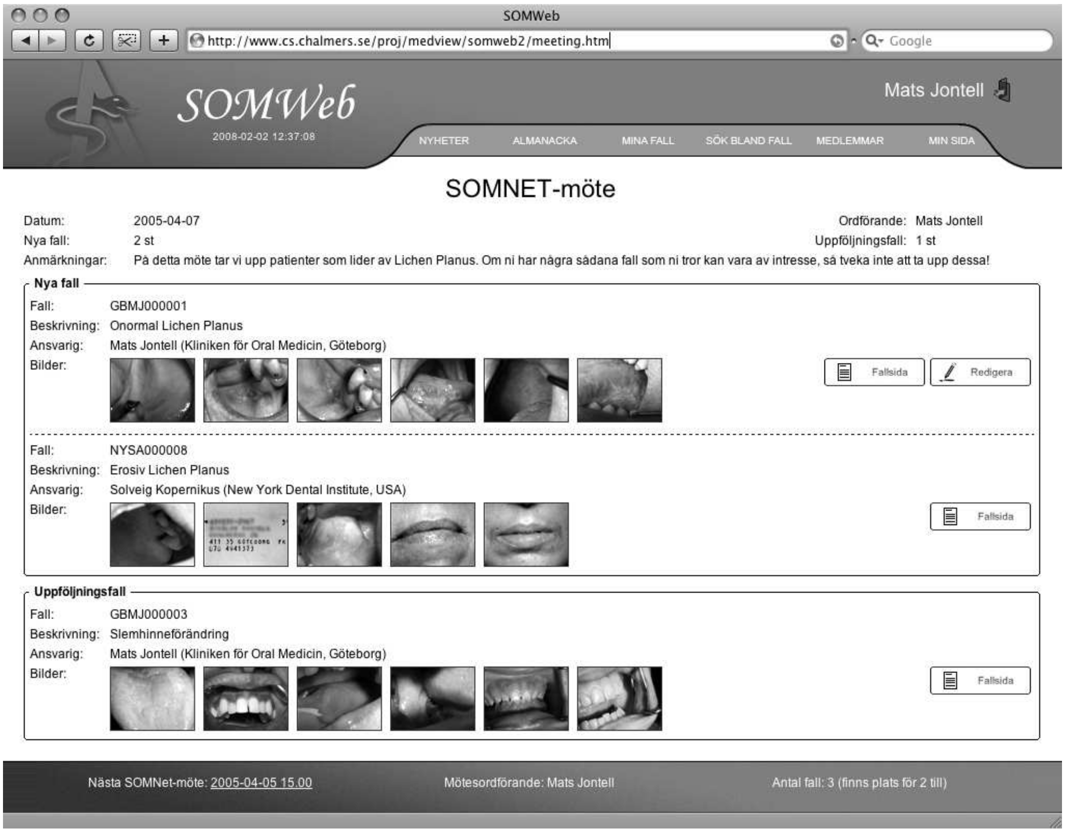


Figure 6.2: The first HTML-prototype of a SOMWeb meeting page. Design by Fredrik Lindahl, Chalmers University of Technology.

6.4 Functionality

The initial functionality of the SOMWeb system included case data entry according to user-defined templates, managing online meetings and assigning cases to these, viewing upcoming and archived meetings and their corresponding cases, and adding comments to cases. Users can employ free text search over examination data, while administrators are provided basic user handling, create and manage meetings, and post news.

More functionality has been added to SOMWeb since its launch: the possibility for potential new users to register themselves and then be accepted by an administrator, the possibility to add more types of material to cases (articles and related material from non-SOMWeb cases), and the case browser. In addition to this, small fixes and upgrades have been performed.

Navigation in SOMWeb is mainly carried out through a menu on the left, with subheadings for the main functions: meetings, cases, communication, and members. The contents of the menu depend on what type of membership users have and their preferences. For example, the possibility to add a case is only available to users who have a SOMNet membership type, and only members with administrative privileges see menu items related to administering users and members. Further, in the user preferences (further described in Section 6.4.1), members can indicate whether they want to access supplementary features such as forums. Figure 6.3 displays three different menus (though others are also possible).

This section continues with a presentation of SOMWeb's functionality related to each of the menu items, divided by the menu's headings: general information (Section 6.4.1), meetings (Section 6.4.2), cases (Section 6.4.3), communications (Section 6.4.4), and administrative functionality (Section 6.4.6). In the screenshots provided, system information, such as headings, is in English, but much of the content is in Swedish. For ease of reading, the screenshots are collected at the end of the section.

6.4.1 General Information

The menu headings under general information are news, user preferences, about SOMNet, and help.

News

The first page a member sees after logging in is a news page (Figure 6.4), where users put information relevant to all members.

User Preferences

From the main menu, members can access a window for editing their preferences. Figure 6.5 is a screenshot of this window. The preferences allow for the updating of contact information, language selection (English or Swedish), and choosing the clinic of the member. SOMWeb has three features that are regarded as supplementary and not initially available to all members: the forums, functions for e-mailing other members, and adding private comments to cases. These can be activated and inactivated in the user preferences.

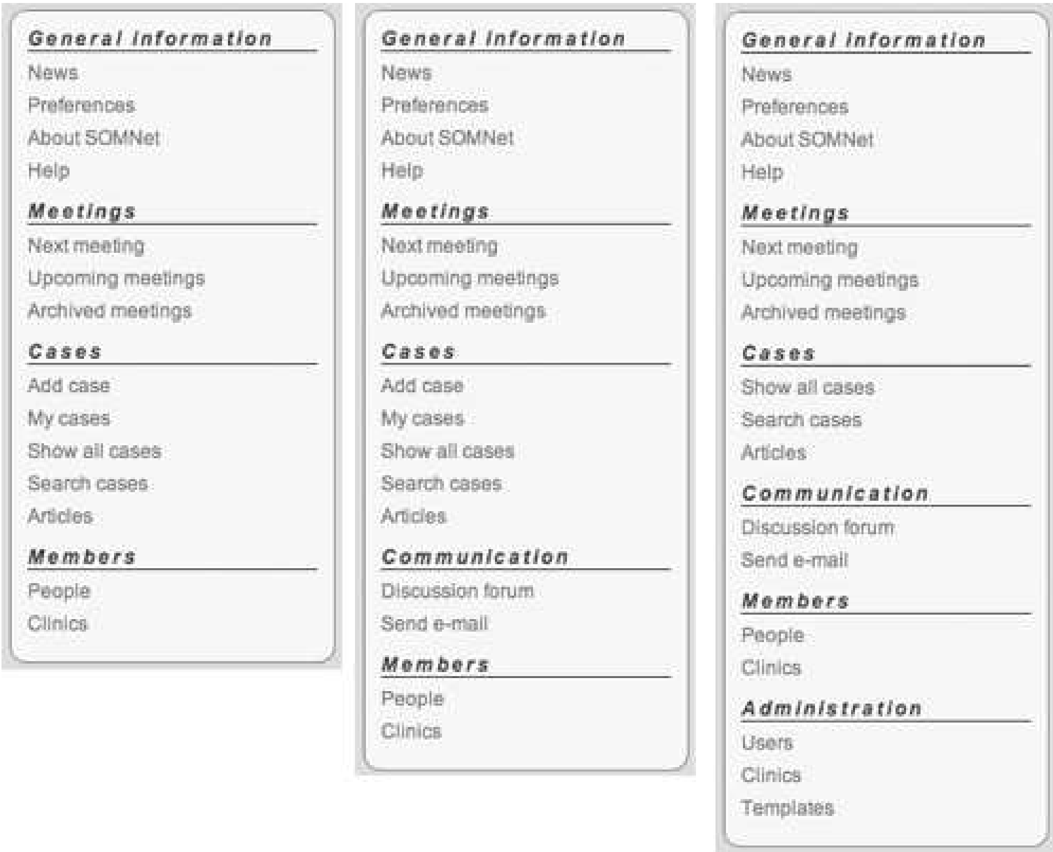


Figure 6.3: Screenshots of navigation menus in SOMWeb. The first menu is that of a SOMNet member who has not enabled forums and e-mail. The second menu is that of a SOMNet member who has enabled forums and e-mail. The third menu is that of an administrative non-SOMNet user who therefore cannot add cases but can, for example, edit membership information.

About SOMNet

The page about SOMNet contains information about how to participate in the telephone conferences, SOMNet's policy about images and patient information, and instructions for chairpersons.

Help

The help section of SOMWeb provides information about how to e-mail for support and explains the different parts of the user preferences.

6.4.2 Meetings

Under the meetings subheading, there is a link to the next meeting and to lists of archived and upcoming meetings.

Meeting Pages

Each meeting in the system has a meeting page, see Figure 6.6, displaying the meeting's date and designated chairperson. It also shows a listing of cases added for discussion at this meeting. The case list is divided into cases to be discussed for the first time (primary cases) and those to be followed up from previous meetings (secondary cases). Each case in the list includes the name of its owner and a short case description provided by the owner, as well as a link to the case presentation page. Finally, there is a list of the meeting's participants, to which members are added as they log into SOMWeb during the time of the meeting.

Archived and Coming Meetings

Figure 6.7 shows the archived meetings page. It lists all the meetings in the system dated before the current date. Each meeting includes information about time and chairperson, as well as a link to the meeting page. From the list of upcoming meetings, users with administrative privileges can add meetings to the system.

6.4.3 Cases

From the cases subheading, a member can add a case, as well as use various means of accessing the cases in the system. It is possible to browse cases via the meeting pages or through one of several options available under the cases subheading of the menu: the user's cases, the ontology-based case browser, listing all cases, and searching cases. If the user has private comments on any cases, an additional link appears in the menu for easy access to these. Finally, users also have access to a list of all the articles that have been entered for cases. In the following, I describe how cases are submitted and presented in the system. Furthermore, several ways of browsing cases are described. We do not look closer at the list of the user's own cases, nor the list of cases with private comments.

Case Entry and Presentation

When a member wants to add a case, they are presented with a blank form, generated from a consultation template. The form includes questions about current medications and tried treatments, for example, and a list of allowed values is shown for each question. If a needed value is missing from the list, the user may enter it into the value list. The questions are grouped into categories such as general anamnesis, diagnosis, and oral status. The form also includes a free text part, where the user can enter information not captured in the questions of the form. Images associated with the case are also submitted from this form. Figure 6.8 shows questions in the form for general information (heading not seen) and for general anamnesis. Figure 6.9, shows image upload, free text entry, and meeting selection. After adding a case, a link to the case presentation is automatically added to the page for that meeting.

All submitted cases generate a case presentation page, shown in Figure 6.10, which begins with administrative data: the case owner with affiliation, a short description provided by the owner, and any assigned meetings. A case consists of a number of consultation occasions, the first one of which is the initial case entry generated from the form in Figure 6.8. In addition to this, there are two other types of consultations: follow-up data and meeting decisions. These have separate entry forms with associated templates. For each consultation, thumbnails of associated images are shown along with a presentation generated from the consultation data. A larger image browser can be accessed from these thumbnails.

A longer case presentation is shown in Figure 6.11, exemplifying the different kinds of entries possible. The first consultation is the initial entry, and next is a follow-up consultation by the case submitter. Both of these were entered before the meeting at which the case was discussed. Next is a meeting comment made by the chairperson for when the case was initially discussed. Another follow-up entry by the case submitter is shown and finally, related material in the form of an article, entered by the meeting chairperson. The case was discussed again at a second meeting, but no comment was recorded.

If the user has activated the discussion forums, a link to the case's discussion thread is shown next to the case ID, if such a thread exists. If it does not exist, a link is shown through which a thread can be created. Next, if the user has activated private comments, a link for creating such notes is displayed. As more information becomes available, it can be added to the case. Both the case owner and other members are given the option of adding more material about the case, to make it possible for pathologists to add images and for users at the same clinic to share a case. If the current user is the chairperson of a meeting at which the case is discussed, then another link is shown for adding SOMNet meeting comments.

Support material can also be added to cases, both in the form of articles and related material, such as images from a similar case. When entering an article, there is a facility for searching PubMed[1] (see Figure 6.12) and automatically retrieving relevant article details using the PubMed API. All users can add such support material to cases.

[1]PubMed is a search engine for accessing scientific literature, especially related to medicine.

Ontology-based Case Browser

In the ontology-based case browser, depicted in Figure 6.13, cases are listed by diagnosis and treatment. For each of these, case browser classes are defined in relation to the refined value list ontology, as described in Section 5.2. Case browser classes for diagnosis include afte cases, cancer cases, and lichen cases. For each case browser class, there is a listing of the system cases that match the case browser description. For the lichen cases, for example, there is a listing of those SOMWeb cases whose tentative or definitive diagnosis belongs to the class of lichen diagnoses. Administrative users adjust which case browser classes are included and what diagnosis belong to each through the case browser ontology manipulator, described in Section 6.4.6. The implementation of the case browser is described in Section 6.6.4.

Listing All Cases

In the listing of all the cases in the system, see Figure 6.14, a table displays one case per row. Each row has information about the submitter's first and surname, the city where the clinic is located, the short description of the case, which is also a link to the case presentation, the date of the meeting at which the case was first discussed, and an indication of the contents of the case. The content is shown through icons for consultations, meeting comments, articles, and related material. The amount of each in the case is shown through a mouseover message on the icons. The table can be sorted by clicking each of the table headers.

Searching Cases

SOMWeb also includes a free text search of the contents of cases, seen in Figure 6.15. For the search term entered in the box, there is a listing of all cases where a match is found anywhere in the case text.

Articles List

Members can add related articles to each SOMWeb case. A list of all the articles can be reached from the menu, as depicted in Figure 6.16.

6.4.4 Communications

The main form of communication between SOMNet's members is the teleconferences. However, within SOMWeb a discussion forum is also provided, see Figure 6.17. For each case, a discussion thread can be created from the case presentation page. If a discussion thread exists for the case, it can be accessed from the presentation. If not, then clicking a link creates a new thread. A discussion forum listing all case discussions is located under the communication subheading. The users can also create threads not related to cases.

Another communication facilitated by SOMWeb is reaching other clinicians by e-mail. These can be sent directly from SOMWeb, either from the communication subheading or to the case owner from a case presentation page.

6.4.5 Members

In SOMWeb, members provide their real names and workplaces. From the members sub-heading, users can access listings of all members and clinics. The listing of members gives each member's name, clinic, and number of submitted cases. The listing of clinics provides the name, city, country, e-mail address, as well as telephone and fax numbers of each clinic.

6.4.6 Administrative Functionality

SOMWeb has functions that only users with administrative privileges can access: handling members and clinics, and manipulating the case browser ontology. Members with administrative privileges are those of type Admin or those of type SOMNet with an admin role.

Handling Members and Clinics

There is one page for handling members and one for handling clinics. Each page lists the member and clinic instances, along with their contact information. For each member or clinic, the administrative user may choose to edit the information or delete the member. Administrators can also approve users who have submitted requests for membership from the front page of SOMWeb.

Manipulating the Case Browser Ontology

The refined value list ontology and case browser ontologies, described in Section 5.2, can be edited via SOMWeb. This is done via the case browser ontology manipulator, seen in Figure 6.19. The user does not interact directly with the OWL representation, but may through SOMWeb:

- Add individual values to a subclass; for example, a `Diagnosis` individual can be added to the `Diagnosis` subclass `Lichen`.
- Create a new subclass of a value list class; for example, add a new subclass of `Treatment`, such as `Extraction`.
- Add a new case browser class and associate it with a subclass of a value list class; for example, add a class `ExtractionCase` and associate it with `Extraction` (this creates a definition similar to that of Figure 5.11).

These options are currently only available to administrative users, but they may be made available to more users in the future. The present system has no quality control for manipulating the ontology, which may be necessary if ontology manipulation is opened up to more users.

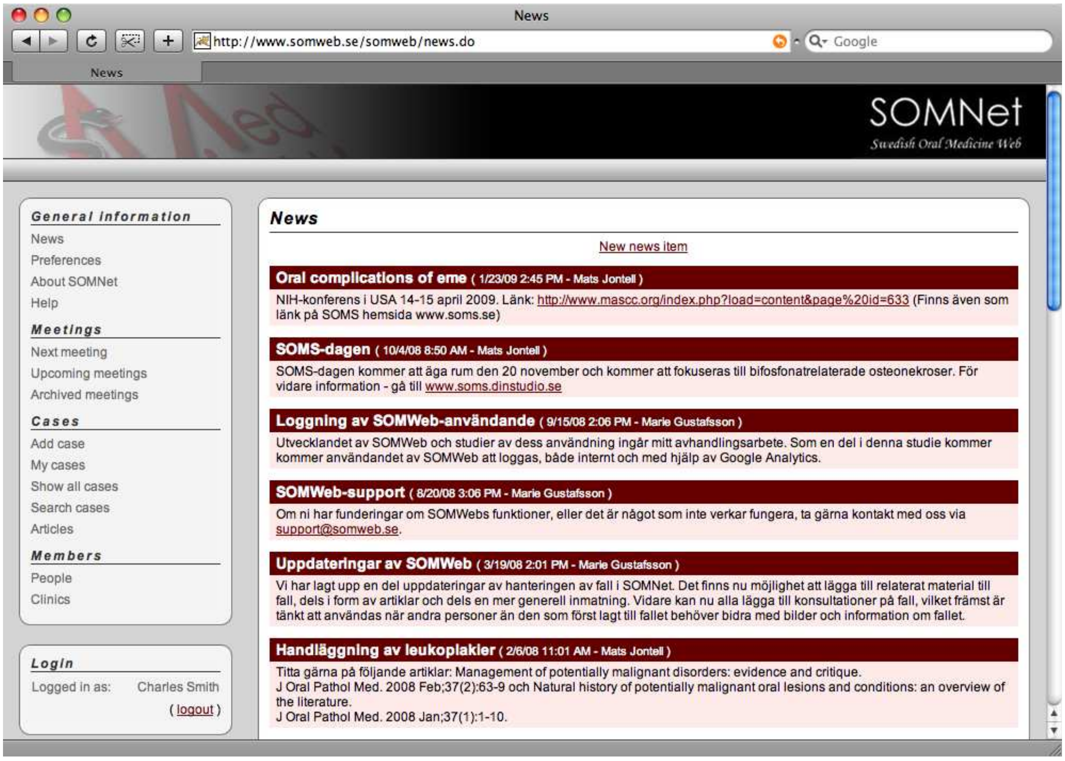


Figure 6.4: News page with information for all members. Any member can add information to the page using the "New news item" link.

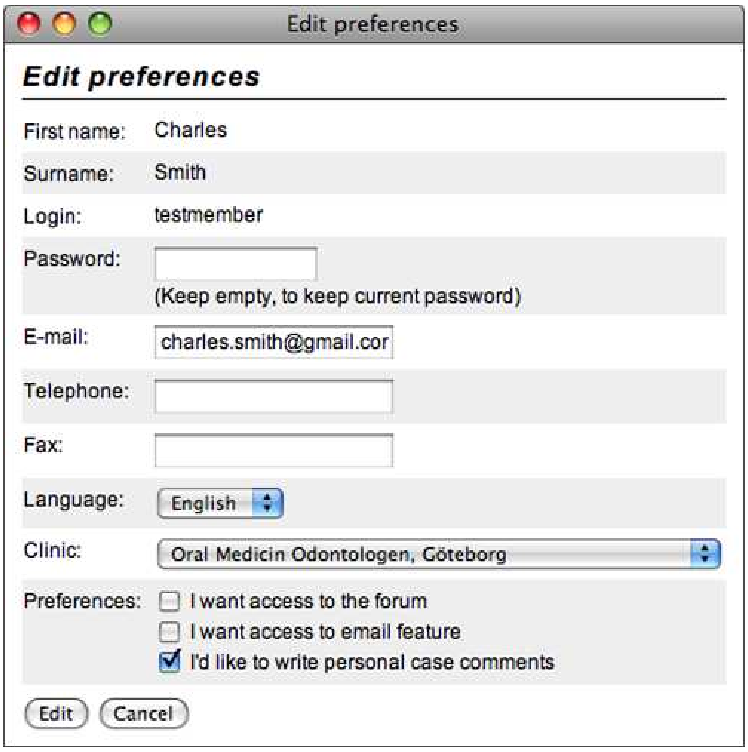


Figure 6.5: Screenshot of SOMWeb window for editing user preferences, with details for a fictive member. Members can update contact information, select language (among Swedish and English), and indicate what clinic they work at. Three SOMWeb features are not initially available to new members: the forums, e-mailing functionality, and private case comments. These can be activated and inactivated here.

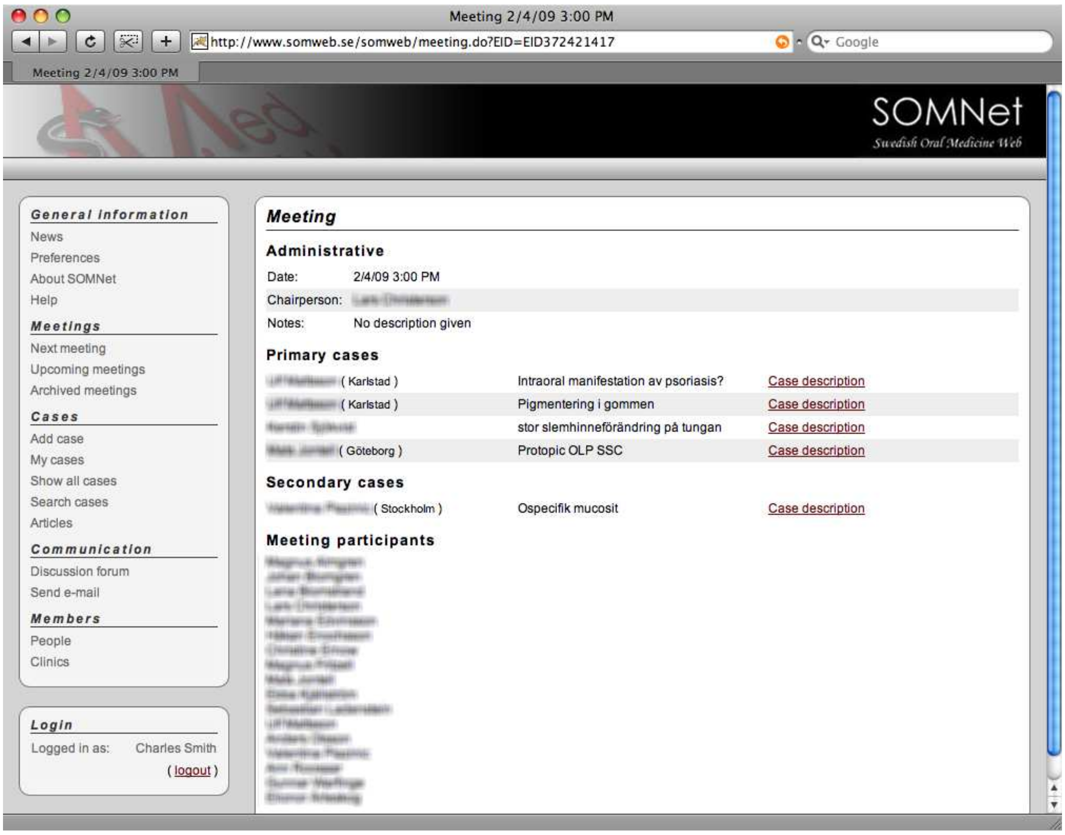


Figure 6.6: Meeting page with date, chairperson, a list of cases added for discussion at this meeting, and meeting participants. The cases are divided into primary cases, those being brought up for the first time, and secondary cases, those being followed up from previous meetings. For each case, the name of the submitter, the clinic, if available, a short description of the case provided by the submitter, and a link to the case description, are provided. Finally, the meeting's participants are listed. Users are added to this list when they log into the system during the time of the meeting.

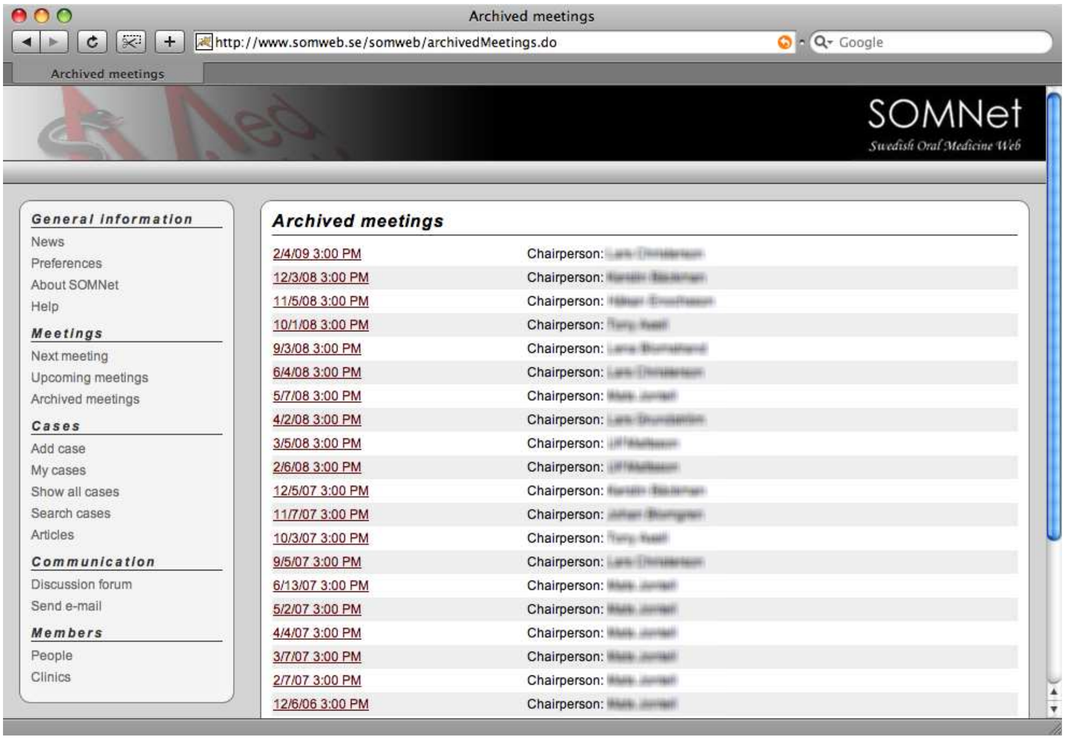


Figure 6.7: Screenshot of page listing archived meetings in SOMWeb. The page collects all those meetings dated before the current date. For each meeting, there is a listing of its date and time of day along with its chairperson. The date and time information is also a link to the meeting page.

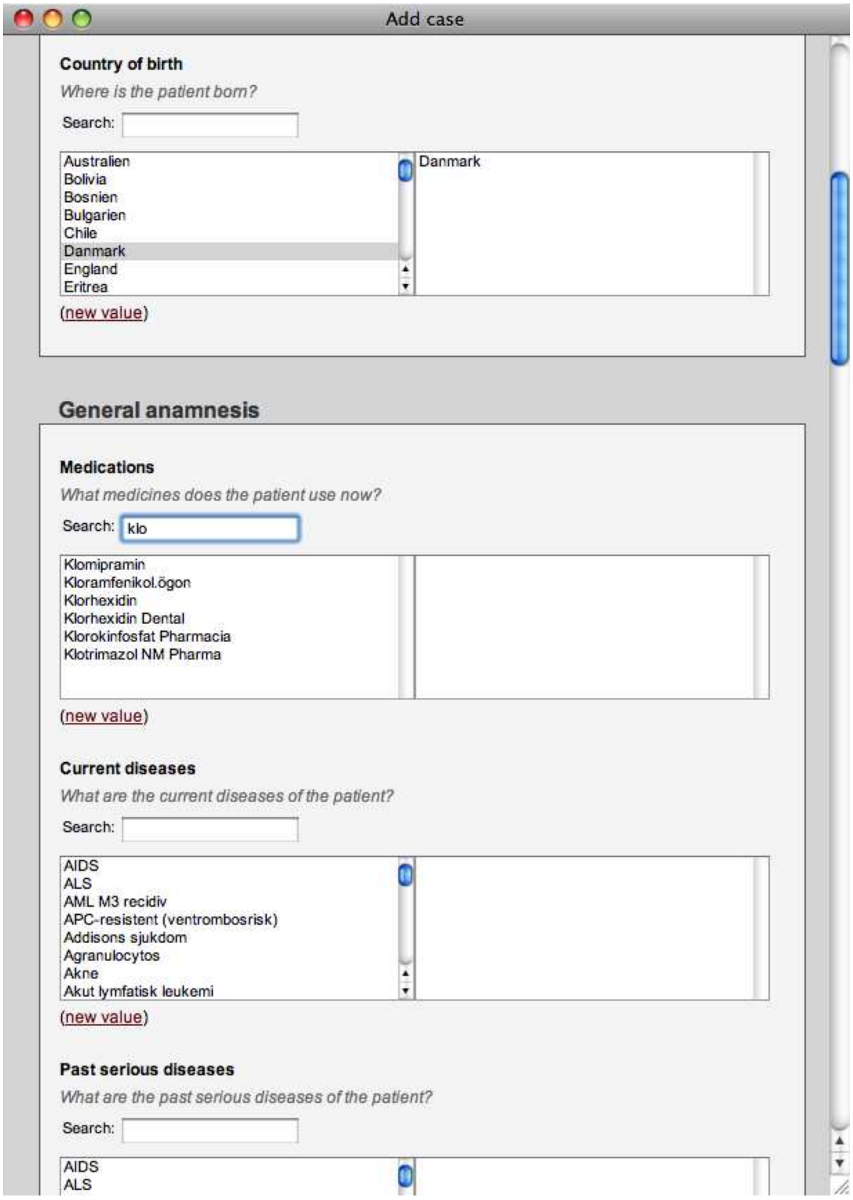


Figure 6.8: Screenshot of part of a SOMWeb case entry form. The country of birth has been selected from the list of values to the left. To indicate medications, a search has helped the user to narrow down the values from which to select.

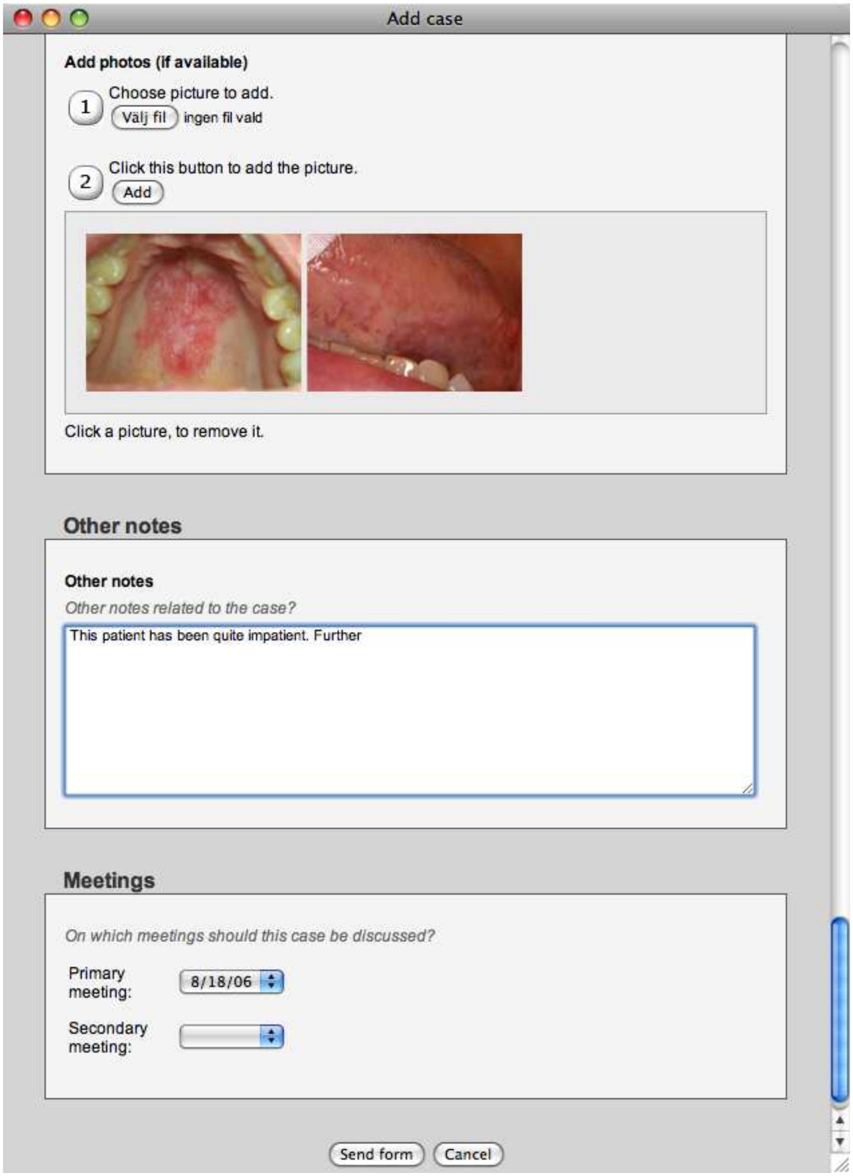


Figure 6.9: Screenshot of the last part of the SOMWeb case entry form. The user has chosen two images to upload and entered some information in the free text entry box. Finally, the meetings at which the case is to be discussed can be selected.

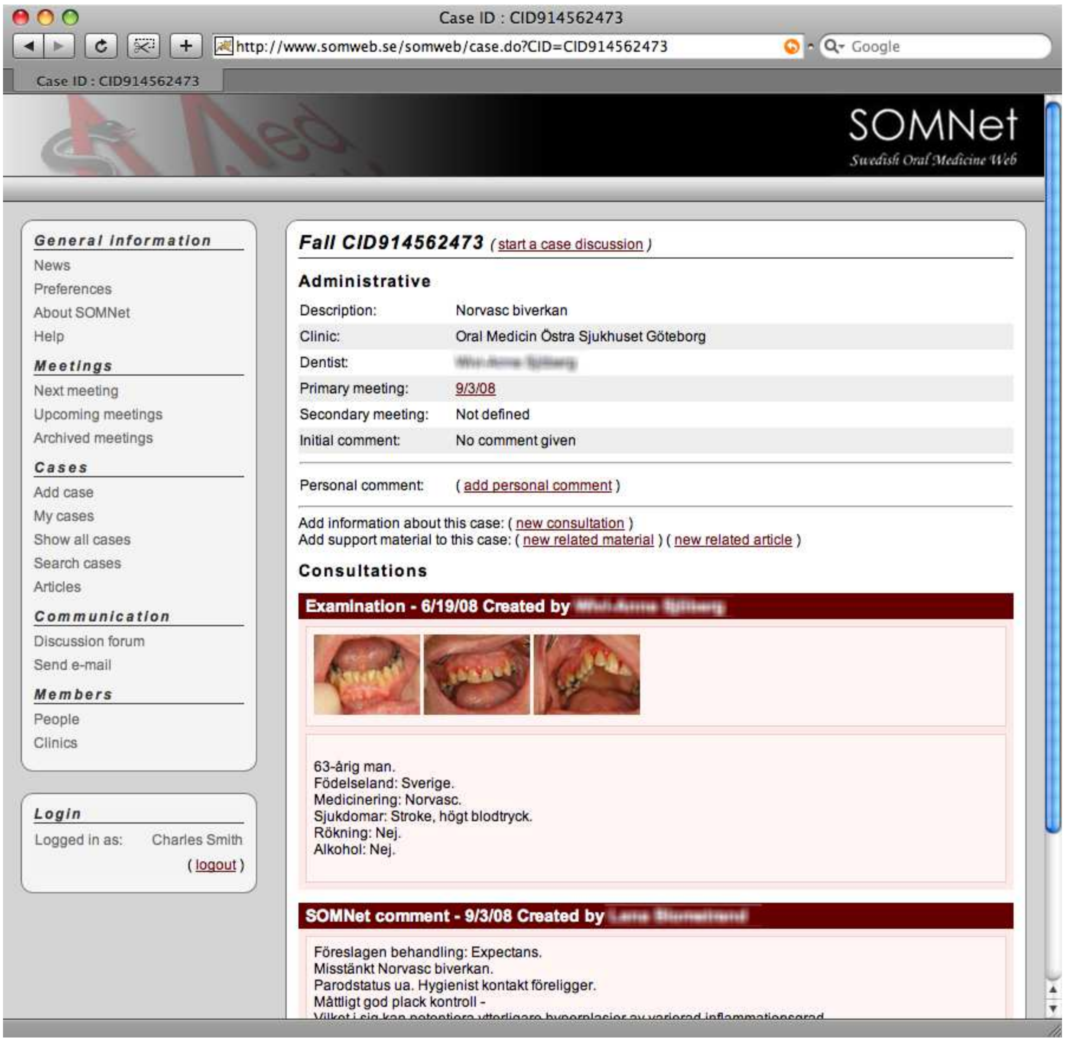
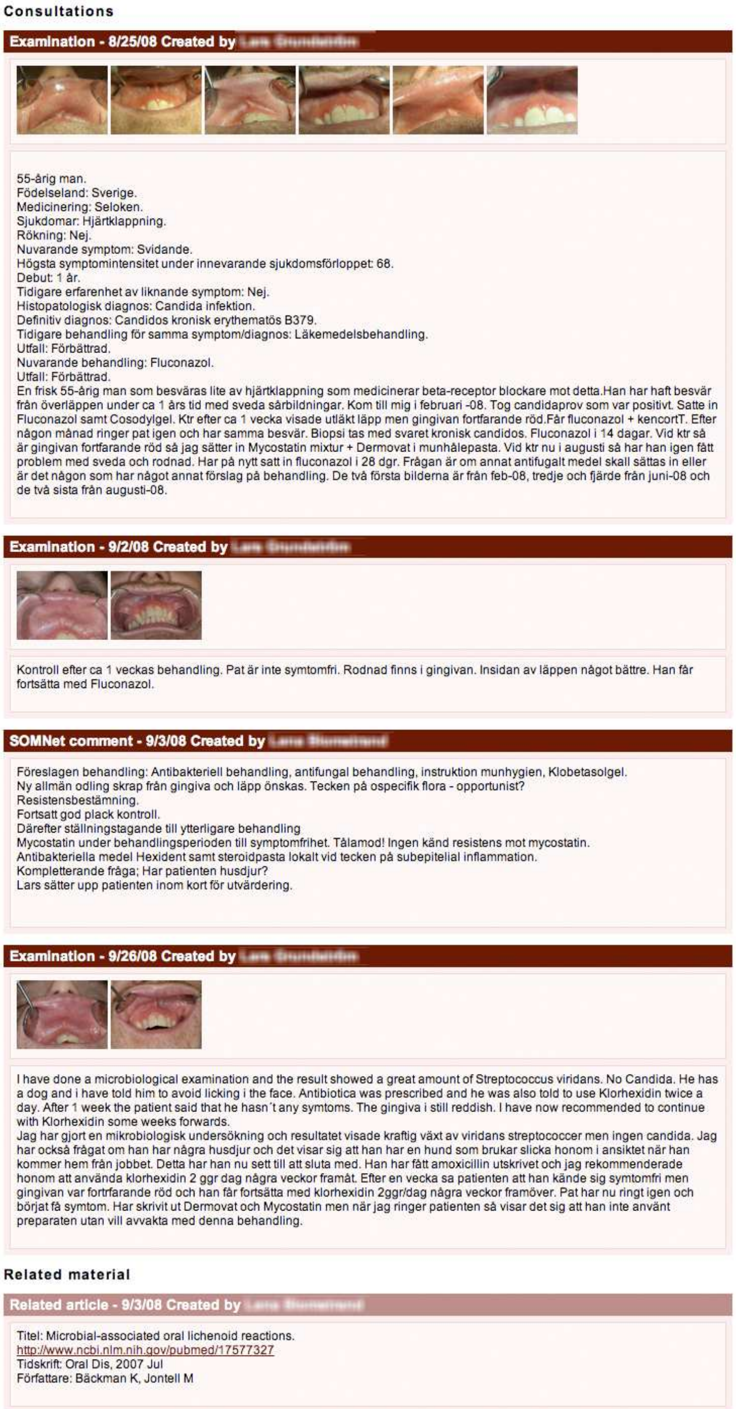


Figure 6.10: Case presentation page listing administrative data, consultation occasions with summarized case data and associated images, and a SOMNet meeting comment. Notice also the link next to the case id for a forum case discussion, the possibility of adding a private comment, as well as additional case information.



Consultations

Examination - 8/25/08 Created by

55-årig man.
Födelseland: Sverige.
Medicinering: Seloken.
Sjukdomar: Hjärtklappning.
Rökning: Nej.
Nuvarande symptom: Svidande.
Högsta symptomintensitet under innevarande sjukdomsförloppet: 68.
Debut: 1 år.
Tidigare erfarenhet av liknande symptom: Nej.
Histopatologisk diagnos: Candida infektion.
Definitiv diagnos: Candidos kronisk erythematös B379.
Tidigare behandling för samma symptom/diagnos: Läkemedelsbehandling.
Utfall: Förbättrad.
Nuvarande behandling: Fluconazol.
Utfall: Förbättrad.
En frisk 55-årig man som besväras lite av hjärtklappning som medicinerar beta-receptor blockare mot detta.Han har haft besvär från överläppen under ca 1 års tid med sveda sårbildningar. Kom till mig i februari -08. Tog candidaprov som var positivt. Satte in Fluconazol samt Cosodylgel. Ktr efter ca 1 vecka visade utläkt läpp men gingivan fortfarande röd.Får fluconazol + kencortT. Efter någon månad ringer pat igen och har samma besvär. Biopsi tas med svaret kronisk candidos. Fluconazol i 14 dagar. Vid ktr så är gingivan fortfarande röd så jag sätter in Mycostatin mixtur + Dermovat i munhålepasta. Vid ktr nu i augusti så har han igen fått problem med sveda och rodnad. Har på nytt satt in fluconazol i 28 dgr. Frågan är om annat antifugalt medel skall sättas in eller är det någon som har något annat förslag på behandling. De två första bilderna är från feb-08, tredje och fjärde från juni-08 och de två sista från augusti-08.

Examination - 9/2/08 Created by

Kontroll efter ca 1 veckas behandling. Pat är inte symtomfri. Rodnad finns i gingivan. Insidan av läppen något bättre. Han får fortsätta med Fluconazol.

SOMNet comment - 9/3/08 Created by

Föreslagen behandling: Antibakteriell behandling, antifungal behandling, instruktion munhygien, Klobetasolgel.
Ny allmän odling skrap från gingiva och läpp önskas. Tecken på ospecifik flora - opportunist?
Resistensbestämning.
Fortsatt god plack kontroll.
Därefter ställningstagande till ytterligare behandling
Mycostatin under behandlingsperioden till symptomfrihet. Tålamod! Ingen känd resistens mot mycostatin.
Antibakteriella medel Hexident samt steroidpasta lokalt vid tecken på subepitelial inflammation.
Kompletterande fråga; Har patienten husdjur?
Lars sätter upp patienten inom kort för utvärdering.

Examination - 9/26/08 Created by

I have done a microbiological examination and the result showed a great amount of Streptococcus viridans. No Candida. He has a dog and i have told him to avoid licking i the face. Antibiotica was prescribed and he was also told to use Klorhexidin twice a day. After 1 week the patient said that he hasn´t any symtoms. The gingiva i still reddish. I have now recommended to continue with Klorhexidin some weeks forwards.
Jag har gjort en mikrobiologisk undersökning och resultatet visade kraftig växt av viridans streptococcer men ingen candida. Jag har också frågat om han har några husdjur och det visar sig att han har en hund som brukar slicka honom i ansiktet när han kommer hem från jobbet. Detta har han nu sett till att sluta med. Han har fått amoxicillin utskrivet och jag rekommenderade honom att använda klorhexidin 2 ggr dag några veckor framåt. Efter en vecka sa patienten att han kände sig symtomfri men gingivan var fortrfarande röd och han får fortsätta med klorhexidin 2ggr/dag några veckor framöver. Pat har nu ringt igen och börjat få symtom. Har skrivit ut Dermovat och Mycostatin men när jag ringer patienten så visar det sig att han inte använt preparaten utan vill avvakta med denna behandling.

Related material

Related article - 9/3/08 Created by

Titel: Microbial-associated oral lichenoid reactions.
http://www.ncbi.nlm.nih.gov/pubmed/17577327
Tidskrift: Oral Dis, 2007 Jul
Författare: Bäckman K, Jontell M

Figure 6.11: Screenshot of a longer case presentation from SOMWeb, only showing the consultations and related material and not the administrative information.

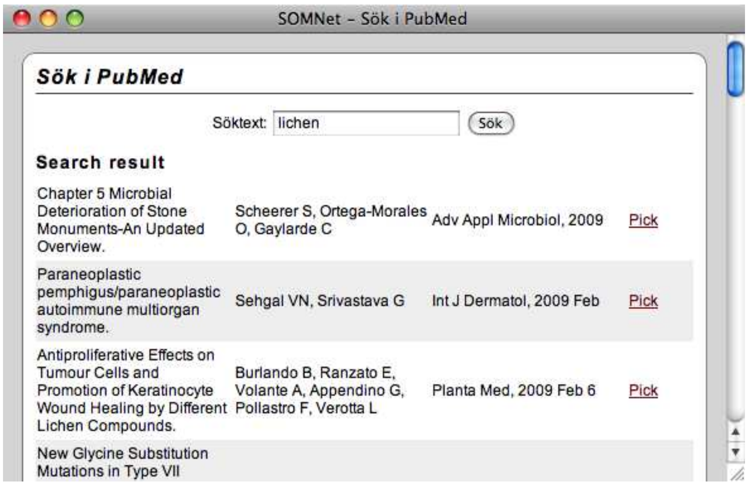


Figure 6.12: Screenshot of related article entry from PubMed. The user enters a search word and matching PubMed articles are displayed. The user can then select one of these for entry into SOMWeb.

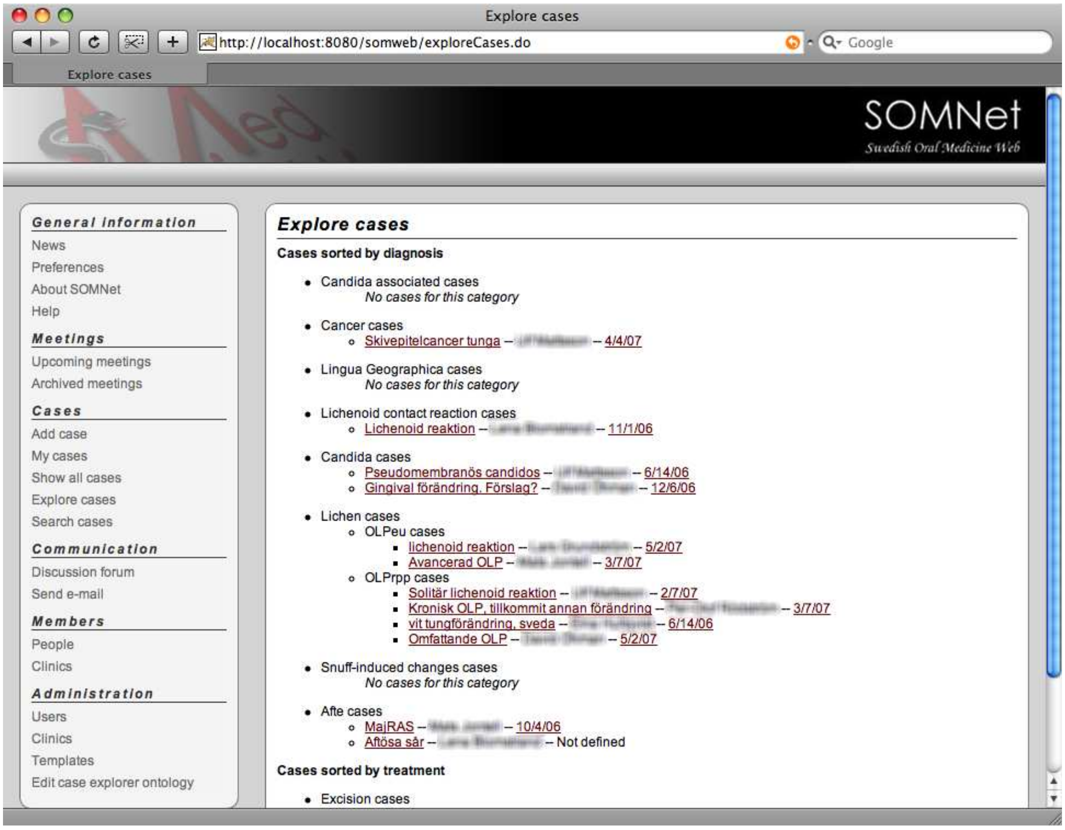


Figure 6.13: Screenshot of ontology-based case browser in SOMWeb. Cases are sorted by diagnosis and treatment, and for each of these various case browser classes have been defined. For diagnosis, these include lichen and afte. Based on the definitions, there is a listing of cases, if any are available in the system. A short description with a link to the case, the case owner, and the meeting at which it was initially presented are given for each case.

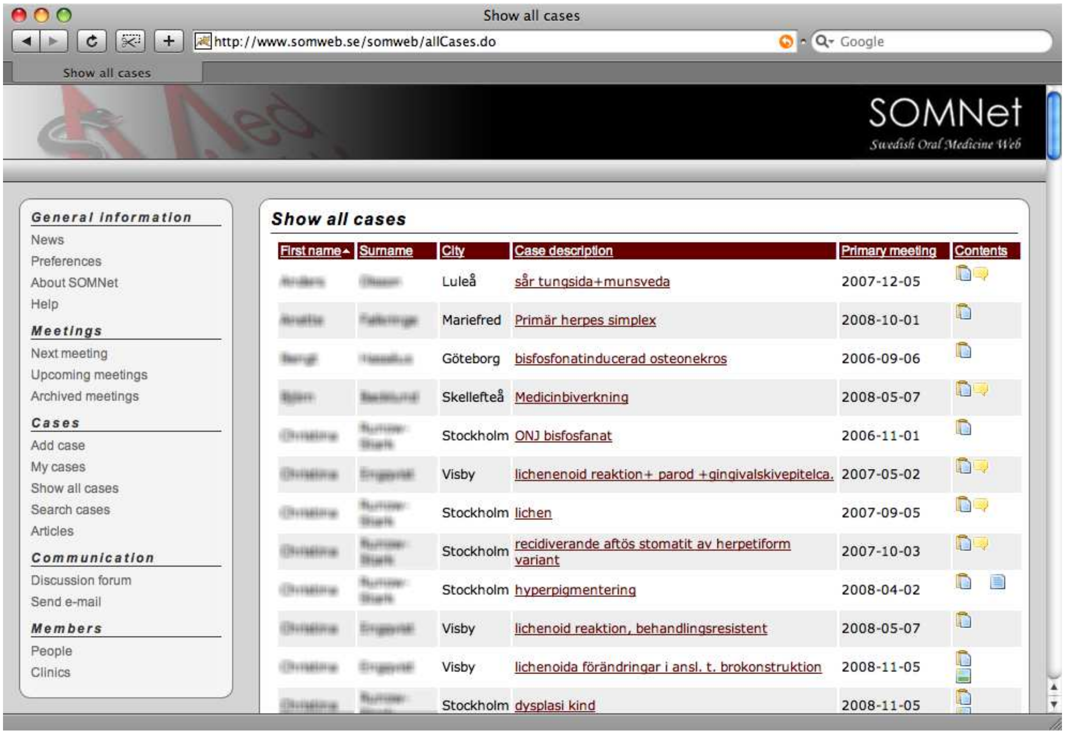


Figure 6.14: Screenshots of page listing all the cases in SOMWeb. Each row in the table is a SOMWeb case, containing the name and city of the submitter, the short description of the case, the meeting at which the case was initially discussed, and informative icons of the contents of the case.

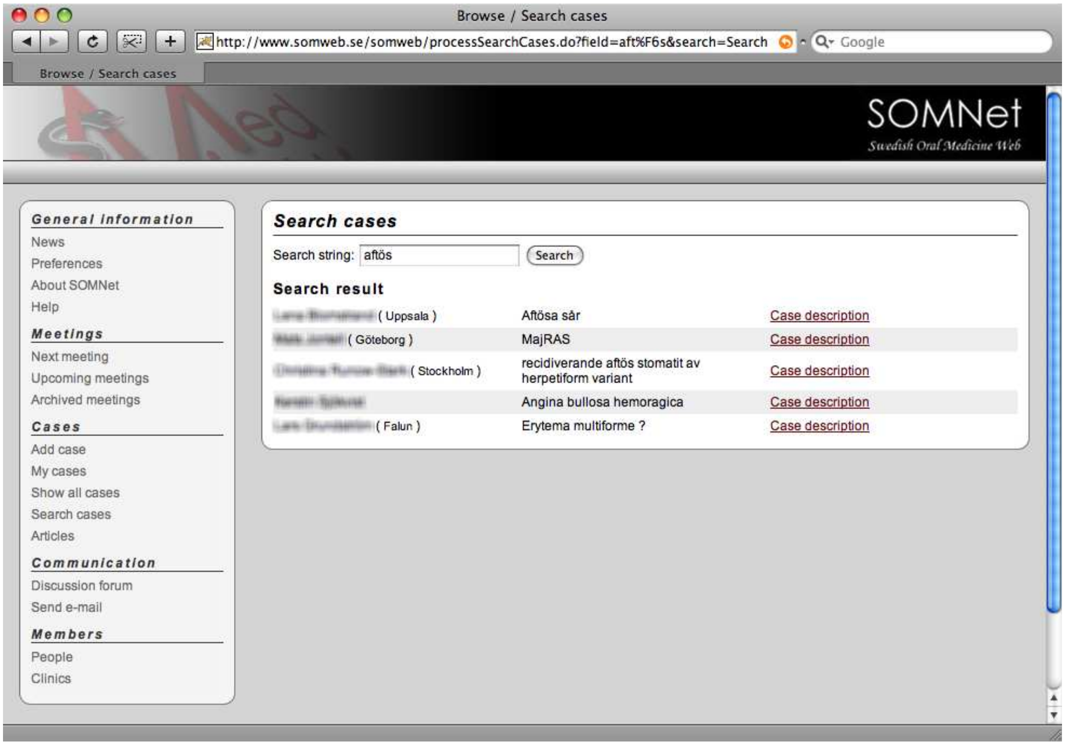


Figure 6.15: Screenshots of case search page in SOMWeb. A search term is entered in the box, and a list of those cases in the system that match this term through free text search is listed.

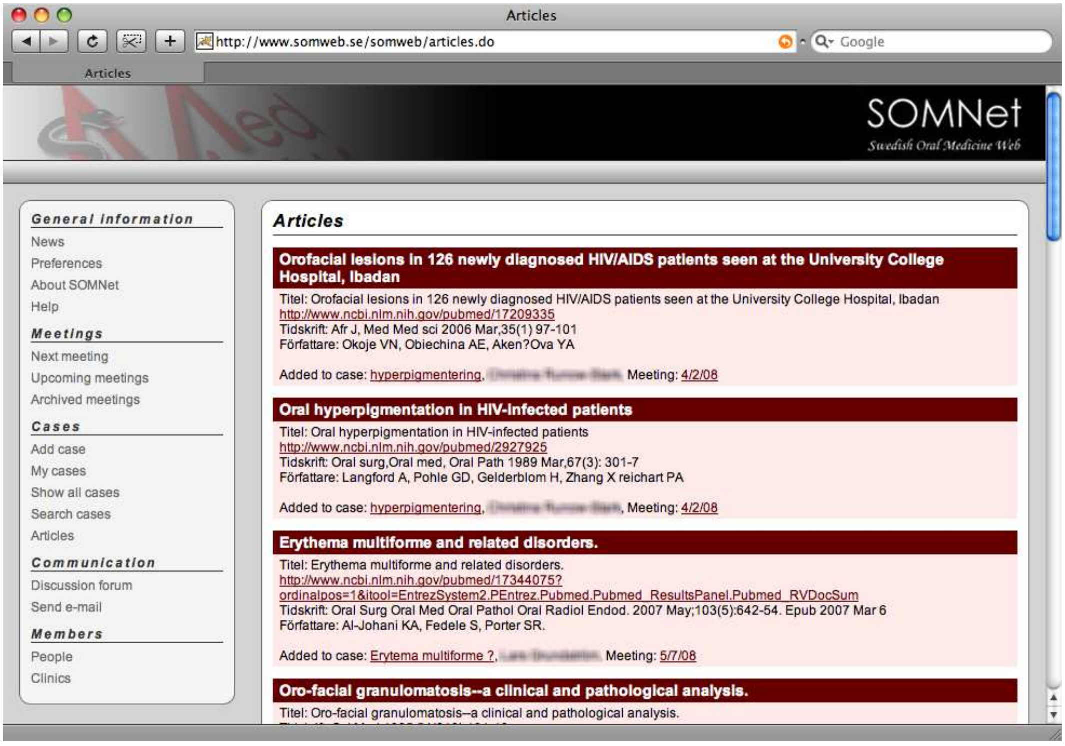


Figure 6.16: Screenshot of page listing all the articles in SOMWeb. The page collects all article entries provided for the individual articles in SOMWeb.

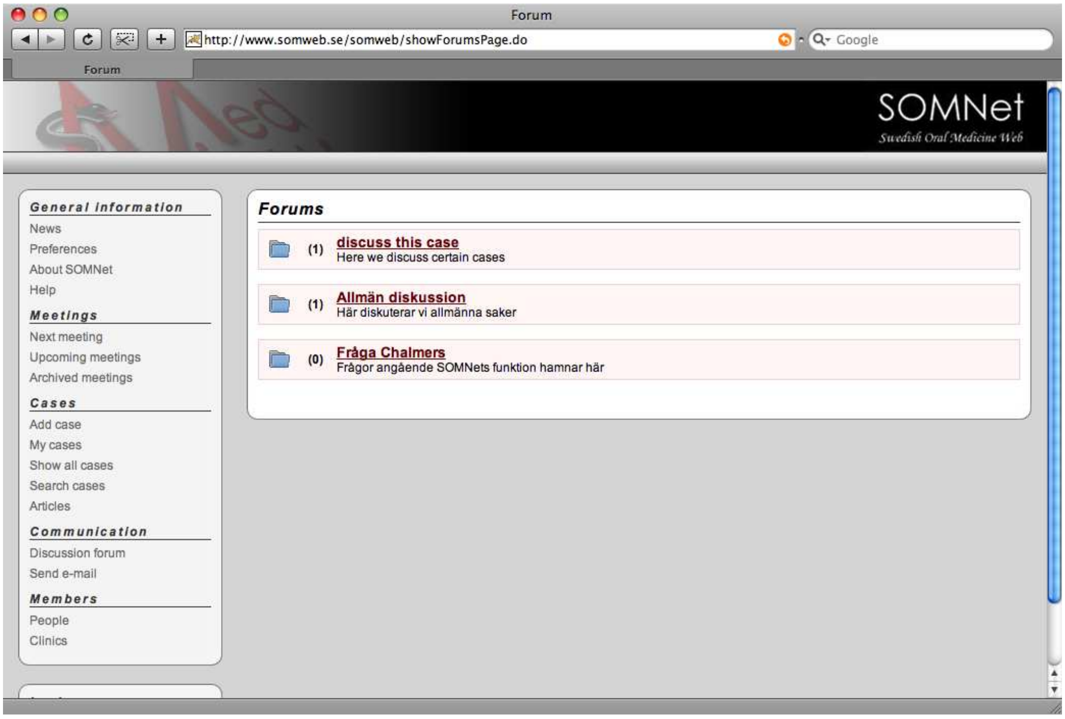


Figure 6.17: Screenshot of page listing discussion forums in SOMWeb. Only part of the forum titles and information is available in English. The first forum is for case discussions, the second for general discussion, and the third is questions for the developers. The number in parenthesis before the discussion title indicates the number of threads in the forum.

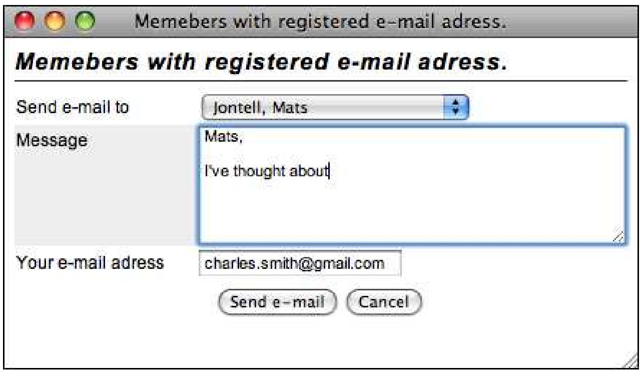


Figure 6.18: Screenshot of e-mailing functionality in SOMWeb. The user can select among members whose e-mail address is recorded and enter a message. The user's own e-mail address is filled in automatically.

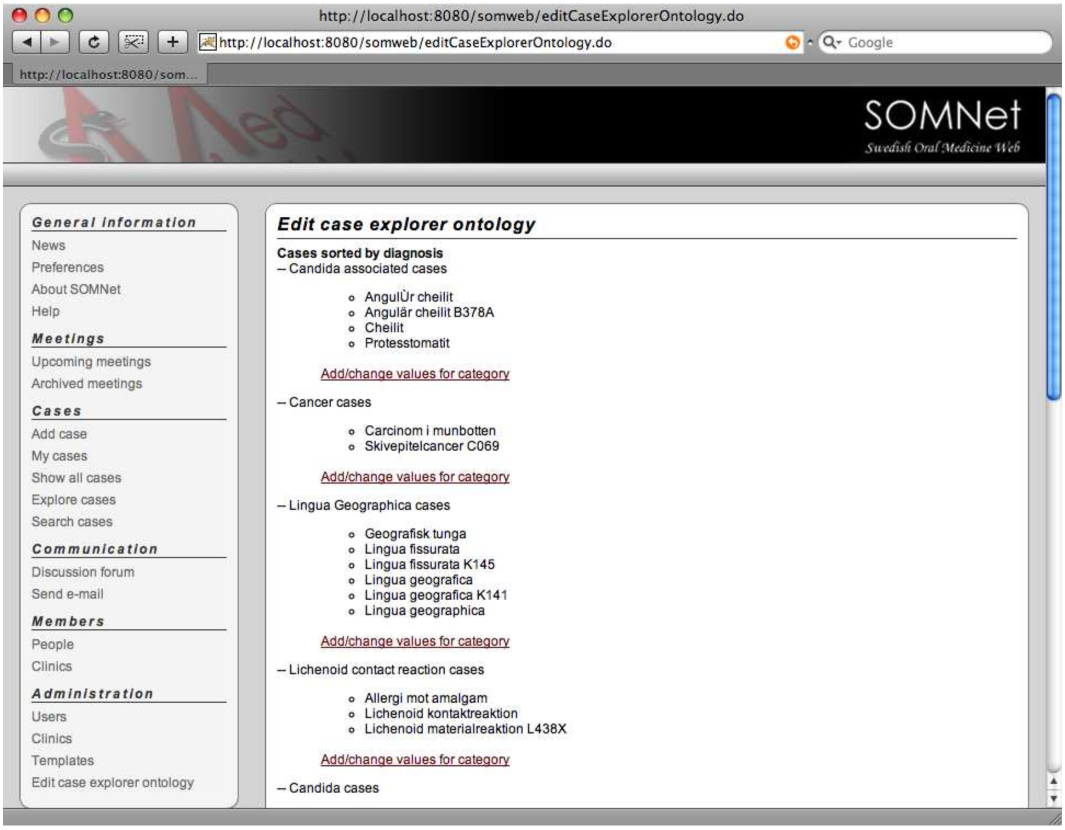


Figure 6.19: Screenshot the case browser ontology manipulator in SOMWeb. Shown are case browser classes which are subclasses of `DiagnosisCase`, displaying the term values that are associated with each. For each case browser class, it is possible to open a separate window for editing, adding or deleting, the values associated with it.

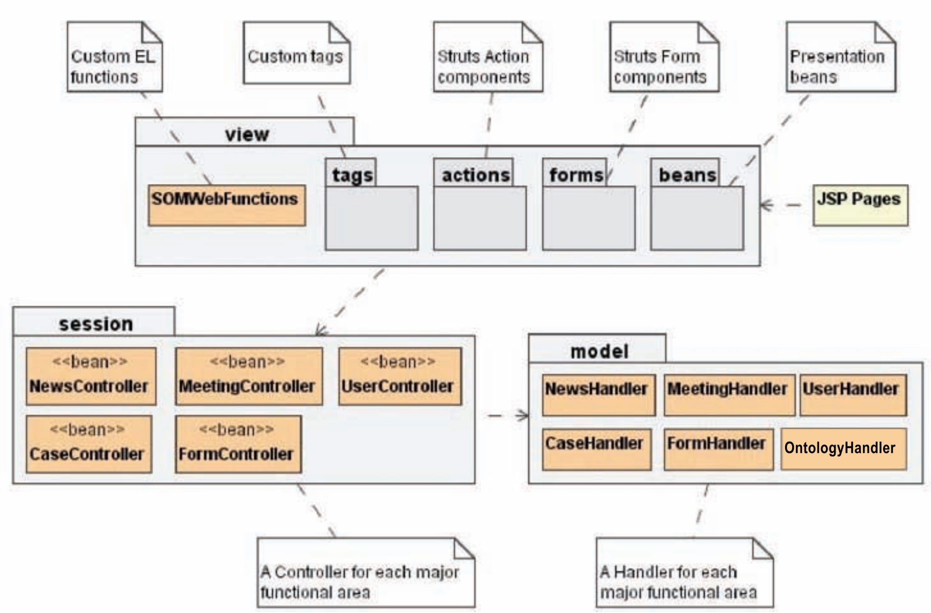


Figure 6.20: Overview of the SOMWeb system architecture. Adapted from a figure by Fredrik Lindahl, Chalmers University of Technology.

6.5 System Architecture

SOMWeb is built on Java Enterprise technology, using Apache Tomcat[2] as the core Web container. The system is an extension of the Apache Struts Model-2 Web application framework.[3] Model-2 frameworks (a variation of the classic Model-View-Controller (MVC) design paradigm) are based on the idea that Java Servlets execute business logic while presentation resides mainly in server pages. As stated in [86], reusing mature technology gives a Semantic Web portal improved usability, reliability, and scalability.

The SOMWeb system is a layered architecture, conceptually divided into four main layers – the view layer, the session layer, the model layer, and the foundation layer, as depicted in Figure 6.20. The view layer is comprised of Java Server Pages (JSP) using Expression Language (EL) constructs, with custom tags and functions in addition to tags from the Java Standards Tag Library (JSTL) and the various Apache Struts tag libraries. The styling and content layout is done using Cascading Style Sheets (CSS). The session layer has components dealing with the current user session, and is responsible for transforming the application's internal state into the presentation JavaBeans used by the server pages. The model layer has components making up the application's internal state, and is roughly divided into the major functional areas provided by the system.

The SOMWeb system's use of Semantic Web technologies is handled in the model layer, and described in the following section.

[2] `http://tomcat.apache.org`
[3] `http://struts.apache.org`

6.6 Use of Semantic Web Technologies

In SOMWeb, Semantic Web technologies are used to handle both clinical concepts and data as well as community resources. By clinical concepts I mean templates for examinations[4] and related terminology, and with clinical data I refer to the examination and consultation data entered by users. By community resources, I mean its central concepts such as users, meetings, news, and case metadata. The use of OWL and RDF to describe these is covered in Chapter 5. In this section I present how the SOMWeb system makes use of and interacts with these. The Jena API is used to access and manipulate OWL and RDF with Java.

The SOMWeb system reuses Java code libraries from the MedView project. In the MedView application suite, almost all data handling functions were put into a common package called MedView data handling. The naming of the package is historical and it has grown to handle more than just the data of examinations. It now also includes the handling of terms and values, the templates and translators used in automatically generating summaries of examinations, the parsing of patient identifiers, and language handling. This has led to the package being further subdivided into the subpackages of aggregation, examination, images, queries, and term values. The MedViewDataHandler class, a singleton-accessed facade in terms of design patterns, is the single access point for outside packages. There are separate data handlers for examinations (with a corresponding interface ExaminationDataHandler) and for terms (with a corresponding interface TermDataHandler).

In the first version of SOMWeb, the previous MedView structures (see the left hand side of Figure 5.3 on page 73) and code were employed for forms, values, and individual examinations. The intention was to migrate the handling of these to the OWL and RDF described in the previous chapter. SOMWeb Java classes have been written to this extent, but it should be noted that while Section 6.6.1 describes the construction of SOMWeb input forms from the OWL examination templates of the previous chapter, such templates are not used in the live version of SOMWeb. This is because many of the requirements set out for the templates were not fulfilled, and because of the conclusion that the current OWL is not very well suited for representing templates.

The Semantic Web technology basis of SOMWeb includes Java classes that parallel the MedView datahandling classes to use OWL-based templates (Section 6.6.1), OWL-based value lists (Section 6.6.2), and to output RDF examination files (Section 6.6.3). Also included in SOMWeb are the Java classes related to the case browser (Section 6.6.4) and manipulating the case browser ontologies (Section 6.6.5), primarily using the OntologyHandler class of the model layer of Figure 6.20. Finally, Semantic Web technologies are used to handle data related to community resources (Section 6.6.6).

6.6.1 Constructing Input Forms from OWL Examination Templates

The SOMWeb system allows its users to select and use different examination templates to enter individual examinations. Such examination templates were originally only available in the MedForm XML format, but adaptations were made so that OWL examination templates

[4]Though, as explained below, the live version of the system does not use OWL for templates

can also be used. These adaptations are made mainly by creating implementations of the FormPersistence and FormReader interfaces which read OWL templates: FormPersistence-OWL and OWLFormReader. Also, the FormUtilities class has an added createRdfExaminationModelFromForm method, complementing its existing createExaminationTreeFromForm method.

The buildForm method of the FormPersistenceOWL takes the names of OWL-files describing different types of examination templates used in the community (such as initial case entry and decisions from SOMNet meetings), and calls the buildForm method of the OWLFormReader with these. This buildForm method differs little on the surface from the corresponding method in MFormReader. It creates a DefaultForm object, adds children to this in the form of categories, and adds children to these categories in the form of inputs.[5]

The difference is how these categories and inputs are read from file, where the MFormReader uses an XML file and the OWLFormReader uses an OWL file. In OWLFormReader, the list of categories is first retrieved through the property `hasExaminationCategories` of the `Examination` class. The reader then iterates through the `Category` classes found in this list and constructs a Category object for each. In the construction of each Category object, the list of categories is accessed through the `hasInputs` property. For each input, an Input object of appropriate type (e.g., single, multiple, and VAS) is constructed. The appropriate type is obtained by examining the `InputProperty`'s superproperty.

6.6.2 Value Lists

The OWL value lists are handled in SOMWeb by adding classes to MedView datahandling that are adapted for this purpose. The TermDataHandler interface of MedView datahandling is implemented using the abstract class AbstractTermDataHandler. In addition to the previous implementation, ParsedTermDataHandler, there is now an RdfTermDataHandler. These classes read the value list files to Java hashmaps, and allow for the accessing of terms and values, where the key is the term name, and the value is a vector of values for the corresponding term.

In RdfTermDataHandler, the terms are found by getting all the named OWL classes in the value list OWL file, which is done by using a Jena method to list the named classes of an ontology model. For each of these classes, another Jena method is used to list the individuals of a given class. The Swedish RDFS-label of these individuals is then added to the vector of values for the given term. Since RDF is unordered, these vectors are sorted alphabetically before being added to the Hashtable for the term.

6.6.3 Examination Data

All the case data in SOMWeb, that is all the consultations, are stored in individual RDF files. The reading and writing of these is performed through adapted classes in the MedView code library, where the ExaminationDataHandler interface defines methods for getting patient and examination objects, and for saving examinations. The class implementing this method

[5] Categories and inputs in MedView are discussed in Section 5.1.1

that was hitherto mostly used is named MVDHandler. A corresponding implementation was created, called SWDHandler (SOMWebDataHandler, or Semantic Web DataHandler if one wants).

In the MedView code base, the Tree class has been an important data structure for handling examination data, with the subclasses TreeNode and TreeBranch. The new class that represents examinations is RdfExaminationModel. In order to be able to pass objects that are both of class Tree and RdfExaminationModel from the SOMWeb community to the MedViewDataHandler class, an interface MedViewExamModel is defined, which both the Tree class and the RdfExaminationModel implement.

Many of the methods employed in the MVDHandler use a class called MedViewUtilities, located in medview.common.data. These methods are used to load and MedViewExamModels, as well as to construct ExaminationValueContainers (which are basically a hashmap of terms and their values for a given examination of a given patient) from them. Methods for performing these functions for RdfExaminationsModels have thus been added. Since both Trees and RDFExaminationModels use ExaminationValueContainers, these can be used to convert examinations in the tree file format to the RDF file format.

6.6.4 Case Browser

A benefit of the SOMNet users entering the cases in a structured manner is the use of this structure in browsing data. Through the SOMWeb case browser, the functionality of which was presented in Section 6.4.3, cases can be viewed from the aspects of diagnosis or treatment. The SOMWeb ontologies have been expanded for this purpose, as described in Section 5.2. The left hand side of Figure 5.1 on page 64 shows how the ontologies are used for browsing.

In SOMWeb, the OntologyHandler Java class, in the model layer, handles the relevant ontologies and inferences from the case data. Within the OntologyHandler, a Jena OntModel instance is used to hold the ontologies, with the OntModel wrapping an inferencing model based on the Pellet reasoner. The OntModel class contains methods for accessing and manipulating the underlying ontologies, such as listing all subclasses of a named class, listing all instances of a class, and creating new classes.

When the OntologyHandler is initialized, the value list and case browser OWL files are read, as well as the RDF cases. Since the OntModel wraps an inferencing model, it contains not only the facts of the loaded OWL and RDF files, but also any facts that can be deduced from these. The OntologyHandler class contains methods for getting relevant information from the OntModel. When generating the case browser content, the subclasses of `BrowserCase`, such as `DiagnosisCase`, are acquired first. Then, for each of these, the Jena method for accessing subclasses of these is called, returning a list containing, for example, `CandidosCase` and `LichenCase`. Finally, for each such class, the Jena method for accessing the instances of the class is called, returning a list of cases. These are the cases (from the case repository) that can be inferred to be instances of the `BrowserCase` subclass through its class definition (see Figure 5.11). Each of the methods used by the case browser OntologyHandler is basically one line of Java code for accessing the relevant subclasses or individuals from the model. This returns an iterator, from which the Jena

Resources can be acquired to access, such as the class's or individual's URI or RDFS-label.

6.6.5 Manipulating the Case Browser Ontologies

SOMWeb also contains functionality for manipulating the case browser ontologies, further described in Section 6.4.6. Behind the scenes, this is performed through the OntologyHandler class. It thus uses some of the methods described above, for accessing the `BrowserCase` subclasses, and in turn their subclasses. Further, there are methods for accessing and manipulating the associated value list classes and their instances. Thus, instances can be added and removed via the user interface. It is also possible to create a new case browser class and to associate value list instances with this.

6.6.6 Community Resources

SOMWeb community resource data is stored in RDF. What should be included in RDF descriptions related to community resources is represented in OWL, as described in Section 5.3.1. Figure 6.21 shows how these components are related.

As seen in Figure 6.20, the model layer of SOMWeb has a Handler class for interaction with each component of the community resources. The model layer also contains persistence classes, which, at the start-up of the system, read RDF files for users, meetings, cases, and news and constructs objects of the corresponding Java classes used by the system. These classes are also used to make changes to the RDF model and writing to file. These persistence classes were manually constructed.

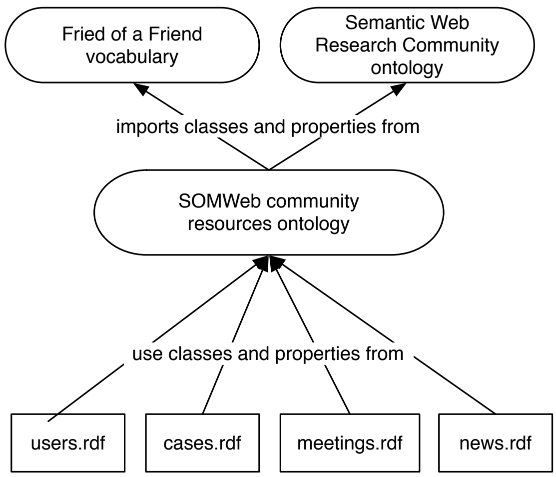


Figure 6.21: Community resource data in SOMWeb. The RDF files for persons, meetings, cases (examination metadata), and news use classes and properties described in the SOMWeb community resource ontology, which in turn imports classes from the Friend of a Friend and Semantic Web Research Community ontologies.

6.7 Discussion

In the following, I discuss SOMWeb in relation to other Web-based systems for clinical collaboration (Section 6.7.1), SOMWeb as a Semantic Web system (Section 6.7.2), and reflect on developing software based on Semantic Web technologies (Section 6.7.3).

6.7.1 Web-based Systems for Clinical Collaboration

In Section 2.3.5, several Web-based systems for clinical practice were presented. I now discuss SOMWeb's approach in relation to these. There are several similarities between the Caisis system [41] and SOMWeb, such as the separation between data entry and data presentation and development being carried out with active involvement from clinicians. Also, both Caisis and SOMWeb can be said to be structured around formalized patient histories, such as cases. However, Caisis lacks SOMWeb's foundation in Semantic Web technologies. The reported problem of a rising learning curve due to more functionality is explicitly addressed in SOMWeb by using a "multi-layered" design for the user interface. That is, some functionality has to be explicitly turned on by the user in their preferences, thus exposing the user to fewer features initially.

The tool for radiological telesessions presented by Vega et al. [154] is similar to SOMWeb in terms of objectives and focusing on "clinical sessions", which in purpose and structure seem to correspond to SOMNet's meetings. However, the cases presented in clinical sessions are not formalized to the extent that SOMWeb's cases are, and Semantic Web technologies are not used. The computer-based information tool for palliative severe pain management presented by Kuziemsky et al. [83] is similar to SOMWeb in that it intends to promote collaboration and learning and in that the development included an in-depth study is made of the domain and work processes of the users. The article also presents a developed ontology, but it does not seem to be represented in a logic-based or standard formalism. Neither Vega et al. nor Kuziemsky et al. clearly address the impact of the tool on the collaboration that they support. The impacts of SOMWeb are addressed in Section 7.7.

6.7.2 SOMWeb as a Semantic Web System

Since SOMWeb does not have any "open Web" aspects, that is, all information is self contained, it does not demonstrate the Semantic Web benefits of integrating distributed information. Though it is an interesting possibility that the members of SOMWeb upload individual RDF case descriptions on local servers, that are then collected to a larger view, this presents at least three problems: the need for encryption to ensure privacy of data, less of a sense of community, and the need to provide tools to help the clinician provide the RDF description. An interesting use case for distributed case data is if one imagines several communities, like SOMWeb, sharing cases among themselves in self-contained communities. Then, cases could be aggregated from overlapping disciplines or from different countries for purposes of learning and analysis. If such publication is to take place, issues of security and encryption in Semantic Web technologies, which is not yet extensively researched (though some work exists, for example [76] and [96]), need to be dealt with.

SOMWeb does not currently reuse any external medical ontologies. In retrospect, this is probably not entirely unexpected, since from the outset, there was no clear conception of what benefit these ontologies would bring, except less work in implementing the SOMWeb ontologies. Another reason is that information integration was not a major purpose of this project, so the need to use the same ontology as another party was not present. For more reflections on ontology reuse, see Section 9.1.3.

6.7.3 Developing Software Based on Semantic Web Technologies

Using ontologies and other Semantic Web technologies means that knowledge structures can be defined in a standard manner and that there are, for example, API's for accessing these. Further, these can be connected with reasoners for deriving additional facts from the ontology definitions, which gives the means for accessing additional information in a multi-purpose way. For example, in SOMWeb, different classes of cases, displayed in the case browser, are defined in OWL. When the ontologies and the case instance data are loaded into a Jena model, the only requirement for getting a list of all the cases that are instances of a given case browser class is one line of code.

However, Semantic Web technologies are still maturing, especially when it comes to their use in applications. While there is a growing amount of literature on Semantic Web technologies, which is becoming more practice-oriented, there is still little material on how to use and integrate these into software. There are quite a few design decisions stemming from how to store and access the ontology model. For example, to what extent should the classes of the API be used, and to what extent is it beneficial to have classes more specifically tuned to the application? In SOMWeb, the community model has Java classes mapping main concepts in the ontology, while the case browser retrieves concepts from Jena more directly. In the first case, we know before hand what the ontology concepts are, while in the latter, these are not constant. Furthermore, to what extent is it possible to keep the ontology model in memory? When developing the case browser, the heap size had to be increased to handle the ontology model when inferenced facts had been added. Since there is a limit to which the heap size can be increased, this points to a need for efficient and practical ways of keeping just part of the ontology model in memory.

Some of these considerations, such as to what extent there should be specific classes that interface with the storage back-end (which in theory makes changing the back-end easier) and whether or not it is really possible to reuse code written with one model in mind when moving to another abstraction, are of course applicable to software development in general. However, they bear to be reexamined in the light of Semantic Web technologies.

6.8 Summary and Conclusions

This chapter has presented results related to the SOMWeb system, including its design, functionality, and how Semantic Web technologies have been used. The design was carried out in conjunction with the clinicians, and system functionality focuses on central aspects of SOMNet's collaborations: meetings, cases, and members. Structured case-entry is used to aid information entry and to help ensure that relevant information is included.

The use of Semantic Web technologies for representing individual cases and case categories enabled the use of reasoning in the system's case browser. However, the use of ontologies in object-oriented systems is not straightforward and further research is needed on appropriate architectures and programming practices for Semantic Web applications.

Conclusions regarding the SOMWeb system are elaborated in Section 10.1.3. The next chapter presents the evaluation of SOMWeb, including functionality and impacts on SOMNet's collaboration.

Chapter 7

Evaluation of the SOMWeb System

The SOMWeb system was introduced in May 2006. To give an indication of its use, in January 2009, SOMWeb had 120 registered users located at 74 clinics. It had been used at 23 meetings and the case repository contained 121 cases. This chapter presents results related to Objective 4, as presented in the introductory chapter, and concerns the evaluation of SOMWeb and the study of how SOMNet's collaboration has changed with the new system. Although the chapter relates to Chapter 4, which describes the collaboration and communication of the distributed clinicians, it focuses on aspects related to the SOMWeb system, described in the previous chapter.

As described in Chapter 3, a variety of data sources are used in this evaluation: a questionnaire (Section 3.6), interviews (Section 3.7), analysis of user activity logs (Section 3.9), and comparison between cases before and after SOMWeb's introduction (Section 3.10). Table 3.1 on page 42 summarizes important figures for each of these.

The chapter begins with data on membership and case submission (Section 7.1). The results of the evaluation of SOMWeb's functionality in general (Section 7.2) is followed by the evaluation of the structured case entry (Section 7.3), which is a central aspect of the system. Results of the how the system is used are then presented (Section 7.4), and followed by an analysis of how the distribution of submitting clinics (Section 7.5) as well as the structure and content of cases (Section 7.6) have been affected by SOMWeb's introduction. I then describe impacts of the system on membership, case submission, collaboration practices, chairpersonship and the recording of meeting decisions, use of external evidence, as well as on SOMNet as a community of practice (Section 7.7). The chapter ends with a discussion of the results (Section 7.8), as well as a brief summary and conclusions (Section 7.9).

7.1 Membership and Case Submission

How the membership has increased in SOMWeb from April 2007 to December 2008 is shown in Figure 7.1. Information about when members joined SOMWeb has not been registered. Therefore, this data was gathered from figures given in publications about SOMWeb as well as from RDF-files of user data that were downloaded at different times during development. Data on the number of members initially entered into SOMWeb is not available.

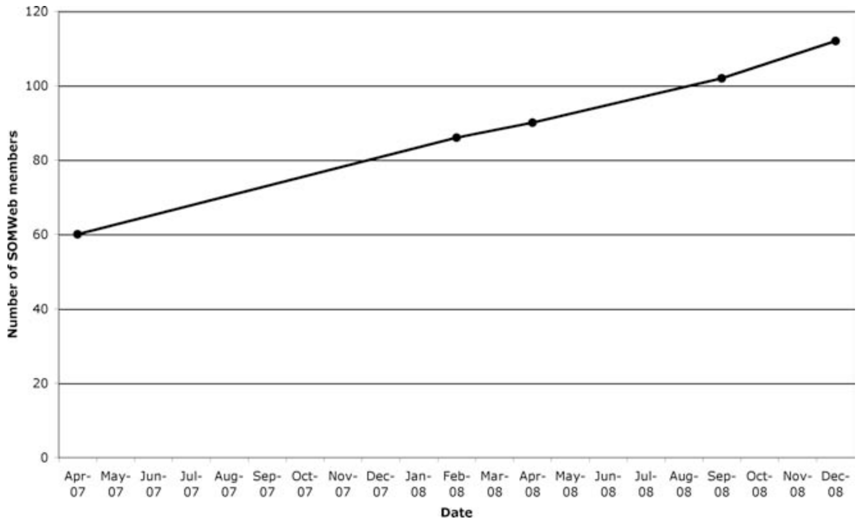


Figure 7.1: Number of members of SOMWeb from April 2007 to December 2008.

About 25 % of the members have submitted at least one case. Five people have submitted about 50 % of the 120 cases in the repository. One person has submitted 20 cases, which may be attributed to that person having chaired meetings where few cases had been entered (the chairpersonship of the meeting is rotated among members).

7.2 Functionality in General

This section deals with the evaluation of the functionality of SOMWeb in general, and not that directly related to case entry, which is presented separately in the next section, since it is a major part of the system. It should be noted that, at the time of the evaluation of SOMWeb's functionality, the ontology-based case browser (see Section 6.4.3) had not been added to the system.

Table 7.1 displays questionnaire responses comparing SOMWeb with the PowerPoint support. These show that fourteen of eighteen respondents find core functionality to be better in SOMWeb, and none find it worse. In reply to the question about how difficult it is to understand how to use SOMWeb, five replied very easy, eight easy, and ten neither easy nor difficult (one person did not reply to the question). None replied that it was difficult or very difficult.

Table 7.2 shows questionnaire results about how suitable respondents found SOMWeb, regarding their own needs, as well as SOMNet's needs in terms of continuing education, patient consultation, and discussion forum. The category with the most responses of 'well' and 'very well' is patient consultations, though this is also the only category with a negative response.

Table 7.1: Questionnaire responses about the system's functionality compared to the previous form of collaboration, with the alternatives of better, neutral, and worse. These questions were answered by the 20 out of the 24 respondents who indicated that they had participated in SOMNet with PowerPoint-support. Out of these 20, several did not answer all questions.

Question topic	Better/neutral/worse
Preparing for meetings	14/4/0
During meetings	15/3/0
Adding cases	13/2/0
Viewing old cases	15/2/0
Support your work in general	13/5/0
Support SOMNet in general	17/1/0

Table 7.2: Questionnaire responses about how suitable SOMWeb is for them, as well as support for continuing education, patient consultations, and discussion forum. Alternatives for the questions were very well, well, neutral, badly, very badly. For the first question, one person did not reply.

Suitability Area	Very well, well, neutral, badly, very badly
Respondent	7/14/2/0/0
Continuing education	8/11/5/0/0
Patient consultations	9/13/1/0/1
Discussion forum	12/8/4/0/0

We now turn to interview responses regarding functionality. This section and the following includes quotations, the numbering of which continues from Chapter 4, and the respondent numbering remains the same.

All those interviewed stated that the SOMWeb system has improved the SOMNet collaboration. Motivations include making case entry easier and less time-consuming (Quotation 28), prompting the supply of more uniform case data (Quotation 29), enabling a collected view of a case over time (Quotation 30), and providing more structure to SOMNet's activities in general.

> **Quotation 28:** Very easy to handle, compared to before. [...] It took longer to make the PowerPoint presentations. (Hospital dentist 6)

> **Quotation 29:** The whole layout is nicer now. Before, we had to add textbased information in a PowerPoint. Now you just click, click, and it is there. We get certain information that is always there. You don't have to ask. Some just wrote that the patient had blisters, period. What medications do they take, you had to ask. Now that

information is there to start with. And all presentations look the same. Because there is a given format. (Hospital dentist 4; has research background)

Quotation 30: This is much more professional and everything stays in one place. [...] You can decide on follow-ups and everything is there. [...] It was so varied before. Now it is more structured. (Hospital dentist 3)

A few interviewees also find that SOMWeb gives a greater sense of presence, since one can see more clearly who the other members are and who adds cases. Other benefits voiced are being able to look at upcoming and previous meetings (Quotation 31) and previously presented cases (Quotation 32).

Quotation 31: Well, this is much more elegant. [...] I am impressed because it has a lot of functionality. [...] Being able to look at upcoming and previous meetings and such. (Hospital dentist 2)

Quotation 32: Before I saved the cases, in an image bank so to say. And I never go back and look at it. It is too much of a hassle. However, I go back and look at old cases in SOMWeb. Because it is structured in a whole other way. The other way wasn't as systematic. (Hospital dentist 7)

Some users have had trouble finding how to submit a case for a follow-up consultation. In addition, images are sometimes loaded slowly when there is heavy system usage during meetings.

When the PowerPoint presentations were used in the meetings, members first went through the slides sequentially and then looked at specific slides as appropriate in the discussion. With the SOMWeb system, users focus more on the images while listening to the presenter, and rely on the textual case information for facts as they need them. In SOMWeb, the cases are presented in the order in which they have been entered into the system, but the actual order of presentation is usually based on the preferences of the presenters.

7.3 Structured Case Entry

Of the 24 persons who answered the questionnaire, fifteen replied to the questions related to case entry. Thirteen of these thought adding cases was better in SOMWeb, and two were neutral. Six of the nine interviewees have added cases (this includes the two pathologists who do not add their own cases). All of these find that it is easier to enter cases with the new system than using PowerPoint presentations. Positive responses regarded case entry being less time consuming (Quotation 33) and that it is easy to enter values (Quotation 34).

Quotation 33: The previous approach took a horrible amount of time. I sometimes skipped entering a case because I thought it took so much time. (Hospital dentist 1)

Quotation 34: It is easy, it is very good. It is like in MedView: you just enter a few letters, and then you find it. You can add values. It works. (Hospital dentist 4; has research background)

However, only four of the six found it very easy. The difference between these numbers indicates that there is some variation in opinion regarding case entry. The problems brought up by one respondent were related to the form, leading mainly to the use of the free text part of the form to enter a narrative. The other respondent found it difficult to distill a complex clinical situation to fill in the form. Several respondents also discussed the quality of the values in the value list. I now elaborate on each of these issues.

The respondent who mainly used the free text entry thought that the more structured approach now used was good, but that the case entry was cumbersome, as illustrated in Quotation 35.

> **Quotation 35:** How you add cases, that I am a little bit critical of. Because the tool, when you fill in... you can add words that aren't there for diagnoses and medicines and all that... but it is unwieldy and cumbersome... it principally builds on... what was it called... MedView. And those that don't work with MedView, they get stuck. When you have filled in the anamnesis... and then you get fields where you don't have the information... The first times I tried to fill it in, but now I don't do that any more, I go straight to the last box and write everything there. (Hospital dentist 3)

As seen in Quotation 36, use of the free text entry was found important by one of the respondents who were positive to structured case entry.

> **Quotation 36:** It is easy to fill in. In any event, it is the comment at the end is where I put my question. (Hospital dentist 6)

The other negative respondent who found it difficult to select which data to enter for patients with a complicated clinical situation, as elaborated on in Quotation 37.

> **Quotation 37:** I have found that for many of the patients that we get referred, there is a very complex medical background. How much should I enter and in what order? Because when I enter data, I find it easier if I can write it as free text. [...] [They have] many medical diagnosis. If I then enter all the values, then there are a few diagnoses that I at least initially don't think seem relevant for the case. But if I don't enter all the values, then I may have precluded some possibilities later. (Hospital dentist 7)

The comments above mainly concern the use of forms in general. In addition, respondents commented on the content of the value lists and the fields of the examination template. The values in the lists and their quality was brought up by the respondent who mostly used the free text entry (see Quotation 35), who elaborates on problems with filling in values in Quotation 38.

> **Quotation 38:** And when you scroll in those long lists... a lot of things are there several times, with different spellings, it becomes strange. [...] And if you want to add a value... it takes a long time. (Hospital dentist 3)

Another respondent found the form appropriate in general, but also had some quite detailed feedback, with examples of different spellings of the same word, inconsistencies in capitalization, and values that were not adequate for the list they were included in. It was also indicated that the respondent was aware that this view was not shared by all, as seen in Quotation 39. This respondent suggested that the values added to the value lists should be approved by senior members.

> **Quotation 39:** The others think that I am whiny. I am a little bit detail oriented. (Hospital dentist 5; has research background)

On the basis of these opinions, I asked a later respondent about the quality of the entries in the value list, with regard to duplicates and entries that are not correct answers for the question. The member's reply, seen in Quotation 40, indicates that he does not consider this as large a problem. However, he also mentions that it is a problem if you search and cannot find the medication because it is misspelled in the case record.

> **Quotation 40:** It doesn't bother me, I smile. Because I can tell you that in my own MedView-lists I can find very strange values. [...] I think the amount of error is negligible compared to other errors in registration. That the patient doesn't remember a medication being taken. (Hospital dentist 4; has research background)

The detail-oriented respondent also thought there were several questions missing from the template. The other respondent discussing value lists indicated that he though that only very basic information was included in SOMWeb compared to MedView. When asked whether the template needs to be reworked, as indicated in Quotation 41, he finds that the current content fits the purpose of discussion but that more data should be included if it is to be used for research purposes.

> **Quotation 41:** That depends on the purpose. If you are just going to... well, we just sit and discuss... and you get to know what diseases and diagnoses they have, I think that is pretty okay. But, if you're going to do research on it, then there are other requirements. Then you have to increase the amount of information. (Hospital dentist 4; has research background)

7.4 System Use

The members' usage of the SOMWeb system is presented through the reported use of questionnaire respondents and interviewees (Section 7.4.1), system content relating to private comments and forums (Section 7.4.2), as well as analysis of logs (Section 7.4.3).

7.4.1 Reported Use

Both the questionnaire and interview responses indicate the SOMWeb is used mainly in conjunction with meetings. Of the 24 respondents to the questionnaire, 19 replied that they had not used SOMWeb outside of the meeting and its preparations. All interviewee's report primarily using the system during meetings and in preparations for these. They use the system a few days before the meeting or on the day of the meeting to go through cases and form their own opinion about them. One person indicated that the personal comments in the system were used to remember these opinions. Another used these comments to record notes during the meeting.

The five questionnaire respondents who had used SOMWeb outside of meeting functions, the most often reported purposes were to get acquainted with the system, to browse cases, to look at cases from missed meetings, and to read the news. Though not an explicit interview question, five interviewees reported that they had logged in to browse previous cases. One of these stated that he had never done so for the previous PowerPoint-based approach. Three interviewees had used the simple free text search functionality, but found that it needed improvement. Two others replied that the search had not been used since they found that the number of cases in the system (approximately fifty at the time of those interviews) did not warrant a search yet.

7.4.2 Private Case Comments and Use of Forums

Results related to minor parts of the system, private case comments and forums, are now presented. What sets these apart from the other functionality is that they have seen relatively little use.

Private Case Comments

Users can make private case comments. As of January 2009, eight members have used this function, making a total of 86 comments on 57 different cases. For the eight users, the number of case comments are 43, 16, 13, 7, 2, 2, 2, and 1. It should be noted that the case comment function is not present by default, but must be switched on in the user's preferences. The reason for this is that the new user should not be confronted with too many functions at once.

Use of Forums

SOMWeb was initially conceived as an online community, and since these often include a discussion forum, such was added to SOMWeb. However, in SOMWeb, very little use of the discussion forum has been seen. This may be due to the fact that the clinicians do not so much wish to discuss the cases online, but use SOMWeb as a common memory, where they can contribute and find cases. The informal communication is carried out during teleconferences, in person, or on the phone. A drawback of this method is that there is no trail remaining after these conversations, which might have benefited those not present.

7.4.3 Analysis of Logs

The results of the analysis of logs of the users' activity in SOMWeb from August to December 2008 is described, using graphs of activity and examples from the logs. The logs should be read bearing in mind that, as brought up in Section 3.9, the back button of Web browsers is frequently used, and this activity does not appear in the log. Therefore the record of system use is incomplete. Also, that a member is not logged in during a meeting does not necessarily mean that they are not participating since that person could be at a clinic with several participants, and somebody else has logged in.

The subsection begins with data on the logins during the time period as well as how the search function was used. The subsequent results of an analysis of ten random members should give the reader an idea of how the system is used and how this use differs between different kinds of members.

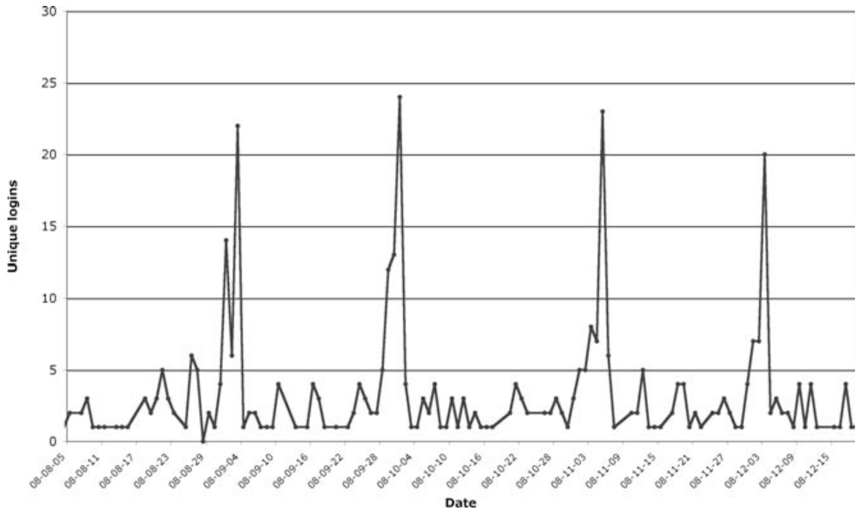


Figure 7.2: Unique logins to SOMWeb during the fall of 2008. The peaks correspond to SOMNet meetings.

Logins

During the time period for which logs were analyzed, 61 different members logged in at least once. Figure 7.2 displays the number of unique logins (that is, a user logging in several times is only counted once) per day. There are four peaks, corresponding to the dates of the meetings during this time period.

Use of Search Functionality

In the logs it can be seen that, during this time period, seven people used the search function, with eleven different searches.

Activity of Ten Members

Ten members were randomly chosen in order to analyze how they use the system. Table 7.3 shows the number of days for which there was system activity and the number of lines of log activity, which gives an indication of the extent of the members' activity.

Member 1 The first member analyzed is a hospital dentist with one case in the system. This person was logged into SOMWeb during all four meetings of the time period. The user chaired one of these meetings, and this was the only meeting for which there was any activity outside of meeting time.

Member 2 The second member is a private practitioner with no cases. There were two logins during the time period. At the first login, only the news page (which is reached upon

Table 7.3: Summary of system activity of ten random members. For each member, the workplace, total number of days with any activity, and number of lines in the log are given. The asterisk next to the numbers of two members indicates that they chaired a meeting.

Member	Workplace	Days	Lines
1*	hospital	6	591
2	private	2	19
3	hospital	4	382
4	private	5	68
5	private	10	296
6*	hospital	10	995
7	hospital	0	0
8	private	3	139
9	hospital	10	269
10	private	0	0

logging in) was viewed. The second login was during one of the meetings, it began ten minutes after the start time, and lasted for twenty minutes. It is unclear whether there was any participation in the teleconference, since the session was shorter than the meeting and the browsing behavior was not typical of meetings.

Member 3 The third member is employed at a hospital, and has no cases. During the time period analyzed, the member logged in on four different days. Two of these were for the duration of two meetings, for which there were no logins that could be regarded as meeting preparation. During the other two browsing episodes, which were within about ten days of each other, the member looked at cases for the coming meeting as well as those of the past two meetings. For the coming meeting referred to here, the member did not login, even though there were preparations. However, another member at the same clinic was logged in for that meeting.

Member 4 The fourth member analyzed is a private practice dentist with no cases. The member logged in on five different days. None of these logins were during meeting times. On one occasion, the member added a “Related non-SOMWeb consultation” to a case, but removed it right away.

Member 5 The fifth member is a private practice dentist with two cases, which were both presented during the period analyzed. The member was logged in during two meetings, the two for which he had cases. The member logged in on ten different occasions.

Member 6 The sixth member works at a hospital and had no cases. The member chaired one of the meetings. There were ten logins during the time period, though none of these were during meeting time. However, other members at the clinic were logged in during meetings.

Member 7 The seventh member analyzed works at a hospital and had no cases. There were no logins by this member during the time period.

Member 8 The eighth member analyzed works at a private practice and had no cases. This member joined SOMWeb during the latter half of the analysis period, when one meeting remained. There were three browsing sessions for this member.

Member 9 The ninth member analyzed works at a hospital and had no cases. This person logged in ten times during the time period, but not during any meetings. It is possible that the member participated in the meetings in a larger group, where somebody else logged in.

Member 10 The tenth member analyzed is a private practice dentist with one case. The member did not login during the time period.

7.5 Distribution of Submitting Clinics

Has the introduction of SOMWeb affected the number of clinics submitting cases and the distribution of cases between submitters? The pre-SOMWeb cases were submitted by twelve different clinics, all located at hospitals. The clinic is not known for four cases. For the SOMWeb cases, sixteen clinics have submitted cases, and while almost all of the submitters are hospital clinics, two are private practices and two are public dental care clinics.

The same three clinics have the most number of cases both for the pre-SOMWeb and SOMWeb cases, and these clinics have been part of the SOMNet collaboration since its inception. Before SOMWeb, the cases from these clinics represented 63 % of all cases. Since SOMWeb's introduction, cases from these clinics represent 51 % of all cases. Figure 7.3 shows the number of cases per clinic, before and after the introduction of SOMWeb. This indicates that the top three clinics for submitting the old cases are in the intervals 41-45, 46-50, and 56-60. For the new cases, the top four (the third and fourth are in the same interval) clinics have 11-15, 16-20, and 21-25 cases. With regard to the old cases, there is a larger gap between the number and cases for the high and the lower submitters than for the new cases. Also, for the new cases, there are more clinics with 1-5 and 6-10 cases than for the old. This could indicate a trend in SOMWeb that there are more submitters of only a few cases than in the previous approach, which is desirable in that it means that more clinics submit, even if not frequently. However, it could also be that over time, as more cases are submitted, the trend in SOMWeb will be similar to that of the pre-SOMWeb cases.

It can be noted that there are five clinics with only one submission in SOMWeb, while there was only one before. Although this information is insufficient to draw any further

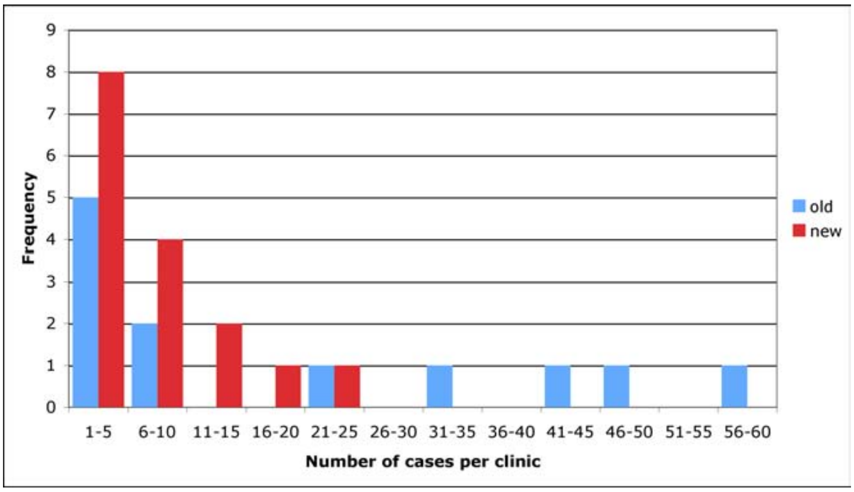


Figure 7.3: Frequency distribution of number of cases per clinic, before and after the introduction of SOMWeb. The x-axis shows intervals for the number of cases per clinic, such as one to five cases, and the y-axis shows the number of clinics within that interval of cases.

conclusions from, it will be a trend to investigate in the future. Two clinics had cases in the PowerPoint file material that have no cases in SOMWeb (though from the log analysis it can be seen that one of these still participates). Seven clinics have cases in SOMWeb that are not present in the PowerPoint file material.

7.6 Case Structure and Content

To see how the introduction of SOMWeb has affected the structure and content of submitted cases, pre-SOMWeb and SOMWeb cases were analyzed, as described in Section 3.10. Below, results pertaining to the pre-SOMWeb cases (Section 7.6.1) and SOMWeb cases (Section 7.6.2), are followed by a comparison (Section 7.6.3).

7.6.1 Pre-SOMWeb Cases

The PowerPoint files present cases with text and images, and there is no standard format, with regard to content or layout. The textual information is sometimes contained in just one or two slides, and sometimes given in a longer presentation, with less text per slide. Very few cases are typical PowerPoint presentations, that is, using the slide title field and bullets.

The different headings usually included in an examination (such as status and treatment) may come in varying order in the PowerPoint file – if they are present. Some cases end with an explicit question, such as “what to do?” or “continued treatment?”. Sometimes one PowerPoint file contains two or more cases, although this is not indicated in the file name. However, this is not always the situation, since one clinic may have several case files for each meeting. That there is no indication of this in the file name could be due to the Swedish word for case being the same in singular and plural form. Some cases begin with a note that the case has been previously discussed (though not always indicating when). In the brief overview of cases, I also found those that had been brought up previously, but showing no indication of this. In order to know what a case is about, the file has to be opened. Sometimes a title is given on the first page of the presentation, but this is not the norm.

Due to time constraints, not all the pre-SOMWeb cases could be analyzed in detail. Instead, twenty cases were randomly selected. For these, notations were made about structure, any signs of a template being used, whether there was a clear chronology, the number of images, and an explicit question. In addition, for the attributes in the templates of SOMWeb, I attempted to find this information in the presentation. Table 7.4 displays the results.

There is a difference in how submitters structure their case presentations, as previously stated. There is also a difference in how words common to the case descriptions are used. For example, sometimes both the headings 'general' and 'general anamnesis' are used, but what is written under each varies. In the pre-SOMWeb cases, if a part of the presentation is structured, it is often the general anamnesis. That is, there is a list, such as, 'medications: ibuprofen, clarityn', 'smoking: none', 'diseases past: measels'.

Table 7.4: Results of analysis of twenty random pre-SOMWeb cases. Clinic 1 submitted the most cases, Clinic 2 the second highest submitter, and so on.

Case	Meeting	Clinic	Headings	Template	Comment
1	Sep 2001	3	General, general anamsesis	Yes	
2	Jan 2002	2	General anamnesis, local anamnesis, referral cause, allergy, medications, tobacco, PAD,[1] blood	No	Mixes headings and specific questions
3	Feb 2002	2	General anamnsis, local anamnesis, blood, local status, treatment, PAD	Partial	
4	Feb 2002	4	Anamnesis	No	Narrative
5	May 2002	1	No	No	Chronology, a lot of PAD

Continued on next page

[1]PAD stands for pathological and anatomical diagnostics.

Table 7.4 – continued from previous page

Case	Meeting	Clinic	Headings	Template	Comment
6	Dec 2002	3	No	Partial	Compact text
7	Dec 2002	1	General, symptoms, PAD	Only for general anamnesis	Narrative
8	Mar 2003	4	General anmnesis, medicine, tobacco, current	Partially for the general anamnesis	
9	Jun 2003	4	Based on chronological events	No	Narrative, PowerPoint style
10	Nov 2003	1	No	No	Narrative (long referral text) and PAD
11	Feb 2004	2	Referral purpose, anamesis, status, note	No	Headings with narrative
12	Mar 2004	3	General, symptoms	Some	Template-based anamnesis and narrative about symptoms. Copied from MedView?
13	Sep 2004	3	No	Yes	Template-based anamnesis and narrative local anamnesis. Copied from MedView?
14	Sep 2004	5	No	No	Very short, five rows

Continued on next page

Table 7.4 – continued from previous page

Case	Meeting	Clinic	Headings	Template	Comment
15	Nov 2004	3	No	Yes	Template-like general anamnesis, no local anamnesis
16	Dec 2004	2	Referral cause, general, allergy, medications	No	
17	Apr 2005	2	Referral cause, general anamnesis, local anamnesis, allergy, medications, tobacco, test results, treatment	No	
18	Jun 2005	2	Referral cause, anamnesis, status, treatment	No	
19	Nov 2005	1	Lab, PAD	For lab data	No headings for general parts
20	Feb 2006	7	No	Partial	Mostly narrative

7.6.2 SOMWeb Cases

For the cases in SOMWeb, the average number of examinations per case is 1.3. A third of the cases have a meeting decision recorded. Also, for each of the nineteen inputs of the initial case entry, as well as photos, the number of values for each input of the initial case entry is counted and Table 7.5 displays the minimum, first quartile, median, third quartile, and maximum over all the cases. The table also includes the number of cases for which no value has been filled in. The average number of photos entered with initial examinations is 3.6, while the average number of characters in the free text entry is 448.

7.6.3 Comparison Between pre-SOMWeb and SOMWeb Cases

Some comparisons that can be made between the pre-SOMWeb and SOMWeb cases regard the presence of structured information, the options available to the submitter, images, and case metadata. When the pre-SOMWeb cases have structured information, this most often refers to the information under the heading of general anamnesis in SOMWeb. The information about symptoms and treatment is rarely structured in the pre-SOMWeb cases.

Table 7.5: Results of analysis of 121 SOMWeb cases for all inputs of the initial case entry. For each of the inputs in the SOMWeb template, what the minimum value is, the first quartile, the median, the fourth quartile, the maximum value, and the number of cases that have no values entered for that term are listed. The horizontal lines divide the inputs into the headings used in the form: general anamnesis, symptoms, diagnosis, treatment, and photos.

Input	Min	Quartile 1	Median	Quartile 3	Max	No Values
Age	0	1	1	1	1	7
Gender	0	1	1	1	1	6
Born	0	0	1	1	1	29
Drug	0	0	1	3	14	37
Dis-now	0	0	1	2	7	38
Dis-past	0	0	0	1	4	65
Smoke	0	1	1	1	1	25
Alcohol	0	0	1	1	1	43
Symp-now	0	0	1	2	6	32
Symp-int	0	0	0	1	1	61
Onset	0	0	0	1	1	70
Symp-prev	0	0	1	1	1	51
Diag-hist	0	0	0	1	2	68
Diag-tent	0	0	0	1	3	67
Diag-def	0	0	0	1	2	80
Treat-past	0	0	0	1	12	70
Result-past	0	0	0	1	1	70
Treat-now	0	0	0	1	5	76
Result-now	0	0	0	1	1	77
Photo	0	2	3	5	13	9

However, this also appears to be the situation in the SOMWeb cases, if one considers the data on the number of cases for which no values have been entered for an input found in Table 7.5. For inputs associated with the general anamnesis, there are, in general, fewer inputs for which no values have been entered than in the latter parts.

The free-form PowerPoint presentations gave the presenter more possibilities to adjust the presentation to the individual case, by, for example, grouping several images on one slide. However, the submitter also had to make more choices in constructing the presentation than is required with the structured case entry regarding, for example, how to layout the pictures and what information to include.

Some old cases have several images per slide, though most have just one image per slide. Sometimes when there are several images this is to provide a comparison. This ability is one advantage of the PowerPoint format. When such a comparison is to be made in SOMWeb, it is sometimes indicated in the free text entry. Although the submitter can make several examination occasions to provide different dates for different pictures, this is not always done. Futhermore, in PowerPoint files, the pictures are sometimes numbered (for example, the submitter has added a note on an image to indicate its number in a series). This is now done automatically. In PowerPoint, the submitter can provide captions for images, which is currently not possible in SOMWeb.

In SOMWeb, it is easier to add metadata to cases, such as the case title, which is a short case description given by the submitter. This provides a quick indication of the contents of the case, and is often a tentative diagnosis. Such information is not available for the PowerPoint cases.

7.7 Impacts

Based on the results presented above, I have identified several impacts of the SOMWeb system on SOMNet's collaboration. These are general impacts on membership (Section 7.7.1), case submission (Section 7.7.2), the collaboration practices (Section 7.7.3), chairpersonship and the recording of meeting decisions (Section 7.7.4), use of external evidence (Section 7.7.5), and SOMNet as a community of practice (Section 7.7.6).

7.7.1 Impact on Membership

When the SOMNet activities started more than ten years ago, only four clinicians participated in the case discussions. At the beginning of this century, PowerPoint-presentations were distributed through e-mail to less than ten participants, all specialists in oral medicine. At that time there were no passive members, that is, SOMNet comprised a small group of active clinicians who all participated in the discussions. The breakthrough came when clinical cases were distributed using SOMWeb. With little administrative effort, all members were able to access the Web site. In fact, the administrator who previously handled the e-mailing of case presentations is not actively involved in supporting the collaboration. The increase in membership can be seen in Figure 7.1. There were approximately 40 members entered into SOMWeb when it started, so there has been a three-fold increase in registered members. New members may have become aware of SOMWeb through presentations and outreach activities of core members, through word of mouth, and an article in a Swedish magazine targeted at dentists. One can speculate that the membership increase due to these activities would have been more difficult if there was no Web page to which prospective members could be referred.

Interestingly, compared to before SOMWeb, more private practice dentists are now members. These probably have different needs and use SOMWeb in other ways than the original members. The increase in private practice dentists is connected to the increase of the number of peripheral participants with the introduction of SOMWeb, and this has enabled the spread of oral medicine expertise beyond the core and active groups. For example, in the members analyzed in Section 7.4.3, two of the private practice dentists had not logged in during meetings. For these kinds of members, the recording of meeting decisions for cases is probably more important. One could also speculate that for these members, who do not come into contact with SOMWeb through their workplaces, the first impression of SOMWeb is more important than for those whose workplaces regularly participate in meetings.

7.7.2 Impact on Case Submission

As seen in Section 7.5, several clinics still dominate the submission of cases, but there is an indication that this prevalence is lower with SOMWeb than previously. One goal of SOMNet is to aid more clinics and to spread awareness of oral medicine diagnoses and treatment. Therefore, increasing the participation of clinics where such activities are not a core part of everyday work signifies a step towards achieving this goal. That seven clinics that had not submitted cases before SOMWeb have now submitted cases may indicate that SOMWeb has enabled the participation of a wider range of clinics. It is also relevant to consider why some clinics submit more cases. One reason for this is that these clinics have members who are very interested and experienced in oral medicine, and who enjoy discussing cases. Some of them also have more research and teaching experience. Another explanation could be that the clinics have many participating members. However, even when this applies, it is often one person who submits most of the cases. Further, one person has submitted all the cases from one of the clinics with the most cases.

7.7.3 Impact on Collaboration Practices

The logs indicate that the members sometimes review an old case “collectively” during the meetings. This is something that is much easier in SOMWeb than in PowerPoint, both with regard to availability of the case and how long accessing it takes. Of course, it would be even better if these links were directly available in case presentations.

The simple e-mailing facility of SOMWeb has led to more contact between the clinicians outside of meetings. Interviewees have found that this simple procedure saves them time since they do not have to update their own address list.

Another change is due to everybody being able to see how many cases have been added to each meeting. Before, a meeting could have quite a lot of cases, which meant some were dealt with at the next meeting. The fact that there are already quite a few cases might deter people from adding another. However, the fact that they can see there are only a few cases might also prompt them to add another one.

7.7.4 Impact on Chairpersonship and Recording Meeting Decisions

SOMWeb also made available the functionality of assigning a chairperson for each meeting, as well as the possibility, for the chairperson, of adding a meeting consultation to the discussed cases, in which the group’s recommendations are entered. The idea is that after the meeting, the chairperson goes through any notes taken and adds relevant parts to each case. However, after about a year of use we found that this functionality was underused, partly due to lack of time for the person chairing all the meetings during that year.

In June 2007, it was decided that the chair should circulate, partly because of the problem noted above. Since this decision, meeting preparations are more thorough. For the fall of 2007 and spring of 2008 notes were added for most cases at five out of eight meetings. Two chairpersons who had not added notes were asked about this, and they gave lack of time and not knowing that it should be done as the reasons. The information in the system has been updated to indicate the duties of the chairperson. However, even after this had been done in the summer of 2008, meeting notes were not added for three of the four meetings during the fall of 2008.

The rotation of chairpersonship also means that more members can examine some cases in more detail. Quotation 42 indicates benefits of this, both for the individual and the group.

> **Quotation 42:** First of all I think that it is really fun to be chairperson, but that is because I can't shut up. But it isn't just that, I get an opportunity to look into the cases in more depth, and I think that benefits all. It is very good if there is somebody who looks in the literature. Because there were several cases where I didn't know that something was available, which I found when looking into it. (Hospital dentist 5; research background)

7.7.5 Impact on Use of External Evidence

In SOMWeb, article references can be added in a structured manner to all cases. This functionality was not included initially, and previously articles were added as part of the chairperson's notes. The news page has also been used to communicate articles of more general relevance. Although not part of the interview questions, four respondents indicated that they usually print and read the articles suggested. Only one has a research position, and thus follows new publications independently of SOMWeb.

7.7.6 Impact on SOMNet as a Community of Practice

A community of practice has a shared repertoire, the common resources that are produced by it. For SOMNet, the primary artifacts have been the case descriptions, first as e-mailed files and, in SOMWeb, as structured case presentations. However, with SOMWeb, this shared repertoire has become more easily and continually available. When files were e-mailed, newly joined members did not necessarily obtain access to previous cases. Further, other kinds of information entities can now be included, such as meeting decisions and articles.

Communities of practices have varying levels of formality. Many may not even be named or recognized as such by its participants. With regard to SOMNet, it has always been recognized as a collaboration between colleagues at different workplaces, although they probably do not call it a community of practice. With the introduction of SOMWeb, the membership has become more clear, and to some extent the community has become more formal.

7.8 Discussion

Issues in structured case entry (Section 7.8.1), note-taking (Section 7.8.2), community rhythm (Section 7.8.3), and technologies to support distributed communities of practice (Section 7.8.4), are now discussed.

7.8.1 Structured Case Entry

The purpose of introducing structured case entry is to attempt to gather all relevant data for cases. An immediate benefit of this is that the data is at hand for meetings. Further, it makes possible the case browser tool described in the previous chapter. Structured case entry can also be regarded as a prerequisite for learning from clinical data. Of the six interviewed members who had entered cases, all found that case entry was better in SOMWeb than using PowerPoint. However, two interviewees were not entirely satisfied. If we look at why two interviewees found the structured case entry unsatisfying (see Section 7.3), an inclination for narrative and reservations about distilling a patient's case into the structure of the form can be seen. Issues related to health information systems and dealing with patients with multiple problems is also mentioned by Scott et al. [141], but no discussion about how to facilitate this process is presented.

While it may be possible to alleviate such issues with, for example, another interface, it also points to more general problems in deciding between structured data versus a narrative form. Related to this is the trade-off between completeness and complexity. If a more detailed form was provided, or maybe different forms for different diagnoses, then a more complicated clinical situation could be captured. However, filling in such a form would be more time-consuming, which is also the case if more questions are added to cater to different interests. Also, a more in-depth analysis of old cases would have been beneficial to inform the content of the SOMWeb template.

An interesting conflict was identified when one interviewee thought duplicate and misspelled entries in the value list were problematic, while others found the breadth of values good and believed that it was impossible to have lists with no odd values. One interviewee thought questions were missing from the form. There is a tool in the system where administrators can upload new examination templates, which has not yet been used. It is probably the case that the community does not yet have processes in place to handle this issue and the current template is "good enough". While one respondent had areas of interest that he wanted included, others voiced concern that the form would become too long.

When analyzing the pre-SOMWeb cases, it was found that when there was any non-narrative information, it was usually the general anamnesis. This tendency can also be seen from the analysis of the SOMWeb cases, in that the terms associated with the general anamnesis have the highest presence of values. Thus far, there has only been one possibility for free text entry at the end of the form, and it is quite liberally used. Since it seems that many clinicians are more comfortable entering certain information in narrative form, then it may be better to have separate free text entries, for example, one for symptoms and one for treatment. With such a method, at least this information is kept apart and can be used separately, for example, as a basis for search.

The submitters of cases to the SOMWeb system enter a short text description of the case, which is displayed when browsing cases. This makes browsing the cases easier than with the PowerPoint cases, since these often had no description, and if they did, the file still had to be opened to find it. However, the description field is also problematic, since information contained there, such as diagnosis, is sometimes not entered into the structured case description.

Just as I found a tendency to keep to the familiar with regards to data entry, Fearn et al. [41] found that new users of their Caisis system (also discussed in Section 6.7.1) for collecting "structured chronological patient histories" intially had difficulties learning how to enter data since they were used to spreadsheets and denormalized databases. These users had a tendency to revert to a more familiar flat structure.

7.8.2 Taking Notes: Meeting Decisions and Private Comments

SOMWeb includes functionality for recording meeting decisions and making private comments. The keeping of collective notes of meeting decisions is the responsibility of the meeting chairperson. However, despite this policy and the availability of the system functionality for the purpose, meeting notes are still rarely recorded. As reported in Section 7.7.4, two reasons for not doing this are lack of time and knowledge that this should be done. Another reason could again be the fear of exposing deficiencies in one's knowledge. It is also possible that there is a connection between a person's general tendency to take notes and their proclivity for entering meeting decisions into SOMWeb, of which there is at least one example in this study.

The functionality for private comments has not been extensively used by SOWeb's members. As presented in Section 7.4.2, four members have more than two comments (among these one sticks out with 43 comments, the average of the other three is twelve), and four have one to two comments. Since the private comments functionality has to be activated in the user preferences, it is possible that some users have not found or turned on the functionality.

The way that SOMWeb is used during meetings, often in larger groups, may affect the use of the private comments functionality. It is possible that if a member participate in a large meeting, they may not have a computer in front of them on which to make comments. Going back and entering comments afterwards is probably unlikely. Even if a member sits in front of the meeting's computer, entering private comments is probably unlikely. It is also possible that a user would make private comments when reviewing cases before a meeting. However, if the comments are not seen during the meeting, there is less incentive to write them. Therefore, it is probable that those clinicians who have a computer to themselves during meetings are more likely to make private comments, which is something that could be investigated in the future.

Note-taking has been studied from an educational and psychological perspective, but I have found little on the effects of note-taking in a professional context or organizational culture and taking notes of decisions. ForsterLee et al. [44] studied the effect of note-taking on verdicts and evidence processing in a civil trial context. It was found that note-taking had an effect on jury performance and that note-taking had more impact in the encoding rather than retrieval stage. For the individual, this could mean that the act of taking notes during SOMNet consultations may positively affect retention, even if the notes are not reviewed later.

7.8.3 Community Rhythm and System Use

When the logins to the system are analyzed, see Figure 7.4.3, it is clear that system activity peaks on meeting days, with an increase of activity in the days before meetings. This can be regarded as the rhythm of the community of practice, a concept discussed by Wenger et al. [159], and previously brought up in Section 4.5. That SOMNet has this regular activity means the system is continuously being used, although its use is not evenly distributed throughout the month. Both from interviews and log analysis we know that many members prepare for the meeting by going through the cases before the meeting.

7.8.4 Technology and Distributed Communities of Practice

SOMNet can be seen as a distributed community of practice, as discussed in Section 4.5. In the background chapter, Section 2.3.3 indicated a need to identify the forms that support for communties of practice can take, and this has been studied through SOMWeb. A community of practice, with its shared repertoire, often has rather specific artifacts around which its problem-solving and learning revolves. For SOMNet, the case is a central artifact, which therefore has a focal role in SOMWeb. When constructing a system to support distributed communities of practice, the identification of their core artifacts cannot be overlooked, and the reinforcement of this in any system of support is essential.

Thus, SOMNet's forms of collaboration played a major role in the design of SOMWeb, while SOMWeb in turn has affected SOMNet's collaboration, as discussed in Section 7.7. This is in line with the results of Koch and Fusco [80], presented in Section 2.3.3. Also, in the case of SOMNet, the participants' already established collaboration probably affected the actual use of SOMWeb positively. However, given that SOMNet's collaboration bears similarities with other forms of medical collaborations, as discussed in Section 4.6, it might be possible to use the system to bootstrap a collaboration.

Another factor that has affected SOMWeb's continued use is the presence of a champion who has been active during its development, introduction, and continued use. This is in line with Lock Lee and Neff [89], who conclude that the introduction of new technologies needs a champion within the community. Thus, if the SOMWeb system is used for other groups of collaborating clinicians, the identification of a champion is likely to be necessary for success.

The SOMWeb system has been designed to be used together with voice communication, that is, with the teleconferences, as these are the core activity of the community. One option could have been not having telephone conferences, and conducting all discussions via text, synchronously or asynchronously. However, it is very possible that an important social element would have been lost. While SOMNet, as such, has no face-to-face meetings, the teleconferences can be said to provide an important social aspect, and that SOMWeb supports these both during and in between meetings. Also, SOMNet's sister organization, SOMS, has a physcial meeting once a year, which means that many members have met in person.

7.9 Summary and Conclusions

In this chapter, results regarding the evaluation of the SOMWeb system have been presented. The evaluation of the general functionality indicate that users find that the system simplifies and provides structure for SOMNet's activities. While the evaluation of the structured case entry shows that submitting cases is quicker and easier, two interviewees find the case entry cumbersome. Further, the analysis of cases suggests that certain aspects, such as the general anamnesis, is more often structured. Thus, even if the possibility of structured entry is provided, it may not be used for several reasons. Though system use will always vary, it is useful to study how case entry can be eased, which information is most important, and how the entry of this can be ensured. When system logs are analyzed, activity peaks around meeting days. While this points toward the system being aligned with the rhythm of the community, it is desirable that the system be used as a resource in clinical activity outside of meeting time. How such usage can be promoted needs more investigation.

Several impact of the system on the forms of SOMNet's collaboration have been identified, such as an increase in membership, a wider range of clinics submitting cases, rotation of chairpersonship, and increased inclusion of external evidence. That the membership has increased and a wider range of clinics submit cases indicates that SOMNet's activities now aides more clinicians in solving cases and in building their oral medicine expertise. The first result chapter indicated that many clinicians do not see the use of research literature as a part of their everyday work. The explicit inclusion of these in SOMWeb suggests a means of facilitating the introduction of a more evidence-based practice, and indeed interviewees report accessing suggested literature.

Section 10.1.3 elaborates on the conclusions regarding the development and impact of systems supporting distributed clinical collaboration. In the next chapter, ways of improving SOMWeb are presented.

Chapter 8

Improving SOMWeb

This chapter outlines ways that SOMWeb has been improved and how it can be further enhanced (Section 8.1). This is followed by a vision of a future SOMWeb (Section 8.2), in which the character of Alex, introduced in the scenario of the first chapter, returns.

8.1 Suggestions for a Revised SOMWeb

This section outlines how SOMWeb can be improved. Some of the improvements have already been performed, which is indicated for each subsection. The suggestions below are based on the evaluation described in the previous chapter and, to some extent, on the collaboration description of Chapter 4. Suggestions have also been provided by our contacts at the Clinic of Oral Medicine, faculty of Odontology, University of Gothenburg, and the members of the development team. Where relevant, quotations from the interviews are provided, the numbering of which continues from the previous chapter. Also included is how the extended community resource ontology of Section 5.3.2 can be used to expand SOMWeb. For example, the evaluation has shown that different users have different background knowledge and different needs when using the system, and I discuss how such information can be represented and exploited using the community resource ontology.

The suggested improvements are organized around the general areas of functionality of the SOMWeb system: individual cases (Section 8.1.1), searching and browsing cases (Section 8.1.2), meetings (Section 8.1.3), members (Section 8.1.4), and instructions (Section 8.1.5). The section concludes with interview comments regarding the importance of focusing on core functionality (Section 8.1.6).

8.1.1 Individual Cases

Cases are central to SOMWeb, and relating the individual cases, suggestions regard structured case entry, adding case information, case images, and indicating purpose for adding cases.

Structured Case Entry

The evaluation of the structured case entry, see Section 7.3, shows that interviewees have differing opinions about this, with two of the six interviewees who had entered cases indicating criticism for the form. System improvements can alleviate this to some extent, by making the adding of new values quicker and by cleaning up the value lists.

For being able to find and classify cases, the form's inputs for diagnosis and treatment can be considered more important than other inputs. However, if we consider which questions were filled in for the SOMWeb cases, presented in Table 7.5 on page 145, it is clear that for about half of the analyzed cases, diagnosis and treatment values were not filled in.[1] One option is to make the filling in of at least one diagnosis-related input and at least one treatment-related input mandatory. It is also possible that with the introduction of the case browser, the users will perceive that filling in this information will make the cases easier to find.

Adding Case Information

The pathologists suggested that they should be co-owners of cases, so that they could add images. The same suggestion was also made by co-located clinicians who sometimes see the same patient and need to add details to a case already entered into the system by their colleague. Such functionality was implemented. However, it was then decided, in collaboration with our primary contact, that all members should be able to add additional consultations to all cases, as it is improbable that this will be misused.

At first, three kinds of entries for cases were possible: initial consultations, follow-up consultations, and meeting decisions. During the spring of 2008 two new categories were added: related material and related articles. When submitted, these are added under the case heading of "support material", and the intention is to include information that is not about the patient directly but which may be relevant.

The private comments functionality has not been widely used, as indicated in Section 7.4.2. The possible reasons for this are discussed in Section 7.8.2. One possibility is that many users have not found the functionality. It may therefore be preferred that this is activated per default.

A feature suggested by the pathologists is making it possible for those submitting cases to tick a box indicating that pathological material is available, thus sending a message to all pathologist members that they can order the material. For this to be possible, the case would have to be added at least a week before the meeting.

Case Images

Images associated with an individual case can be viewed as thumbnails, which are displayed with each consultation occasion, or as larger images in the image browser, where the user goes through them one at a time in the order of their listing in the case presentation. One

[1] Though it could be the case that there is an overlap between what is filled in, so that a histopathological diagnosis, but no other diagnoses, may be filled in.

interviewee suggested that it would be useful to be able to put images next to each other for comparison. It has also been proposed that SOMWeb members should be able to make annotations on images, to, for example, draw attention to a certain detail. A first implementation of this has been carried out as a student project at Chalmers University of Technology. However, it has not been finalized and integrated with the live version of SOMWeb.

SOMWeb users need to be able to provide the dates on which pictures were taken. In SOMWeb, the suggested method of doing this is associating the appropriate images with a consultation for the case. That is, providing the first images and entering the date of that consultation with the initial case entry. Images from subsequent occasions are then added as part of follow-up consultations, entering the date of that further consultation and any additional information from that patient visit. However, in practice, users often enter all the images with the initial case entry, and have therefore asked for a means to provide a date for each of the images. If such functionality is provided, it would be counter to the idea of having separate entries for different encounters with the patient. Rather, better instructions could be provided, or a case entry mechanism where images were uploaded together with indications that they belong to separate consultations.

Indicating Purpose for Adding a Case

As described in Section 4.2.3, the interviewees gave three reasons for submitting cases for discussion: diagnosis or treatment discussion, matters of principle, and unusual and curious cases. I therefore thought that it could be interesting to indicate the purpose for presenting a case, upon case entry, so that you could then, for example, retrieve all the cases that were submitted because they were unusual. When I asked the interviewees about this, however, only one person had a positive response.

For example, Quotation 43 shows the spontaneous response, that discussions should be kept open. When given the suggestion that you could then retrieve cases of a certain kind in the system, the dentist raised the question of how you defined what a curiosity case is and that what is a curiosity depends on the kind of clinic you work in: a curiosity in a public dental clinic is not necessarily a curiosity in a specialist clinic. After an example of a case that was to be presented at the day's meeting, that is apparently rather unusual, the interviewee stated that this was something that "everybody" understood anyway.

> **Quotation 43:** Without having given it much thought: no. I think the discussion should be unprejudiced. (Hospital dentist 4; has research background)

Another interviewee problematized making assumptions about what others know, as seen in Quotation 44.

> **Quotation 44:** I don't think so. You could have it... but if I say that I add something for the purpose of teaching, or some such thing, that could step on my colleagues toes. It could feel a bit presumptuous. (Hospital dentist 5; has research background)

These opinions show the differences in perspective between system developers and clinicians. Developers see what system functionality would be possible with information about purpose, while users see the problematic aspects of differences of perspective while also regarding this as something that "everybody" knows, either tacitly through context or from explicit, free text, questions.

8.1.2 Searching and Browsing Cases

As the SOMWeb knowledge base grows, the interviewed members have recognized the need for an improved browsing and search functionality. The analysis of logs, see Section 7.4.3, shows that seven members used the search functionality during the five month period analyzed, which is small considering that 67 members logged in during the time period. This is probably in line with the opinion of the interviewees that the current search functionality is not good enough, exemplified by Quotation 45. Another interviewee suggested that the search should be based on key words, for the categories of method of diagnosis, diagnosis, and treatment.

> **Quotation 45:** There are a lot of cases here, that I might come back to later. I can't do it now, because I don't think the search functionality is good enough. (Hospital dentist 5; has research background)

The case browser, presented in Section 6.6.4, recently added to the system, is one step in improving the function. Another improvement could also be, for example, using Lucene,[2] an open source search engine library, to power the search of case information, especially the free text entries. Also of interest is examining approaches that combine the structured and unstructured case information.

It is likely that the different kinds of SOMWeb members have different needs, and that they would benefit from having browsing and search results adapted to those needs. For example, a difference could be made in the kinds of resources that are displayed to primary care dentists and those displayed to hospital dentists, where the former might not encounter as many oral medicine related cases in their everyday work, and are probably thus interested in more general information, such as links to high quality information sources on oral medicine related diagnosis. The hospital dentists on the other hand, might find links to scientific articles more relevant. Investigating the needs of different user groups is an important step in updating the system to provide such adaptions.

The extended community resource ontology (see Section 5.3.2) is a good starting point for adaptations, since it provides a fine-grained user model that includes different kinds of education and interests. It also takes the level of participation in SOMWeb into account, by dividing users into groups of core, active, and peripheral. The latter distinction may lead to adaptations similar to those described in the paragraph above, where, for example, core and active members are provided with more articles, even though they may be in primary practice, since it can be assumed that they have a more in-depth interest and knowledge in oral medicine.

Finally, one interviewee suggested the use of some kind of decision support, where you enter the color of the change, where it is located, and so forth. This is then matched against

[2] `http://lucene.apache.org`

the entered cases and you get suggestions of diagnosis and treatment. While interest in such support among the members is thought-provoking, it is also currently beyond the intentions of the system.

8.1.3 Meetings

An automatic listing of meeting participants was added on suggestion from the core members. This feature both facilitates their administration and makes the members more visible to each other.

One of the most important issues regarding meetings is the recording of meeting decisions. While the availability of such functionality in the system has led to this being possible, it is still often happens that shared meeting decisions are not noted for most of the cases. It was hoped that the rotation of chairpersonship would improve this issue, but that has not been the case. One reason could be that chairpersons are not aware it should be done. Although this policy is displayed on the "About SOMNet" page, it could have been overlooked. A simple solution may be moving this information to the meeting page, for display only to the chairperson.

The classes of the community resource ontology can be used as building blocks in collaboration patterns, as described in Falkman et al. [39]. Collaboration patterns have both a descriptive and a prescriptive role, in that they take SOMNet's collaboration as a starting point while, at the same time, also including elements not consistently present currently, but which ideally should be. Identified collaboration patterns include request and activity patterns. When a case is submitted to SOMWeb, this is seen as a request, and the pattern specifies what actions should be seen as part of this process. The request is an input to an activity pattern, which in SOMWeb mostly consists of case activities. In an activity pattern, different components are specified as necessary, and these patterns may be used to support activities related to meetings. For example, they can give information about activities that need to be performed before, during, and after a meeting. One manner of realizing this in the system is sending an automated e-mail to the chairperson before the meeting as a reminder of these duties, or sending such a reminder after the meeting if a given percentage of the meeting's cases do not have a recorded decision. The patterns could also play a part in ensuring that sufficient relevant support material is provided for cases.

Currently, SOMNet's meetings are not audio recorded. The participants have discussed the need for this, to preserve meeting content, so that it can be used by, for example, a case submitter wishing to go back to listen more closely to any advice or by members who did not take part in the meeting. If the meetings were recorded, ideally, sound files would automatically be added to the meeting page. One step in achieving this is the work of another Chalmers student project, which implemented a Skype client to be used in conjunction with SOMWeb. This also makes recording the meetings easier. However, the results of the project have not yet been integrated with the live version of the system. When included, the use of regular telephone conferences would remain, but there would also be the option of connecting via Skype.

8.1.4 Members

The pathologists suggested that it would add to the social presence if you could upload an image of yourself. This suggestion was also made by another clinician via e-mail. Currently, SOMWeb does not have any member presentation pages. Members are presented in a list including their name, clinic, and number of cases. This page could provide links to individual member presentations, which could contain, as suggested above, a picture of the person, contact information, and a list of the member's cases.

8.1.5 Instructions

SOMWeb has limited instruction material, mainly because the user-centered design hopefully precludes the need. However, as SOMWeb's membership grows, it is likely that more members will not initially be aware of SOMNet's manner of collaboration. Thus, more introductory material will probably be needed. Also, as the system increases in functionality, so probably does the need to provide more information about the different parts.

8.1.6 Keeping with the Core Features

As indicated above, SOMWeb's users have made suggestions about features to include in SOMWeb, as have the people involved in its development. However, several interviewees also pointed out the problems of adding too much functionality. When asked about the suggestion that you should be able to add article references to cases (something which was later done), the response of one interviewee indicated apprehension with adding too much functionality, as seen in Quotation 46.

> **Quotation 46:** All such things are really nice, but at the same time you need somebody who does it, somebody who takes care of it. I've been a member of the board of SOMS for several years, and other such groups, and everything builds on that there is somebody who is a driving force. You can never get the collective to do it, even though the collective thinks that it is very good that somebody does it. [...] The important thing is to keep with the cases, that is the knowledge base. Things need to be kept up to date, it isn't any fun if you come in 2011 and it says that it was last updated in 2007. (Hospital dentist 3)

8.2 Vignette: Visions of a Future SOMWeb

In the first chapter of this thesis you met Alex, a dentist who was just submitting his first SOMWeb case. We now return to him and his interactions with SOMWeb, but in the future, with visions of what SOMWeb could become.

Alex has just entered his tenth case into SOMWeb, something that he would hardly have imagined when he entered his first one four years ago. While he has not participated in every meeting, he has had the opportunity of seeing some very rare cases as well as finding *out that there are many nuances to what would seem like a straightforward case, if you bring together a few experts and you are in a tricky discipline such as oral medicine.*

Then again, most clinicians will probably hold that their field offers complexities not present in many others. Lucky for them, Alex muses, that SOMWeb has gotten several "siblings" in other disciplines, such as dermatology. These groups of clinicians use their own instance of the SOMWeb system to enter cases for discussion at distributed meetings. Some groups hold meetings every week, and some just two times each year. Each group has had to find how to make their collaboration work for them, and some adjustments have been made to the system to fit different set-ups, but it really is quite similar to the original SOMNet collaboration.

There is even some interaction between the different groups' systems. Relevant cases from other communities are identified and can be accessed. Alex has a vague recollection that this is done through something called ontologies. Whatever it was, it works, because he was actually contacted by a dermatologist who found one of his cases relevant to one of their cases.

The next meeting is special, because it is the first one that Alex will chair. He is excited and a little nervous, but knows that the system provides some useful prompts for chairpersons. Yesterday he got an e-mail that a case had been entered for the meeting – the first one! He has already looked at the case and added some relevant articles for it in the system. As soon as he has time he will try to find similar cases in the case base using the brand new feature for identifying similar cases.

Chapter 9

Recommendations and Lessons Learned

This chapter presents results related to Objective 5, presented in the introductory chapter. It includes recommendations to prospective developers of Semantic Web and OWL based systems (Section 9.1) and to developers of systems supporting clinical collaboration and knowledge sharing (Section 9.2). The chapter ends with a short summary and conclusions (Section 9.3).

9.1 Recommendations to Prospective Semantic Web and OWL Developers

In the development of the SOMWeb ontologies, I learned several lessons that are valuable to those starting in ontology development, especially in using OWL. They also suggest areas where more ontology development research is needed. The recomendations consist of OWL properties to be aware of (Section 9.1.1), the importance of competency questions (Section 9.1.2), the difficulty of reusability (Section 9.1.3), and not aiming for the perfect ontology (Section 9.1.4).

9.1.1 Properties of OWL to be Aware Of

While familiarity with OWL and RDF has grown over the past years, they are still fairly recent technologies, which means that developers are not as familiar with them as with, for example, XML. This entails spending more time initially becoming familiar with new nomenclature and new API's. It is also uncertain how much DL expertise is needed for successful ontology development in OWL.

With regard to the SOMWeb ontologies, in designing the larger examination template ontologies, the initial barriers were more substantial than for the community data ontology. This was initially caused by confusion regarding the appropriate use of the constructs of domain and range. Related was the subsequent realization that OWL does not inherently support the concept of templates (see, for example, Rector and Stevens [129]).

This can partly be attributed to the use of open world and no unique names assumptions in OWL, which were decided by the creators of OWL and based on the nature of the open Web. However, the assumptions also mean that reasoning with OWL may not behave the way that many developers expect. Validation, for example, is not present in the manner of checking that data holds to a schema. I had intended to validate that the examination data adhered to the examination template it was based on. Due to the open world and no unique names assumption, this is not possible in the default case. However, tools exist that close the world and provide a unique names assumption, so that such schema validation can be performed. One such tool is Eyeball. Also, in the case of SOMWeb, all data is entered from a form, where most input is chosen from lists of values, so there is little need to validate that data conforms to the template. However, were we to take examination data from several sources, this might be needed.

For developers of OWL, it is useful to understand why OWL is constructed the way it is. The various efforts that preceded and influenced OWL meant that a number of trade-offs had to be made in devising OWL in a way that it could both have various desirable features and keep enough compatibility with its roots. Horrocks et al. [68] describe some of these trade-offs. Education and outreach resources on OWL should also be clearer about when an OWL ontology is an appropriate artifact for solving a problem and when it is not.

Often, teaching material is demonstrated with toy examples, leaving many gaps to be filled by system developers. Further, concrete advice to inform design decisions is needed. Much of the most relevant material on how to make design choices for OWL can be found on W3C mailing lists and on their IRC channel. While this indicates an active community, it does not always give an accessible appearance. Over the last year this void has begun to be filled, for example by Allemang and Hendler [2].

9.1.2 Competency Questions are Important

In developing ontologies, one of the first suggested steps is the establishment of competency questions [108]. That is, know what questions the ontology should be able to infer the answer to, which helps determine the scope of the ontology. However, designing relevant competency questions is not an easy process, and it may be tempting to start creating the ontology instead. Further, it may be argued that in some cases the development of an initial ontology is necessary to get a feel for competency questions.

The view of the usage of the SOMWeb ontologies has changed somewhat during development. Initially, the main purpose was the design of templates which could be used in generating input forms and in validating the information that was entered. However, the fact that OWL has no true support for templates and validation prolonged development, both in gathering information to find out that this was the case and in system development. Later, with the case browser ontology, competency questions were clearer, for example, giving cases with certain diagnoses. However, throughout the process, the SOMWeb ontologies would have benefited from having clearer competency questions.

A step in aiding the developer in using competency questions is the provision of sample questions, that can give the developer a sense of what can be asked of ontologies. A literature search on the subject has not revealed any work in this area. While competency questions will vary with the domain, it is still probable that certain competency questions will be common to many applications. Thus, including templates for this in ontology development methodologies and applications can aid potential ontology developers. To elucidate different sorts of competency questions and what is needed to address them, a rigorous investigation of types of competency questions used by successful projects is needed.

9.1.3 Reusability is Hard

While reusability of ontologies is one of their major selling points, reusing ontologies is not a trivial matter. In fact, the developer looking into using ontologies hopefully soon realizes that it is in fact an active research field. One problem is identifying where in the knowledge modeling reuse may be beneficial. For example, when in the process should this be performed, how do you do it systematically, and what sort of ontologies are useful?

Another aspect is finding ontologies that are of use to the project. These problems of course overlap, and there is a bit of a chicken and egg problem: a need might be identified, but no external ontology is found, and it might not be realized that a need exists until the external ontology is found. However, without first considering what the potential needs are, beginning the process of finding an external ontology can be daunting.

At the outset of the ontology development, the conception of what the reuse of external ontologies would contribute to the project was mostly limited to reducing the work in developing the SOMWeb ontologies. Also, the presence of existing classes and individuals meant that it was difficult to find ontologies with an appropriate level of detail and content.

Thus, instructive material should highlight difficulties with finding ontologies of an appropriate conceptualization and formalization (such as OWL), in the language needed (such as Swedish), and how to handle mappings between the external ontology and any pre-existing internal knowledge structure. A step in doing this can be the demonstration of projects that have successfully reused ontologies and the methods employed.

9.1.4 Do Not Aim for the Perfect Ontology

Many of the problems I experienced relate to whether or not there is one, correct way of using OWL, and how important it is to follow. This was especially apparent for the examination template ontology, when it became clear that OWL did not contain an appropriate mechanism for templates. However, it also seemed odd that the proposed standard for knowledge representation was not able to include something that many applications would probably need. Therefore, the work carried on, with a sentiment that the ‘right’ choices had to be made, which sometimes led to stalled progress.

When creating an ontology, it is hard to decide when the ontology is good enough to use. There is a compulsion to create the ‘perfect’ ontology. Combined with a lack of support for some design choices, it becomes difficult to determine when the ontology is ready to be deployed. There is therefore a need for aid for developers in determining when an ontology is ready to be deployed. This can take the form of checklists mapped to the level of complexity the project aims for as well as the ontology’s competency questions.

9.2 Recommendations for Developers of Systems for Clinical Collaboration and Knowledge Sharing

The development, deployment, and maintenance of the SOMWeb system has provided experience that may be of value to other developers of systems supporting clinical collaboration, specifically those who do this within a computer science or informatics research setting. From this I have extracted lessons learned and recommendations relating to the trade-off between developing research and basic functionality (Section 9.2.1), differences in perspective between clinicians and system developers (Section 9.2.2), prioritizing system uptime (Section 9.2.3), and realizing that clinicians are busy and task-oriented (Section 9.2.4).

9.2.1 Trade-off Between Research and Basic Functionality

If the system is developed for the purposes of computer science research, there is still functionality to be implemented that is not directly related to the research issues. However, the basic functionality still has to be present and work well, otherwise it does not matter that the research relevant parts of the system work. There is thus a trade-off between the amount of time and effort spent on the non-research related parts of system development and those related to research. One way to balance this is to ascertain a minimum set of basic functionality needed to fulfill the requirements, and then focus on the research aspects.

9.2.2 Differences in Perspective

The developer has to learn about the particularities of clinical practice and the terminology of the speciality in question, even though the proficiency will still be basic. At the same time, the clinicians' insight into systems development is probably small. Further, if the system is part of a research project, as is the case here, then there is a further divide between the users and, for example, the perspectives of computer science research.

Also, because the users are accustomed to a "usual" way of doing something, they may be skeptical about new methods. Further, there may be limited insight into the benefits and limitations of different kinds of information entry. For example, in SOMWeb much information about a case is given in a free text case description. However, even though the tentative diagnosis is given in this field, if it is not provided in the form as well, using the value list, it cannot be found in the case browser.

Thus, when introducing systems that mean extra work for the clinician or change a habitual way of working, it is also important for users to be able to see the benefits of the new system quickly. This is the cost/benefit gap present in much structured information entry. In SOMWeb, it would have been beneficial if the case browser had been in place earlier, so that the benefits of entering the diagnosis in a structured form rather than the free text box would have been clearer.

9.2.3 Prioritize Uptime

SOMWeb is a working system and is still being used after several years. While it has not been without problems, there have been bugs and exceptions that the users have probably noticed, these have been dealt with as soon as they were brought to the developers' attention. Also, since there is a clear rhythm to the usage of the system – the heaviest usage is early in the month near the meeting day – updates to the system have been performed outside of this time period. Even though SOMWeb has been a research project, the availability of the system to the users is important for them to trust it as a basis for their collaboration.

9.2.4 Clinicians are Busy and Task-oriented

Clinicians usually have patient visits scheduled throughout their day, and therefore limited time for matters that are not part of their regular work. This leads to two more specific concerns: users seldom tell you that they have problems and how much instruction in the use of SOMWeb is needed.

Users have told the developers of the system very little of their problems. Issues of case-entry were brought up during interviews and in the log analysis there was an occasion where case entry was unsuccessful because the session had timed out, which was never brought to our attention directly. Information about an e-mail address that users could get system support was added to the news page of SOMWeb in September 2008. No e-mail have been sent to this address.

It is important to realize that participation in similar projects takes time for the clinicians in addition to the researcher. There is a trade-off in making this clear at the beginning of the project while not scaring off potential participants.

SOMWeb includes limited instruction material: there is information about the preferences, how to add images to different consultations to provide different dates, and the introduction of new functionality on the system's news page. A screencast was also made in which one of the senior members presents the different parts of the system. However, the kind and extent of instruction material useful in research projects needs further studies. For example, the instructions should perhaps be placed in the context of their use, more oriented toward the task.

9.3 Summary and Conclusions

This chapter presents recommendations regarding development using Semantic Web technologies, and specifically OWL, as well as developing systems supporting clinical collaboration, especially in a research setting.

The first set of recommendations can both provide aid to potential developers, as well as indicate areas that need further investigation. Related to these, I see a need for more support for the development of OWL ontologies at different levels of sophistication. On the one hand, Semantic Web technologies in general, and OWL in particular, have to be accessible enough that being an expert in Description Logics is not a necessity. On the other, the potential of employing more advanced techniques, such as use of reasoning, should not be lost.

More guidance is needed to fill this gap. A part of such guidance would be to clearly inform prospective users what their choices are. I propose that different development paths should be provided depending on the intended ontology, giving support for the transition from a simpler ontology to a more complex one. Conclusions relating to these recommendations are part of Section 10.1.2.

The second set of recommendations pertain more to the trade-offs inherent in developing research artifacts which are quickly brought into use. These recommendations suggest a need to be aware of the compromises involved, to be focused both when it comes to basic and research functionality, and to work closely with the clinicians over an extended time period. Conclusions regarding these recommendations are included in Section 10.1.3.

This chapter ends the part of the thesis presenting results. The next chapter is the final one, presenting lengthier conclusions in relation to the thesis aims, as well as suggestions for future work.

Chapter 10

Conclusions

This thesis investigates how to support the collaboration and improve the knowledge sharing of distributed clinicians of oral medicine. More specifically, this issue has been examined within the pre-existing collaboration of SOMNet and the development of a Semantic Web-based tool aligned with their needs. In doing this, a broad range of methods were used: ontology development, system development, interviews, observations, a questionnaire, analysis of system logs, and analysis of cases.

I begin this final chapter by presenting conclusions related to the thesis aims (Section 10.1). This is followed by reflections on the research process (Section 10.2) and an outline of future work (Section 10.3). The chapter ends with some final remarks (Section 10.4).

10.1 Conclusions Related to the Thesis Aims

In Section 1.3, the following research aims were presented:

1. Characterize how geographically distributed Swedish clinicians in oral medicine collaborate and share knowledge.

2. Explore the benefits and limitations of using Semantic Web technologies to support distributed clinical collaboration, and through this identify practical issues facing developers.

3. Study the design and development of Web-based tools for distributed clinical collaboration, as well as investigate the impacts of such tools on the collaboration they support.

I now present conclusions related to each of these. The following touches on some related work, but more such discussions can be found at the end of each result chapter. Also, the first and third aims interlace, wherefore some conclusions presented in relation to the third aim also extend our knowledge about distributed collaboration.

10.1.1 Aim 1: Collaboration of Distributed Clinicians

A better understanding of clinical collaboration is necessary to support collaborations both technically and organizationally. However, the overall understanding of the structure of collaborations and the issues they face has not been sufficiently studied (see, for example, [160] and [47]). As a step in filling this gap, the collaboration of SOMNet was studied in order to gain a better understanding of how geographically distributed Swedish Clinicians in oral medicine collaborate and share knowledge. To my knowledge, there is no description in the literature of a collaboration of SOMNet's character, where a wide number of distributed clinicians with varied expertise hold distributed meetings for the purpose of case consultation. Rather, the common format of tele-consultations is the communication between an expert and a clinician asking advice. In the following, conclusions are given regarding: SOMNet as a distributed community of practice; the centrality of rhythm and cases; expertise, case submission, and levels of participation; the clinicians' lack of time; and supporting collaboration.

SOMNet, a Distributed Community of Practice

SOMNet's collaboration can be characterized as a distributed community of practice where, as seen in Section 4.5, the joint enterprise is furthering and spreading the knowledge of oral medicine, the mutual engagement is the monthly meetings and informal contacts between these, and the shared repertoire includes explicit elements, such as the case presentations, but also tacit components of their shared history and knowledge of diagnostics and treatments. The principles for community of practice growth, as identified by Wenger et al. [159], can be discerned in SOMNet, and implications regarding two of the principles, community rhythm and different levels of participation, are discussed below.

Rhythm and Cases

The presence of regular teleconference meetings with a structured format centered on case discussion, as presented in Section 4.2, means that there is an activity around which the participants can organize. This gives, in the terms of Wenger et al. [159], a community rhythm which I believe this is one reason that SOMNet has able to sustain activity for almost fifteen years. The meetings both give a deadline for case submission and ensure that submitted cases will be responded to, as opposed to open discussion boards where there is no guarantee of response. Further, the centrality of the cases gives a sense of immediacy and connection with everyday work in a way that a lecture or article seminar may not, providing an authentic context for learning. Indeed, as reported in Section 4.3.1, the continued learning and access to experts are given as main benefits of participation, in addition to getting help on individual cases.

Expertise, Case Submission, and Levels of Participation

The purpose in submitting cases varies with the submitter's level of expertise and involvement in the collaboration. The results of Section 4.2.3 indicate that while all participants submit cases due to needing diagnosis and treatment advice, the senior members reflect more on what they want to convey with the case. For example, they submit a case in order to give a new angle on a diagnostic procedure or to disseminate research findings. Further, the group's experts enjoy finding and sharing cases with very rare diagnoses. On the one hand, this gives members the opportunity for recognition of such diseases in the future, which is significant given that oral medicine has many low prevalence diagnoses. On the other hand, such cases may give the impression to the less experienced that submitted cases have to be of special interest.

The study of SOMNet thus suggests an interesting interplay between barriers to case submission, such as anxiety over whether a case is interesting and fear of exposing gaps in knowledge (discussed in Section 4.2.3), and senior members expressed eagerness to encourage broad participation (presented in Section 4.4.2). I believe that when less experienced clinicians do submit cases, the collected knowledge of SOMNet has the possibility of having a large health impact, both by specific suggestions on the case and by exposure to the reasoning of the senior members.

The varied expertise and amount of participation, both with regard to case submission as well as meeting presence and vocalness, can be related to the concept of levels of participation of Wenger et al. [159]. As the results presented in Section 4.5 show, these levels of core, active, and peripheral participation can be perceived in SOMNet. There is one group of people who submit many of the cases and speak most at meetings (the core group), one group who submit few cases, speak sometimes, but often participate in meetings (the active group), and one group who seldom submit cases, rarely speak, and only sometimes participate in meetings (the peripheral group). A main tenet of Wenger et al. is that such variance in participation is a natural part of communities, and that there should not be an expectation that all need to participate equally. However, I believe it is beneficial if systems supporting communities of practice take this into account, which is something that needs to be further investigated. For example, do peripheral users feel overwhelmed by too much content and do they need different instruction material than active and core members?

Lack of Time

One of the main barriers to participation is the clinicians' lack of time (see Section 4.4.3), which has been found to prevent case submission, shorten meeting preparations, and leave relevant research literature unread. A lack of time is a persistent issue, mentioned by, for example, Dawes and Sampson [30], the causes of which would be interesting to investigate specifically for SOMNet's members. Apart from the SOMNet meetings themselves, participation is largely extracurricular. For many clinicians, patient loads prevent meeting preparation and reading of articles during working hours. Apart from the possibility of organizations providing more time for such activities, it also suggests the importance of facilitating case submission and preparation, as well as easy access to research literature of high relevance.

Supporting Collaboration

The portrayal of SOMNet's collaboration also provides insights into the kinds of functionality needed in tool support. The most important insight is that the meetings provide a necessary rhythm for the community and that the cases give context to their learning which points towards the centrality of these in a tool will benefit collaboration. Meeting preparation should be facilitated since these are seen as important both for the individual and the community (see Section 4.2.2). Since many clinicians do not use research literature as a part of the everyday work, a system supporting clinical knowledge sharing should enable those participants who have more contact with research to disseminate relevant findings. The SOMWeb system further illustrates the sort of functionality found beneficial in reinforcing SOMNet's collaboration and knowledge sharing.

10.1.2 Aim 2: Semantic Web Technologies for Clinical Collaboration

The value of knowledge formalization in learning from collected clinical data as a step in supporting evidence-based medicine is a central tenet of the MedView project and has previously been investigated through a definitional knowledge representation approach (Section 5.1.1). The development of SOMWeb, carried out within the MedView project, addresses the need to adopt a more widely used knowledge representation. Over the last few years, Semantic Web technologies and especially OWL (introduced in Section 2.4.3) have been presented as standard choices for knowledge representation, on and off the Web. However, practical issues in the use of these technologies remain to be elucidated. Therefore, this thesis aims to explore the applicability of Semantic Web technologies to support distributed clinical collaboration. Below I present my conclusions regarding the applicability of OWL in the context of SOMWeb, design decisions made in the ontology development process, developing applications based on Semantic Web technologies, and the recommendations presented in the previous chapter.

Benefits and Limitations of OWL

To investigate the benefits and limitations of Semantic Web technologies in SOMWeb, ontologies pertaining to the domain, oral medicine, and the community resources were developed and used in the SOMWeb system. To recapitulate, the oral medicine ontologies were developed based on the previous representation of MedView, which includes examination templates and value lists (internally developed terminology). The examination template ontology (Section 5.1.5) was intended for generating input forms for examinations as well as to provide the structure of individual examinations, and the value list ontology (Section 5.1.6) for selecting values when filling in an examination. In a later iteration, the case browser ontology (Section 5.2) was developed for browsing SOMWeb cases. It contains defintions for grouping, for example, cases of a certain category of diagnoses. The community resource ontology (Section 5.3) represents community information for the SOMWeb system for users, meetings, case metadata, and news.

From the results of the development of the SOMWeb ontologies, I find that OWL was least appropriate for representing the examination templates, as reported in Section 5.5.1.

This is in line with others, such as Rector and Stevens [129], where the problem is the lack of integrity constraints. This implies that more research is needed, either to incorporate means of representing templates within OWL, or on drawing up guidelines for integrating use of OWL and RDF with other technologies for representing templates and forms. For the value list ontology, which mainly contains instance and taxonomic relations, OWL is appropriate, and further provides the possibility of extending the ontology, adding more detailed class descriptions at a later time. This was demonstrated with the refined value list ontology (Section 5.2.1). In SOMWeb, the use of OWL gives the most benefit when used in the case browser, which combines the structured definition of individual cases with the refined value list ontology and definitions of the case browser to classify individual cases by diagnosis and treatment (Sections 6.4.3 and 6.6.4). The current version of the community resource ontology (Section 5.3.1) is used to represent community data in the system. However, no reasoning is used and the data is not shared, lessening the use case for Semantic Web technologies. The extended community resource ontology (Section 5.3.2) indicates how users can be classified by activity level, which can be used to adapt the system to different users.

Design Decisions

In the construction of the SOMWeb ontologies, several design decisions were given lengthy consideration (Sections 5.1.5 and 5.1.6). A first category of decisions stems from taking a previous representation as a starting point, which is probably the case for other ontology developers as well. As some knowledge acquisition has already been performed, ontology creation may be simplified, but it is also constrained by previous conceptualizations. The same applies for the existing code base: it gives a framework in which the ontologies can quickly be brought to use while past code design decisions may lead to compromises in the ontologies.

A second category regards the appropriate use of OWL. For example, for the value list ontology, the fact that a class cannot be the object of a statement in OWL DL means that all values have to be instances, since these are used in individual examinations. One consequence of this is that it is possible to interpret the reference to the instance `Tongue` in two different examinations as indicating the same object in the world. A possible solution within OWL DL would be to have a class `Tongue` for which instances are created specifically for each examination. However, this would create a memory heavy model containing a very large number of instances, which in our case provides little added benefit. Another possibility is to refer to the class `Tongue` in examinations, but this brings us into OWL Full, for which tool and reasoner support is not as developed as for OWL DL. Reflecting on this issue, I see a need for concrete recommendations for how to handle the issue in different scenarios within OWL DL.

A third category are design decisions relate to ontology develoment in general and the proposed open nature of the Semantic Web. One such decision was naming in URIs, where using a numeric codes and English names were considered before deciding on using Swedish names. In retrospect I believe that the larger vision of the Semantic Web led to small design decisions being considered in too much detail. Regarding naming, when knowledge structures are intended for local use, it should be realized that the naming of concepts is not as large an issue as when there is a possibility of global use. However, prospective global use may not initially be known.

Developing Applications Based on Semantic Web Technologies

While the ontologies are of intrinsic interest, their utilization and the value of their utilization in applications also needs investigation. In SOMWeb, using OWL and RDF has made it easy to update the community model and data as the need has arisen. I have also sometimes found that the changes needed in application code can limit the benefit of an easily updated model. In the present system, use of, for example, XML would have produced the same results, and indeed, in an earlier version of the system this was used. If, however, the extended community resource ontology (see Section 5.3.2) is included in SOMWeb, there is a clearer benefit to using OWL and RDF, but further research remains in defining the classes of the different categories of members. The generation of input forms from OWL examination templates has been implemented, but is not running on the live version of SOMWeb, due to my findings that OWL is not currently appropriate for this. Contrary to the two previous findings, the value of Semantic Web technologies is clear in the SOMWeb case browser (Sections 6.4.3 and 6.6.4), which uses reasoning over the value list and case browser OWL ontologies as well as RDF examination data to collect cases by, for example, diagnosis category. The common thread between this and the other suggested example of effective use of Semantic Web technologies, the extended community resource ontology, is that both make use of reasoning. Thus, good use cases for employing OWL are those that emphasize reasoning.

SOMWeb illustrates how Semantic Web technologies can be applied in a clinical knowledge management system. However, further research is needed on appropriate architectures and programming practices for Semantic Web applications. One issue is whether to have object-oriented classes that mirror the central classes of the ontology. Having this mirroring may ease programming, while requiring code maintenance in the face of ontology updates and dealing with differences in conceptualization between, for example, Java and OWL, where in the former properties are not first-class objects while in the latter they are. Another topic is the need for practical and efficient means of keeping only part of the ontology model in memory, since an ontology may be very large, as may the instance data referring to the ontology. Furthermore, for Semantice Web technologies to reach wider use, more practice-oriented literature is needed. Of course, this is a chicken and egg problem, since practical experience is necessary within the community before such literature can be produced. It seems that this point has been reached, with the publication of one such book last year (2008), Allemang and Hendler [2], and two upcoming publications this year, Segaran et al. [142] and Hebeler et a. [65].

Recommendations

When it comes to the benefit of using OWL, I concur with the view of Knublauch et al. [79] that OWL's breadth offers a "migration route from entry level, handcrafted taxonomies of terms, to well defined, normalized ontologies capable of supporting reasoning." In my licentiate thesis [56] I also suggested the need to support such a route, which guides the developer in the appropriate way of representing these 'entry-level' ontologies, so they are coherent and so the path to more well-defined ontologies is clear or even possible.

As part of such guidance I have derived four recommendations for prospective Semantic Web and OWL developers based on the development of the SOMWeb ontologies, found in Section 9.1. I believe these recommendations are valuable for other developers and to guide future research. For example, the first recommendation, regarding properties of OWL to be aware of, such as the accurate interpretation of the constructs of domain and range, suggests a need for investigating assumptions of novice Semantic Web developers, as well as the reasons for these assumptions. For example, object-oriented programming is taught in many programming courses, and therefore, when introducing Semantic Web based development, distinctions from the familiar approach should be made clear early on.

10.1.3 Aim 3: Web-based Tools for Distributed Clinical Collaboration

The third aim of the thesis concerns the design, development, and impact of Web-based tools for distributed clinical practice. This was studied through the SOMWeb system: its conception, evaluation, and impact on SOMNet's collaboration. The SOMWeb system enhances SOMNet's idea of having distance consultations among many clinics, by collecting all community information about members, cases, and meetings in one place and by providing a template for the information to be provided for submitted cases. The main difference between SOMWeb and other similar initiatives for distance consultations within oral medicine is that, in latter systems, the clinical information is only shared between the specialist and the general practitioner. No efforts are made to save the data systematically for further use and comparison with similar cases. Furthermore, there is no collective follow-up of suggested treatment strategies, which will hamper the learning process. SOMWeb also brings in knowledge from external sources, for example, scientific papers, as reported in Section 6.4.3. Thus, SOMNet-internal experiences can be integrated with best available knowledge to the benefit of a single case, thereby contributing to a more evidence-based oral medicine practice.

The SOMWeb system was launched in May 2006. In January 2009, SOMWeb had 120 registered users located at 74 clinics. It has been used at 23 meetings and the case repository contains 121 cases. I now present conclusions related to functionality to support clinical communities of practice, community rhythm, structured case entry, system impacts, recommendations to developers, and the importance of interdisciplinary teams.

Functionality to Support Clinical Communities of Practice

The questionnaire responses, reported in Section 7.2, indicate that 92 percent find that SOMWeb suits patient consultation very well or well, and 91 percent said that SOMWeb suits them very well or well. As reported in Section 7.2, all those interviewed stated that the SOMWeb system has improved the SOMNet collaboration, due to the benefits of having all community information in one place, easier and less time-consuming case entry, more uniform case data, and the collected view of a case over time. The system is thus able to deal with the problems identified in the previous approach (see Section 6.1).

The functionality of SOMWeb, presented in Section 6.4, illustrates relevant collaboration and knowledge sharing functions to be supported for a community of practice of SOMNet's type as well as exemplifies how this has been accomplished, by focusing on cases, meetings, users, and news. A commonly used approach in other systems suppporting such communities of practice is using discussion forums and mailing lists. However, by using abstractions central to SOMNet's collaboration, such as cases, a clearer focus on important, clinically motivated, concepts is gained. This also indicates that the identification of a community's core artifacts is a priority and that these artifacts should be reinforced in the system.

Community Rhythm

The analysis of logs, see Section 7.4.3, shows that system activity peaks the days of meetings, with an increase in activity before meetings. This is to be expected, as the system was explicitly designed to support these meetings. However, one can wonder whether or not this is desirable. On the one hand, the meetings provide a rhythm for the collaboration, a desirable property of a community of practice. The usage patterns of SOMWeb point to a successful alignment with this rhythm. On the other hand, increased use of SOMWeb between meetings, for example by clinicians seeking information related to current cases, would heighten the everyday clinical benefit of the system. Further investigation is needed to examine the activities in SOMWeb between meetings, and to ascertain when and how SOMWeb can be used in daily work.

Structured Case Entry

One of the intentions of SOMWeb was to enable a more uniform case content to be collected. In order to follow up on this, SOMWeb and pre-SOMWeb cases were compared to identify differences in structure and the kind of information provided, as reported in Section 7.6.1. For the pre-SOMWeb cases, there was a wide variety in the content, headings, and whether information was structured. The information included in the general anamnesis was most commonly structured. For the SOMWeb cases, values are more commonly provided for some parts of the initial case entry form than others, and the tendency from the pre-SOMWeb cases persist, in that the terms associated with the general anamnesis have the highest presence of values. This indicates that certain case aspects, such as the general anamnesis, are more easily or commonly structured.

In connection with this, the interviewees' opinions about case entry, found in Section 7.3, are relevant. A majority of those interviewed were positive. However, two interviewees found the structured case entry unsatisfying, due to an inclination for narrative and reservations with distilling a patient's case to the structure of the form. This points to a trade-off between completeness and complexity, where parts of the form are more readily provided in the form of a free text narrative. It can be concluded that even if the possibility of structured entry is provided, it is not always used. While this is an inherent characteristic of system use, it is relevant to consider how one can alleviate entry and how to ensure that important parts are included.

System Impacts

The SOMWeb system's impacts on SOMNet's collaboration, as reported in Section 7.7, includes enabling the participation of a wider range of clinics. Factors influencing this can be the more accessible submission process as well as the increased tangibility and formality that a Web system gives over e-mailing. This also makes outreach to potential new participants easier, and indeed the membership of SOMNet has grown since SOMWeb's introduction. This expansion is probably also part of the natural growth of a healthy community of practice. However, the technical support must be in phase with the community growth, and the initial procedure probably could sustain fewer members than SOMWeb. Further, as the membership grows, it is less likely that members personally know each other. Thus, the increased visibility of SOMNet's members in SOMWeb, via lists of members and what clinic they work at, becomes a necessity.

Another important change is that the chairpersonship now rotates among core and active members, as reported in Section 7.7.4. This has several benefits, such as reducing pressure on the original chairperson, which means that notes about the cases from the meeting can be more consistently entered. It also suggests that more members feel involved in the work of SOMNet, and that knowledge of how this work is carried out is spread to more people. Since it amounts to more external evidence, such as article references, being added, those clinicians less experienced in searching and using literature get more such exposure.

Recommendations

In order to provide more general lessons that have been attained through the development, updating, and study of SOMWeb's use, I also extracted recommendations for developers of systems supporting clinical collaboration and knowledge sharing, as presented in Section 9.2. The recommendations are especially relevant for development carried out in a computer science or informatics research setting. They also differ from those given for Semantic Web developers, in that they largely involve trade-offs and differences in perspective that both constrain and provide a dynamic for the development and research process. For example, the first recommendation, balancing the set of basic functions that the system has to support and the functionality that will be developed with a research purpose, can be alleviated by concisely defining basic functionality, but it cannot be resolved. I also believe that the research team can learn much about the collaboration from the implementation of basic functionality. Several of the recommendations are related to the differences in perspective between developers and researchers on the one hand, and clinicians on the other. One such recommendation is clinicians should quickly be able to see the benefit of work patterns that are changed due to research related functionality. To make this possible, as with the basic functionality, attempts should be made to have more precise conceptions of the research functionality.

Interdisciplinary Teams

Finally, it should be pointed out that SOMWeb is the result of more than ten years of collaboration between medical practitioners and researchers, computer scientists, and researchers within interaction design. It is thus an example of an interdisciplinary team that can successfully address and solve complex research problems within the dental informatics domain, which is in line with the suggestion of Schleyer and Spallek [138]. Further, this is probably a main success factor of the reported work. Already from the start, the composition of the development team included members acting as a 'bridge' between the clinicians and the researchers, securing the results of the latter being of real use and being adopted in practice by the former. A distinguishing feature of SOMWeb is the delegation of control of fundamental parts of the system to the end-users. This means that the clinicians themselves have been able to adopt the system to their specific needs, requiring little interaction with computer specialists, contributing to the overall acceptance of the system. Further, the importance of a community champion, a precursor within the domain in question and the guiding example that others will follow, is stressed within communities of practice literature. I believe that the champion of SOMWeb has, together with a dedicated group of core users that are prepared to try out new ideas and solutions, been essential in the introduction and continued use of the system.

10.2 Reflections on the Research Process

In order to address the issues of this thesis, a broad range of methods was used. I believe that this breadth has served to illuminate the connected issues involved in improving collaboration and knowledge sharing in a manner that would not have been possible taking only one of the approaches. However, that one person carries out these varied methods has benefits and drawbacks. One main benefit is in terms of coherence, where an overarching perspective can be maintained. A drawback is a potential lack of depth caused by the need to learn several methods and perspectives in different areas. In addition to addressing several topics related to computer science, the thesis research also entails a computer scientist entering the field of oral medicine, which adds yet another aspect of learning terminology and the pragmatics of the work carried out. Another drawback with one person wearing many hats is with regard to bias, where I as one of the developers of SOMWeb may have had a tendency to put larger weight to observations and interview statements that were positive toward SOMWeb. While I have tried to keep this in mind when collecting and analyzing data, other measures to counter this problem, such as having a second researcher analyze the data, have not been carried out.

In this thesis, a specific case has been studied, namely the collaboration of SOMNet. On the one hand, this case has to be deemed unique enough to warrant a study, and as stated in Section 3.1, within odontology in Scandinavia, SOMNet is a unique collaboration. At the same time, if the case being studied is too idiosyncratic, the conclusions that can be drawn may not be applicable beyond the case itself. However, as pointed out by Oates [111], cases will often include both factors unique to the case and those shared with other cases. In presenting SOMNet's collaboration, rich descriptions have been provided so that the reader can judge whether SOMNet is similar to a case that they are familiar with. The reader can then decide the extent to which the conclusions from this study are transferable to theirs. The connections with communities of practice [159], discussed in Section 4.5, as well as the structured of clinical team meetings described by Kane and Luz [78], discussed in Section 4.6, point toward this being possible.

In retrospect there are, as with any major undertaking, things that I would have done differently. Some of these are due to my increasing interest in the SOMNet collaboration, the evaluation of SOMWeb, and its impact on the collaboration as the project progressed. Had I known this, I would have observed SOMNet's meetings prior to SOMWeb's introduction. To inform the development of the SOMWeb system, such observations were made, but by another developer. Since these observations had a different purpose, they were not documented, and there is thus no material available for comparison with the meetings after SOMWeb's introduction. Furthermore, data about when a person joined SOMWeb should have been stored, and system activity should have been logged earlier. Also, the usability of SOMWeb has not been specifically addressed, as could have been done through heuristic evaluation [103] or cognitive walkthroughs [125]. However, researchers in interaction design were part of the design team, and thus provided consideration for usability aspects.

With regard to the use of Semantic Web technologies, again a broad approach is taken and a wide variety of results are presented, such as ontologies, design decisions in creating these, and the use of the ontologies in the SOMWeb system. This resulted in practical recommendations while providing potential venues of further research. Some of the design decisions presented could have been the topic of investigation in their own right, but such in depth studies were beyond the scope of this project. In the ontology development, there was little direct end-user involvement, since much of the knowledge elicitation had already been carried out within the MedView project. However, given the increased number of users, a reassessment of the previous conceptualization could be beneficial.

This thesis studies the collaboration of clinicians and researchers. However, in order to carry out this research, close collaboration is also needed between researchers from computer science and clinicians and researchers of oral medicine (or whatever the discipline of application may be). While this places practical constraints on the research, such as significant effort spent on developing and maintaining non-research aspects of the system, it is also a prerequisite for the research's existence, makes it meaningful, and ensures its relevance.

10.3 Future Work

Directions for future work suggested by the thesis research are now presented, organized according to the three thesis aims. Related to the collaboration of distributed clinicians, the first aim, it would be interesting to:

- Study the distributed collaboration of clinicians in other specialities to determine similarities and differences from that of SOMNet. This will give an indication of how transferable the characterization given in the thesis is and extend our knowledge of the forms that distributed collaboration can take, which in the end enables better organizational and technical support.

- Investigate the needs of participants of SOMNet and similar collaborations with regard to their level of participation. For example, this can include the examination of whether newer and more peripheral participants have different needs than core members and how SOMWeb and similar tools can vary their support according to this. This should also lead to enrichment of the community resource ontology of Section 5.3.

- Examine the evolution of SOMNet over time. How do the forms of collaboration and use of SOMWeb change with increased diversity and number of members? This can give insight into the lifecycles of distributed communities of practice and variations in needs for technical support provided at different stages.

- Further analyze the data from the observations of SOMNet's meetings. For example, the frequencies of utterances from different members and the content of statements could be analyzed to give a more complete picture of the collaboration.

The results and conclusions related to the second aim, the use of Semantic Web technologies, suggest that it is important to:

- Investigate appropriate mechanisms for representing templates within the Semantic Web framework. In this work, limitations were found in using OWL for representing templates. However, templates are important in many systems, and Semantic Web technologies would become more useful and accessible if such a mechanism was included.

- Enrich existing methodologies for ontology development to include different paths depending on the sought for level of sophistication of the ontology. This should address varying ontology development goals and help ensure that the initial development does not encompass more formalization than is necessary while maintaining the possibility of supplementing the ontology at a later stage.

- Establish competency question templates that can be used by prospective ontology developers to aid in determining what reasoning tasks their ontology can support, which could result in higher quality ontologies developed with more ease. A step in providing such templates is an investigation of types of competency questions used by successful projects.

- Develop guidelines for application-based evaluation of ontologies, which is probably the form of evaluation most accessible to many projects.

- Employ automatic or semi-automatic ontology learning methods (for example [23] and [12]) to add more detail to the oral medicine ontology, which can in turn be used to provide improved browsing and visualization of cases.

Potential future work related to the third aim, Web-based tools for distributed clinical practice, includes:

- Study is the adoption of the SOMWeb system by similar collaborations. This could, for example, give an indication of how important the user-centered development process is to the success of SOMWeb.
- Investigate the impact of SOMWeb through the "most significant change" method [29], which involves the systematic collection of stories capturing change and the analysis and discussion of these. Such a study would elaborate on the impacts identified in this work and provide more insight into the effects of collaboration and knowledge sharing.
- Further examine the data collected in studying SOMWeb. For example, the log analysis could be complemented with further statistical and data mining studies to establish patterns of use of SOMWeb outside of meetings. This can inform how clinicians use external evidence as part of the everyday work.
- Implement improvements derived from the evaluation of SOMWeb, presented in Section 8.1. These include the use in SOMWeb of the patterns described in Falkman et al. [38].

10.4 Final Remarks

Through the case of SOMNet, with its regular teleconference meetings, this thesis has explored distributed clinical collaboration and knowledge sharing in oral medicine, the development of Web-based tools to support this, and the use of Semantic Web technologies.

During the time of the research of this thesis, there have been substantial developments on the Semantic Web research scene. The work presented here should be seen as a piece in this puzzle, in trying to determine how standardized knowledge representation techniques can be used to further the development of clinical knowledge management systems. By participating in activities such as the OWL: Experiences and Directions Workshop, I have been able to present my observations of and needs for OWL ontology development, which has in turn been a part of informing later iterations of the OWL recommendation and the developer tools that are built around it.

Meanwhile, the SOMWeb system has been in use for three years, and through this has actively aided the collaboration and knowledge sharing of the clinicians. Positive impacts, such as increased membership and rotating meeting chairpersonship, have been identified. At the same time, challenges remain, such as trade-offs in structured case entry and how to accommodate varying levels of expertise.

Appendix A

Interview Guide

These themes and questions were used as guides in the interviews. Interviews were held in Swedish, and this is a translation of the interview guide.

The purpose of the interviews were (as stated to the interviewees):

- To understand how the SOMWeb system is used and how it has changed SOMNet's meetings and the members' knowledge use.
- To understand the clinicians knowledge needs and how SOMNet better can support these.
- To understand how SOMNet works as a virtual organization.

Interview questions, sorted by theme:

- Initial data: How long have you been a member of SOMNet?
- Adding cases
  - Describe how you go about adding a case to the SOMWeb system.
    - Describe how you go about collecting information for adding a case.
    - How do you decide that you want to add a case?
  - What purposes have you had in adding cases for discussion? (If we don't touch upon it above)
  - How would you like to add your purpose in bringing up the case when you fill in the "Add a case"-form?
  - In the SOMWeb system, you fill in a form when adding a case. What do you think of this form?
- Meetings
  - Describe how you usually use the SOMWeb system at SOMNet's meetings.

    - How has it changed since SOMNet used PowerPoint presentations?
    - When does it work well?
    - When does it work badly?
    - Suggestions for improvements?
  - Describe how you usually prepare for SOMNet's meetings.
  - How often do you participate in SOMNet's meetings?

- Knowledge needs and benefits

  - SOMNet probably fills different needs for different participants. What do you see as the main benefit of SOMNet for yourself?
  - What do you think the benefits are for others?
  - What kinds of cases do you think that SOMNet should discuss? (purpose and level of difficulty)
  - Can you give a concrete example of when knowledge from SOMNet directly or indirectly "solved" a case that you would not have been able to solve as well/quickly otherwise?
  - How has participation in SOMNet and use of SOMWeb improved your ability to perform you work activities?
  - How has participation in SOMNet affected your knowledge seeking?
  - How do SOMNet and SOMWeb fit into your everyday work activities?
  - How could this be improved?

- Use of SOMWeb outside of current meeting

  - Have you used SOMWeb to browse and/or search among cases that were not to be brought up at the current meeting?

- Is there anything that you have thought about that has not been brought up?

- Age and background (education, how many years working, in what position)

Appendix B

Questionnaire

Questions used in the questionnaire (translated from Swedish).

Introductory text: The SOMWeb system has been developed to support SOMNet work by making possible the presentation and discussion of cases, both at the monthly telephone conferences and by discussion forums online. The system was introduced in May 2006. Before, PowerPoint-presentations were used to present cases. As a part in continued developments we need feedback from the users on their experiences in using the system and with suggestions on how SOMNet's activities can be further supported in SOMWeb.

1. What do you view as the primary purpose of SOMNet?
   (a) Forum for discussion, (b) Patient consultations,
   (c) Continuing education activity

2. When did you receive the possibility to log in to SOMWeb?
   (a) April–June 2006, (b) July–September 2006,
   (c) October–December 2006, (d) January–April 2007

3. When did you begin to use SOMWeb?
   (a) April–June 2006, (b) July–September 2006,
   (c) October–December 2006, (d) January–April 2007

4. How many telephone conferences have you participated in since SOMWeb was introduced?
   (a) 0, (b) 1–2, (c) 3–6 (d) More than 6

5. If you have participated in conferences, have you looked at the cases before the meeting?
   (a) Never, (b) Rarely, (c) Often, (d) Always

6. Have you used SOMWeb outside of meetings and meeting preparations?
   (a) Yes, (b) No

7. If yes, what have you used the system for?
   (a) Getting acquainted with SOMWeb, (b) Reading news, (c) Browsing cases, (d)

Searching cases, (e) Looking at other members, (f) Discussing cases with other members, (g) Looking at cases from missed meetings, (h) Instructing colleagues

8. Where are you usually located when you log into SOMWeb?
   (a) Workplace, (b) Home

9. How hard is it to understand how to use SOMWeb?
   (a) Very hard, (b) Hard, (c) Neither hard nor easy, (d) Easy, (e) Very easy

10. How well does SOMWeb suit your needs?
    (a) Very badly, (b) Badly, (c) Neutral, (d) Well, (e) Very well

11. How well does SOMWeb suit SOMNet's needs in continuing education?
    (a) Very badly, (b) Badly, (c) Neutral, (d) Well, (e) Very well

12. How well does SOMWeb suit SOMNet's needs for distance consultations?
    (a) Very badly, (b) Badly, (c) Neutral, (d) Well, (e) Very well

13. How well does SOMWeb suit SOMNet's needs for discussion?
    (a) Very badly, (b) Badly, (c) Neutral, (d) Well, (e) Very well

14. How many SOMNet meetings did you participate in before SOMWeb was introduced?
    (a) 0, (b) 1–4, (c) 5–10, (d) More than 10

15. If you participated in SOMNet before SOMWeb's introduction, how do you find that SOMWeb works compared to using PowerPoint-presentations, with regard to:
    (all of the following were answered on a scale of (a) Worse, (b) neutral, (c) better)

    - Viewing cases before meetings?
    - During meetings?
    - Adding cases?
    - Looking at old cases?
    - Supporting your work in general?
    - Supporting SOMNet in general?

16. Have you added cases to SOMWeb for discussion at meetings?
    (a) Yes, (b) No

17. If yes above, what was the reason for adding the case?
    (a) Consultation, (b) Unusual case, (c) Create discussion, (d) Other:

18. Have you had cases that you considered submitting but did not?
    (a) Yes, (b) No

19. Why did you not add it? (Free text answer.)

20. What would motivate you to add more cases? (Free text answer.)
21. What would motivate you to use SOMWeb outside of meetings?
    (Free text answer.)
22. Other comments?
23. Gender
24. Age
25. How would you describe your expertise in the use of computers?
    (a) Very large, (b) Large, (c) Medium, (d) Small, (e) Very small
26. Describe your workplace:
    (a) Private practice, 1 dentist, (b) Private practice, more than 1 dentist,
    (c) Public dental care (folktandvård), 1 dentist, (d) Public dental care (folktandvård), more than 1 dentist, (e) Hospital dental care, 1 dentist, (f) Hospital dental care, more than 1 dentist, (g) Specialist clinic.
27. Describe your position:
    (a) General practitioner, private, (b) General practitioner, public.
    (c) Specialist, private, (d) Specialist, public
28. How many years in this field?
    (a) 0–5, (b) 5–10, (c) 10–20, (d) More than 20.

Appendix C

Examples of Templates, Value List, and Examination

C.1 MedView XML Examination Template for Meeting Consultation


```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE examination PUBLIC "form"
    "http://www.somweb.se/somweb/form.dtd">
<examination>
  <!-- information about the form -->
  <forminfo>
    <author>Fredrik Lindahl/Marie Gustafsson (translation)
               </author>
    <date>2005-11-23</date>
    <title>SOMWeb form for meeting consultations</title>
  </forminfo>
  <!-- administrative information -->
  <category>
    <name>Admin</name>
    <description>General information</description>
    <input type="text" locked="true" included="false"
               required="true" visible="false">
      <name>CID</name>
      <description>Case ID</description>
      <instruction>Automatically generated by the
               system</instruction>
    </input>
    <input type="text" locked="true" included="false"
               required="true" visible="false">
      <name>DID</name>
      <description>Consultation ID</description>
      <instruction>Automatically generated by the
               system</instruction>
```

```
    </input>
    <input type="text" locked="true" required="true"
               visible="false">
      <name>Reg-person</name>
      <description>Registering care-giver</description>
    </input>
    <input type="text" locked="true" required="true"
               visible="false">
      <name>Reg-clinic</name>
      <description>Registering clinic</description>
    </input>
  </category>
  <!-- meeting consultation -->
  <category>
    <name>Meeting</name>
    <description>Meeting consultation</description>
    <input type="multi" free="true">
      <name>Treat-sugg</name>
      <description>Suggested action/treatment</description>
    </input>
    <input type="note">
      <name>Note-epi</name>
      <description>Epikris</description>
      <instruction>Collected judgement of the case</instruction>
    </input>
  </category>
</examination>
```

C.2 SOMWeb OWL Examination Template for Meeting Consultation

```
Namespace(rdf = <http://www.w3.org/1999/02/22-rdf-syntax-ns#>)
Namespace(xsd = <http://www.w3.org/2001/XMLSchema#>)
Namespace(rdfs = <http://www.w3.org/2000/01/rdf-schema#>)
Namespace(owl = <http://www.w3.org/2002/07/owl#>)
Namespace(generalExam = <http://www.somweb.se/ontologies/
      generalExaminationOntology.owl#>)
Namespace(meetingConsultationForm = <http://www.somweb.se/
      ontologies/meetingConsultationForm.owl#>)
Namespace(somwebValueList = <http://www.somweb.se/ontologies/
      somwebValueList.owl#>)

Ontology( <http://www.somweb.se/ontologies/
      meetingConsultationForm.owl>

Annotation(owl:imports <http://www.somweb.se/ontologies/
      generalExaminationOntology.owl>)
Annotation(rdfs:comment "A meeting consultation template
        for the SOMWeb community.")

Class(meetingConsultationForm:meeting_consultation partial
      generalExam:Examination)

Class(meetingConsultationForm:Admin partial
      generalExam:ExaminationCategory
  restriction(meetingConsultationForm:CIDInput
      allValuesFrom(xsd:string))
  restriction(meetingConsultationForm:DIDInput
      allValuesFrom(xsd:string))
  restriction(meetingConsultationForm:Reg-clinicInput
      allValuesFrom(xsd:string))
  restriction(meetingConsultationForm:Reg-personInput
      allValuesFrom(xsd:string)))

Class(meetingConsultationForm:Meeting partial
  generalExam:ExaminationCategory
  restriction(meetingConsultationForm:Note-epiInput
      allValuesFrom(xsd:string))
  restriction(meetingConsultationForm:Treat-suggInput
      allValuesFrom(somwebValueList:Treat-sugg)))

DatatypeProperty(meetingConsultationForm:CIDInput
   annotation(generalExam:descriptionProperty "Case ID"@en)
   annotation(generalExam:descriptionProperty "Fall-ID"@sv)
   annotation(generalExam:instructionProperty
      "Automatically generated by the system"@en)
   annotation(generalExam:instructionProperty
```

```
      "Genereras automatiskt av systemet"@sv)
   Functional)

DatatypeProperty(meetingConsultationForm:DIDInput
   annotation(generalExam:descriptionProperty
      "Consultation ID"@en)
   annotation(generalExam:descriptionProperty
      "Konsultations-ID"@sv)
   annotation(generalExam:instructionProperty
      "Automatically generated by the system"@en)
   annotation(generalExam:instructionProperty
      "Genereras automatiskt av systemet"@sv)
   Functional)

DatatypeProperty(meetingConsultationForm:Reg-clinicInput
   annotation(generalExam:descriptionProperty
      "Registering clinic"@en)
   annotation(generalExam:descriptionProperty
      "Anmälande klinik"@sv)
   Functional)

DatatypeProperty(meetingConsultationForm:Reg-personInput
   annotation(generalExam:descriptionProperty
      "Registering care-giver"@en)
   annotation(generalExam:descriptionProperty
      "Anmälande vårdgivare"@sv)
   Functional)

ObjectProperty(meetingConsultationForm:Treat-suggInput
   annotation(generalExam:descriptionProperty
       "Suggested action/treatment"@en)
   annotation(generalExam:descriptionProperty
       "Föreslagen åtgard/behandling"@sv))

DatatypeProperty(meetingConsultationForm:Note-epiInput
   annotation(generalExam:descriptionProperty "Epikris"@en)
   annotation(generalExam:descriptionProperty "Epikris"@sv)
   annotation(generalExam:instructionProperty
       "Collected opinion of the case"@en)
   annotation(generalExam:instructionProperty
       "Samlad bedömning av fall"@sv))

)
```

C.3 Part of the SOMWeb Value List

```
Namespace(rdf = <http://www.w3.org/1999/02/22-rdf-syntax-ns#>)
Namespace(rdfs = <http://www.w3.org/2000/01/rdf-schema#>)
Namespace(owl = <http://www.w3.org/2002/07/owl#>)
Namespace(somwebValueList =
      <http://www.somweb.se/ontologies/somwebValueList.owl#>)

Ontology( <http://www.somweb.se/ontologies/somwebValueList.owl>

Annotation(rdfs:comment "Value list ontology of the
        SOMWeb community.")

Class(somwebValueList:Drug
     annotation(dc:creator "termValues")
    annotation(somweb:medviewType multiple))
Class(somwebValueList:Occup
    annotation(dc:creator "termValues")
    annotation(somweb:medviewType regular))
Class(somwebValueList:ResultNow)
    annotation(dc:creator "termValues")
    annotation(somweb:medviewType regular))

Individual(somwebValueList:Eucardic
  type(somwebValueList:Drug)
  annotation(dc:creator "termValues")
  annotation(rdfs:label "Eucardic" @sv))

Individual(somwebValueList:Doktacillin
  type(somwebValueList:Drug)
  annotation(dc:creator "termValues")
  annotation(rdfs:label "Doktacillin" @sv))

Individual(somwebValueList:Inredningssnickare
  type(somwebValueList:Occup)
  annotation(dc:creator "termValues")
  annotation(rdfs:label "Inredningssnickare" @sv))

Individual(somwebValueList:helt_utlakt
  type(somwebValueList:ResultNow)
  annotation(dc:creator "termValues")
  annotation(rdfs:label "helt utläkt" @sv))
)

)
```

C.4 Example Examination Instance

```
<rdf:RDF
    xmlns:generalExam="http://www.somweb.se/ontologies/
        generalExaminationOntology.owl#"
    xmlns:somwebValueList="http://www.somweb.se/ontologies/
        somwebValueList.owl#"
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:examForm="http://www.somweb.se/ontologies/caseForm.owl#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
<generalExam:Examination rdf:about="generalExam#
        ExaminationSMW0001279780-071203000000">
    <generalExam:hasExaminationCategory rdf:resource="examForm#
        TreatSMW0001279780-071203000000"/>
    <generalExam:hasExaminationCategory rdf:resource="examForm#
        PatientSMW0001279780-071203000000"/>
    <generalExam:hasExaminationCategory rdf:resource="examForm#
        Anamn-genSMW0001279780-071203000000"/>
    <generalExam:hasExaminationCategory rdf:resource="examForm#
        AdminSMW0001279780-071203000000"/>
    <generalExam:hasExaminationCategory rdf:resource="examForm#
        Anamn-locSMW0001279780-071203000000"/>
    <generalExam:hasExaminationCategory rdf:resource="examForm#
        NotesSMW0001279780-071203000000"/>
    <generalExam:hasExaminationCategory rdf:resource="examForm#
        OralSMW0001279780-071203000000"/>
    <generalExam:hasExaminationCategory rdf:resource="examForm#
        DiagSMW0001279780-071203000000"/>
     <generalExam:hasExaminationCategory rdf:resource="examForm#
         NotesSMW0001279780-071203000000"/>
</generalExam:Examination>
<examForm:Patient rdf:about="examForm#
        PatientSMW0001279780-071203000000">
    <examForm:AgeInput rdf:datatype=
        "http://www.w3.org/2001/XMLSchema#int">50
        </examForm:AgeInput>
    <examForm:GenderInput rdf:resource="somwebValueList#Kvinna"/>
    <examForm:BornInput rdf:resource="somwebValueList#Sverige"/>
</examForm:Patient>
<examForm:Diag rdf:about="examForm#
        DiagSMW0001279780-071203000000">
    <examForm:Diag-histInput rdf:resource="somwebValueList#
        Skivepitelcancer"/>
    <examForm:Diag-tentInput rdf:resource="somwebValueList#
        Skivepitelcancer"/>
</examForm:Diag>
<examForm:Anamn-loc rdf:about="examForm#
        Anamn-locSMW0001279780-071203000000">
    <examForm:Symp-nowInput rdf:resource="somwebValueList#
```

```
        Irritation"/>
    <examForm:Symp-intInput rdf:datatype=
      "http://www.w3.org/2001/XMLSchema#int">30
      </examForm:Symp-intInput>
    <examForm:Symp-prevInput rdf:resource="somwebValueList#Ja"/>
</examForm:Anamn-loc>
<examForm:Admin rdf:about="examForm#
        AdminSMW0001279780-071203000000">
    <examForm:CIDInput>CID117333945</examForm:CIDInput>
    <examForm:DIDInput>DID755679464</examForm:DIDInput>
    <examForm:Reg-personInput>Nils Nilsson
        </examForm:Reg-personInput>
    <examForm:Reg-dateInput>2007-04-03
        </examForm:Reg-dateInput>
    <examForm:Case-titleInput>Tungcancer
        </examForm:Case-titleInput>
</examForm:Admin>
<examForm:Anamn-gen rdf:about="examForm#
        Anamn-genSMW0001279780-071203000000">
    <examForm:Dis-nowInput rdf:resource="somwebValueList#
        Astma"/>
</examForm:Anamn-gen>
<examForm:Treat rdf:about="examForm#
        TreatSMW0001279780-071203000000">
    <examForm:Treat-pastInput rdf:resource="somwebValueList#
        Clobetasol_gel"/>
    <examForm:Result-pastInput rdf:resource="somwebValueList#
        helt_utlakt"/>
    <examForm:Treat-nowInput rdf:resource="somwebValueList#
        Extirperad"/>
    <examForm:Result-nowInput rdf:resource="somwebValueList#
        forbattrad"/>
</examForm:Treat>
<examForm:Oral rdf:about="examForm#
        OralSMW0001279780-071203000000">
    <examForm:PhotoInput>SMW0001279780_071203000000_1.jpg
    </examForm:PhotoInput>
    <examForm:PhotoInput>SMW0001279780_071203000000_2.jpg
    </examForm:PhotoInput>
</examForm:Oral>
<examForm:Notes rdf:about="examForm#
        NotesSMW0001279780-071203000000">
    <examForm:Note-otherInput>The patient has been...
    </examForm:Note-otherInput>
</examForm:Notes>
</rdf:RDF>
```

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