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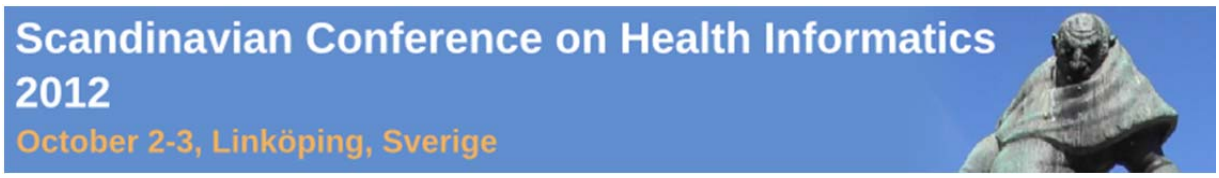

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Papers

Posters

Global applicability of a local physical examination template

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Abstract

Achieving semantic interoperability is a challenge due to the complexity and variability of health care and clinical information systems. Applying locally developed templates in other organisations and in standardisation work requires that the local templates have a global applicability. Therefore, the aim of this paper is to examine the global applicability of a physical examination template from Odense University Hospital. This was done by comparing the content of the template with an international text book description of a physical examination as well as 42 clinical findings derived from randomly chosen international clinical notes from physical examinations. To quantify differences and similarities between clinical notes and the template, SNOMED CT was used for analysis. The study showed that approximately ¾ of the 42 clinical findings could be represented in the Odense Template. This suggests that local templates, at least for well defined clinical processes, have a global applicability.

Keywords: Computerized medical records, SNOMED CT

Introduction

The heterogeneity of existing systems is said to be a major challenge when aiming at semantic interoperability in health care. Semantic interoperability means "ensuring that the precise meaning of exchanged information is understandable by any other system or application not initially developed for this purpose"[1]. Semantic interoperability is a prerequisite if benefits of electronic health records like e.g. shared care, quality assessment and research should be achieved. Heterogeneity is a challenge at different levels, firstly, from a technical viewpoint, different systems with a variety of underlying information models and proprietary terminology requires massive re-design to be able to support semantic interoperability. Secondly, from a clinical viewpoint, local clinical workflows and documentation might hinder the homogenisation that interoperability requires.

Local templates for clinical documentation have typically been adapted to local practices, and stepwise improvements have continuously been implemented in paper-based charts. Thus local templates typically become heterogeneous and are thus thought difficult or impossible to use in similar departments elsewhere. However, medicine as a discipline is international and so are many clinical standards. Thus, if local templates support a "global" clinical practice, there is a possibility that local work can serve as an input to standards development in medical informatics.

Typically in standards development, experts join to formulate the clinical content of standards e.g. in the openEHR community.[2] Similar examples of experts formulating the clinical content of standards can be found in the scientific literature.[3] These standards development initiatives often consider completeness and accuracy as the important quality criteria and leaves implementation to separate implementation groups or the users of the standards. In contrast, standards developed from analyzing local documentation and templates might ease standards implementation in local projects because the point of departure is clinical templates in use. This would be a step towards improved semantic interoperability between clinical information systems, especially if the clinical standard (e.g. a physical examination) was expressed using standardized information models (like HL7 v.3 RIM and templates/CDA or ISO13606 RM and archetypes/templates) and standardized terminology (like SNOMED CT).[4]

The objective of this study was to investigate how general a clinical template is in a global perspective. This was done by examining the "global" applicability of the local "Physical Examination template" developed at Odense University Hospital. The content of this local template was compared with an international procedural description of a physical examination and the content of international clinical notes regarding physical examination. Part of the comparison was done using SNOMED CT as reference. Hereby the differences and similarities of the content can be compared in detail in terms of their meaning and not only the terms used, because closeness of related terms in SNOMED CT can be a measure of how different or how similar the terms are.

Materials and Methods

Firstly, the physical examination is categorized using a text book description, MTSamples notes and a template from Odense University Hospital. Secondly, this material is analyzed using SNOMED CT.

Materials

The physical examination template from Odense University Hospital was collected in January 2011, and is a template in everyday use. The template was developed as part of an electronic health record (EHR) project based on a detailed requirement engineering process and with emphasis on standardisation within the organisation. Odense University Hospital has implemented Cambio Cosmic. This EHR-system is customizable, i.e. for each well-defined workflow a local template can be designed to support structured documentation. An earlier study has shown that the Odense University Hospital requirement engineering process consisted of two steps. First a clinical reference group with representatives from relevant specialties and with different clinical educations formed an overall documentation approach developing a number of standard workflows to describe e.g. the general medication and admission. As a second step each department in the hospital had the opportunity to add special cases from their local workflows to the standard workflows and special fields to the general templates. [5]

MTSamples[6] is a collection of clinical notes made available via internet as a resource. The notes from MTSamples do not have a well-defined source and they are provided by various users and the accuracy and quality of the notes is not guaranteed. However, an earlier study that used MTSamples notes together with notes from two hospitals has shown that 77% of statement types in the social history section could be found from MTSamples alone[7]. Therefore, the types of clinical statements in the physical examination section are expected to have a similar quality and thus be useful for the purpose of representing typical concepts and terms in physical examination notes.
MTSamples contains 491 notes in the category "Consult - History and Phy" where "Phy" is short for physical examination. 40 of these were randomly selected and the physical examination part was extracted if present. 6 notes did not have a physical examination which left 34 notes for further analysis.

For a global description of a physical examination the well-cited textbook, Clinical Methods: The history, physical and laboratory examinations, was used. In this textbook, the physical examination is summarized in 11steps and ordered in a table. [8]

Categorization of a physical examination

For comparison the structure of the Odense template and the MTsamples notes were itemised in accordance with the textbook table.

Analysis of the information content in physiological examination notes

To obtain an overview of the content of the MTSamples physical examination notes a word-count on similar words (not case sensitive, no numbers) was performed ignoring common English words (like, are, and etc.). The resulting list was analyzed from the most frequent words to the least frequent. From this list concrete clinical findings were identified. For this study both actual clinical findings like "lymphadenopathy" and findings related to a specific part of the body like "Heart" was considered concrete clinical findings. To identify these findings, firstly, non-clinical findings was taken away (like patient, supple.), then unspecific clinical findings were analyzed. Unspecific clinical findings were e.g. normal, vital, bilateral and sounds. Going back to the original text, if the term was always used in the same (or a few) context(s), the context was specified. For example vital was always used in "vital signs" and therefore "vital" and "signs" was linked together for the word count. Also sound was used in two contexts namely "bowel sounds" and "breath sounds", the correct context was specified in the word count. If the term was used in many different contexts like "normal" it was deleted from the word count. When the top 42 terms in the list were all concrete clinical findings, these terms were sorted according to the structure given by the text book material.

Comparison using SNOMED CT

To be able to compare the content of the clinical notes from MTSamples with the Odense template; all terms were mapped to SNOMED CT and structured in terminology-trees as illustrated in figure 1. Afterwards, it was analyzed how the terms from MTSamples were linked to the Odense template terms through the hierarchical relationships in SNOMED CT. This was done by analysing the terminology trees i.e. exact matches was identified as the concepts present in both the Odense template and MTSample derived clinical findings. Partial matches were identified in two groups. The first group consisted of concept pairs where MTSample derived clinical findings were children of Odense terms. The second group consisted of concept pairs where Odense terms were children of MTSample derived clinical findings. Also, unmatched terms were identified. Hereby, the analysis answered what information from the clinical notes could be expressed in the Odense template.
This was done for each of the 11 categories in textbook description of the physical examination. All negative findings from MTSamples were mapped to the corresponding positive finding, since SNOMED CT cannot handle negations systematically.

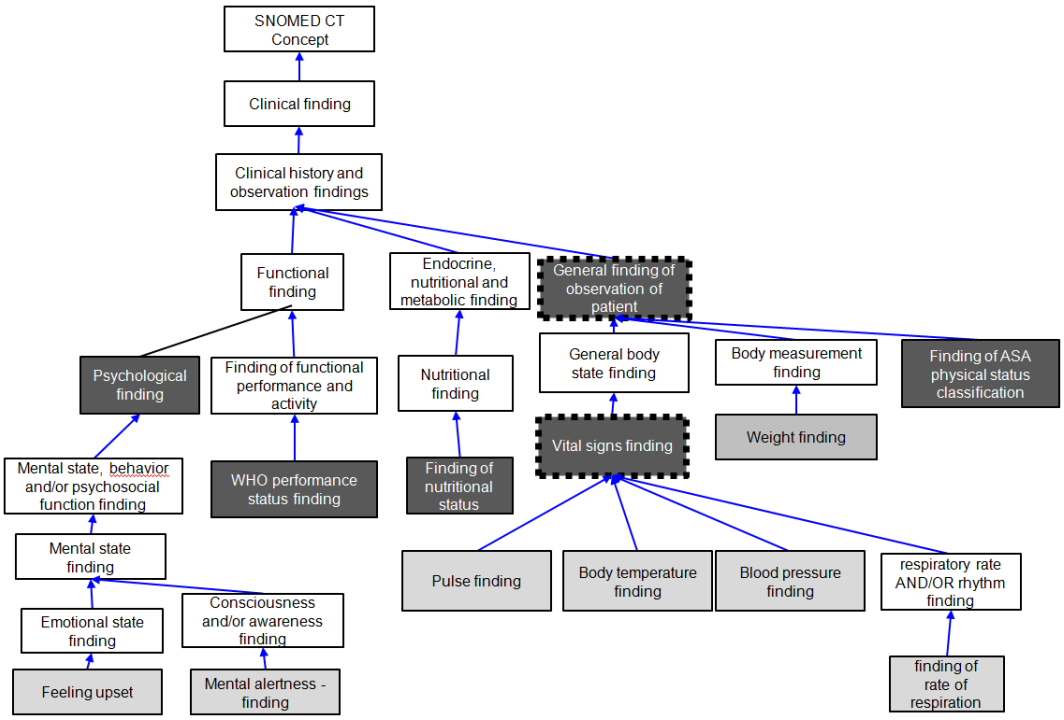

Figure 1 The figure shows a SNOMED CT tree for the first of 11 steps in a physical examination. The dark grey boxes are Odense template terms, the light grey boxes are MTSamples terms. The dark grey boxes with dotted lines are found in the Odense template as well as the MTSamples examples.

Results

In table 1, the text book categorization of the physical examination is described in the first column. The second column contains the terms from the Odense template, and the right column contains the findings identified in the physical examination notes from MTSamples.

In terms of similarities between the Odense template and the text book description it is clear that both are physiological examination descriptions mentioning organ systems systematically from head to toe with many similar terms e.g. eyes, neck, thorax and abdomen. When looking at the differences, it is clear that templates are much less process oriented than the text book description. For example, the text book description contains patient comfort and position whereas the template focuses on the organ systems that the findings are related to. In short, where the text book is process oriented, the template is information oriented. This is a predictable consequence of comparing a textbook on how to perform a physiological examination with a documentation template. However, there is some indication that the template is also sometimes a process support tool both when it comes to the sequence of the terms but also when a term includes a method e.g. cardiac auscultation and otoscopy. This creates other differences as well. For example motor strength, reflexes and proximal lower extremities are mentioned at different places in the text book description. However, the Odense template only has one field, namely, “limbs” that could possibly include information from all tree clinical areas. Another notable difference is template fields that are not mentioned as areas of interest in the text book description like “psychological”, “laboratory test results” and “additional” and vice versa, e.g. salivary glands and pelvic examination.

Physical examination		
Textbook categorization	**Odense template keywords**	**MTSamples physical examination notes findings**
Comfort	-	-
Optimal environment	-	-
Vital signs and general inspection	Vital signs reference, General clinical state, WHO Performance score, ASA score, Psychological, Nutritional status	Vital signs, Temperature, Pulse, Blood pressure, Respiratory rate, General, Distress, Alert, Weight
Head (Eyes, Ears, ophthalmo-otoscopy, nose, mouth, face)	Skull and face, eyes, otoscopy, mouth and pharynx	HEENT (Head, Eyes, Ears, Nose, and Throat), Pupils, Head, Head atraumatic, Normocephalic
Neck (e.g. Lymph nodes, salivary glands and thyroid)	Neck, Lymph nodes, thyroid	Neck, Lymphadenopathy
Anterior torso (e.g. breast and heart)	Cardiac auscultation, Respiratory auscultation	Lungs, Heart, Cardiovascular, Heart Rhythm, Heart Rate, Murmur, Auscultation
Posterior torso (e.g. veterbrea collum)	Back	
Completion of the "sitting" portion of the ination (motor strength, reflexes, pulse and sensation)	Neurological,Thorax, Breast finding, Abdomen, limbs	Pulses, Reflexes, Motor, Muscle strength, Chest, Abdomen, Abdomen nondistended, Bowel sounds, Extremities, Extremities cyanosis, Extremities edema, Extremities clubbing
With the patient supine (Thorax, abdomen, proximal lower extremities)		
With the patient standing(external genitalia of male, station and gait)	Genitals, Gait	Motion
Pelvic and rectal examination	Exploration of rectum	
	Skin, Additional, Laboratory test results	Skin

Table 1. The table lists a textbook categorization of a physical examination in the first column. The second column contains the terms from the Odense University Hospital template, and the third column contains the findings identified in the physical examination notes from MTSamples.

Exact matched terms	General finding of observation of patient, Vital signs finding, eye/vision finding, Ear and auditory finding, finding of neck region, General finding of abdomen, finding of region of thorax, finding of limb structure, finding of skin

MTSamples terms children of Odense terms	**General finding of observation of patient**(Weight finding, vital signs finding) **Vital signs finding** (Pulse finding, Body temperature finding, Blood pressure finding, finding of rate of respiration) **Psychological finding**(feeling upset, mental alertness finding) **Cardiac auscultation finding** (Heart murmur) **Finding of face** (Nose finding) **Skull finding** (head normal shape, fracture of skull) **Mouth and/or pharynx** (Pharyngeal finding) **Eye/vision finding**(Pupil finding) **Cardiac auscultation finding** (Heart murmur**) Neurological finding** (Motor nervous system findling, O/E motor sensory, O/E neurological reflexes) **Finding of Limb structure**(Blue extremities, edema of extremity, finger clubbing) **General finding of abdomen** (Swollen abdomen, finding of bowel sounds)
Odense terms children of MTSamples terms	**Head finding**(Mouth and/or pharynx, finding of face, skull finding) **General finding of observation of patient** (Vital signs finding, Finding of ASA physical status classification) **finding by auscultation** (Respiratory auscultation finding, Cardiac auscultation finding) **Cardiovascular finding, Cardiac finding**(Cardiac auscultation finding) **Respiratory finding**(Respiratory auscultation finding) **Finding of region of thorax** (Breast finding)**Finding related to ability to move** (finding related to ability to walk)
Unmatched Odense terms	Finding of lymph node, finding of thyroid gland, WHO performance status finding, finding of nutritional status, Endoscopy of ear, Finding of back, Genital finding, rectum finding Unmapped: Additional, Laboratory test results
Unmatched MTSamples terms	Lymphadenopathy of head and/or neck , finding of heart rate, finding of heart rythm, finding of power of skeletal muscle, finding of peripheral pulse

Table 2. The table presents the results of the analysis of how the content of the physical examination notes from MTSamples relates to the terms in the Odense University Hospital template according to the common reference, SNOMED CT.

Table 2 shows that the physical examination content of MTSamples and the Odense template is highly interrelated. The terms that are exact matches mean that similar content is found in both places. “MTSamples terms children of Odense terms” describe when there is an IS-A relationship between an Odense and MTSample term with the MTSample term being the subsumer. So, according to SNOMED CT Pulse finding, Body temperature finding, Blood pressure finding and finding of rate of respiration from MTSamples can be documented in the Odense template in the field vital signs finding, which makes perfect sense. Other examples are less operational e.g. it is doubtful that anyone would document weight finding and vital signs finding in a field called “General finding of observation of patient”.

“Odense terms children of MTSamples terms” describe when there is an IS-A relationship between an Odense and MTSamples term with the Odense term being the subsumer. In this category, the MTSample terms resembles coarse grained information compared to the Odense terms. This means that the information from MTSamples cannot be expressed in the Odense template unless the granulation level of the Odense template is slightly altered.

The unmatched Odense terms means that there are fields in the Odense template, which would never be instantiated if the 34 MTSample terms were representative for all findings in the physical examination. So the terms could possibly be candidates for deletion or coarser granularity. However, the text book description clearly mentions several of the unmatched Odense terms, so the evidence level is insufficient in terms of recommending deletion.

The unmatched MTSamples terms means that it is clinical notes that cannot be documented in any fields in the Odense template. However, as in the other categories (but most notable here), the conclusions are not any more valid than the validity of the relationships in SNOMED CT. E.g. in SNOMED CT Lymphadenopathy of head and/or neck is not a finding of lymph node, which it obviously could be in the context of the physical examination. Another example, showing a general challenge when using standardised terminology is finding of heart rate and finding of heart rhythm. In the context of a physical examination these are probably found by cardiac auscultation. So, in the physical examination, heart rate and finding of heart rhythm could be children of cardiac auscultation, but this would not be true in other contexts, as they could be found by ECG or other more sophisticated methods.

The analysis shows that approximately ¾ of the findings extracted from MTSamples can be represented in the Odense template without any changes in the Odense design nor the semantic relationships in SNOMED CT.

Discussion

The use of SNOMED CT to analyze information match between notes and template have both benefits and shortcomings. Benefits include the possibility of linking together terms with different granulation level, relying on an international standard instead of personal judgement. If this method of analysis was used when evaluating proposed templates, there might also be a possibility to correct the granulation level of the template to match the content of actual clinical notes by reducing the template terms that are children of terms from clinical notes. The shortcomings include missing relationships e.g. between Lymphadenopathy of head and/or neck and finding of lymph node and relationships unfit for registration purposes e.g. "weight finding" and "vital signs finding" in "General finding of observation of patient".

In this study very simple Natural language processing (NLP) techniques are used. More advanced NLP has been used for analysis of clinical notes[9], as well as manual categorization [7]. For this study, we did not aim at a complete list of clinical findings, but a list of common clinical findings. Therefore, the simple method was regarded sufficient for this purpose. Also, if the method was to be used in a clinical setting to evaluate proposed templates, the simplicity of the method might increase the probability that an analysis is performed on existing clinical notes before implementing the template.

Using clinical templates from similar organizations and analyzing them using local clinical notes could possibly reduce time spend on local requirement engineering. However, exploiting the global applicability of local templates to develop standards might support new template development even better. The global applicability of the local Odense template is notable, as the terms used are highly related to both text book descriptions of and clinical notes regarding the physical examination. This indicates that local templates where the underlying clinical process is well-defined could be very useful in standardisation work. However, the complexity of using existing templates changes when having two or more templates describing the same procedure from different organisations or different clinical specialties. Imagine one physical examination template having a "cardiac auscultation" field and another having a field called "Cardiovascular findings". The terms are clearly related, but the granulation level is different. E.g. findings related to heart rhythm would fit into both fields, whereas the finding "Abdominal aorta is not palpable" would only fit into the latter category. The implications of reaching interoperability between the two sites are obvious. Examining the challenge of using multiple templates in standardisation work will be a priority in future works.

Conclusion

Achieving semantic interoperability is a challenge due to the complexity and variability of health care and clinical information systems. Therefore re-use of material from other institutions compose a promising point of departure. This study shows that a local physical examination template has the ability to structure common physical examination clinical findings from another context. This suggests that templates, at least for well defined clinical processes, have a global applicability. Of course, this claim should be examined further for other clinical processes, other templates and other clinical notes. Global applicability would make local templates useful in standardisation projects.

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Web-based Knowledge Portals in Swedish Healthcare – Overview and Challenges

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Abstract

Healthcare organizations are increasingly becoming dependent on knowledge management activities to improve the quality of care, to maintain a high level of efficiency and innovation as well as to flexibly adapt to rapid change. Utilizing knowledge management support systems - e.g. Internet based knowledge portals - to manage medical information and healthcare knowledge aimed to support the full spectrum of knowledge needs has become an important issue for all healthcare professionals. This paper reports on the main findings from analyzing the characteristics and challenges of 15 Swedish knowledge portals containing healthcare information. The analysis is based on inspection of the portals and interviews with their owners. The main challenges found concern fragmentation of knowledge, structuring of knowledge content, usability, interaction and resources for maintaining knowledge content. Future successful development and use of knowledge portals to disseminate healthcare knowledge depend on addressing these challenges, which requires portal owners to have a long-term strategy as well as a systematic way of working.

Keywords

Knowledge management, knowledge portal

1. Introduction

Knowledge Management (KM) has established itself as good management practice for modern organizations that strive to be efficient and competitive, since it helps getting the right knowledge to employees when they need it [1]. Healthcare organizations are increasingly becoming dependent on knowledge management (KM) activities to improve the quality of care, to maintain a high level of efficiency and innovation as well as to flexibly adapt to rapid change. Utilizing knowledge management support systems (KMS) to manage medical information and healthcare knowledge aimed to support the full spectrum of knowledge needs has become an important issue for all healthcare professionals [2, 3]. On the other hand, adopting KM is a complex process. In the past, many KM initiatives and projects have not been successful and even the more successful ones have struggled to make a broader impact. Often it can be observed that KM approaches, methods, and tools are tried out but the results are unimpressive or they do not meet exceptions. One of the reasons for these problems is that the implementation process of KM system is too ad hoc and unplanned [4].

Healthcare organizations are knowledge-rich, yet healthcare knowledge is largely under-utilized at the point-of-care and point-of-need. It is well known that new healthcare knowledge is being generated at a rapid pace and its utilization can profoundly impact patient care and health outcomes. However, this growth of knowledge, dispersed across different mediums, is making it extremely difficult for healthcare professionals to be aware of and to apply relevant knowledge to make the 'best' patient care decisions. Recent research has shown that the inability of physicians to access and apply current and relevant knowledge, leads to the delivery of suboptimal care to patients [3]. It is often difficult to ensure that healthcare professionals use the latest and newest healthcare knowledge. Education is one way of spreading knowledge. However experience shows that education must be supplemented by other systematic efforts to ensure sustainable uptake of knowledge. Furthermore, knowledge that has been captured and packed as written knowledge in some form usually resides in repositories, manuals, the intranet, etc. An important issue identified is that knowledge shared through manuals may be difficult to absorb since the documents, in essence, are not adapted to the target group. A further complicating factor is that healthcare professionals need to relate to national, regional and local knowledge bases dispersed across different mediums. One way of accommodating a single point of access to knowledge is through so-called knowledge portals, often Internet based.

The goal of this paper is to report on an analysis of a representative number of Swedish Internet based knowledge portals. The second author of this paper has been involved, since many years, in developing methods and tools to create and maintain KMS, in particular Internet based knowledge portals, implementing them in both business and public organizations, e.g. in healthcare. A successful case of implementing such a system was reported in [4]. The experiences from this case form the basis of the analysis.

The remainder of the paper is organized as follows. In section 2 the method is presented, while section 3 contains the results. The results consist of a number of observations about the characteristics and challenges of the analyzed knowledge portals. In section 4 the results are discussed and some concluding remarks are given.

2. Method

The analysis has been made according to the following steps:

Firstly, we selected a number of portals to analyze. We aimed at collecting a variety of portals which would demonstrate the multitude of approaches to creating knowledge portals. We took as a starting point the national projects initiated by the National Board of Health and Healthcare, e.g. Kunskapsguiden (www.kunskapsguiden.se). We then selected portals that have been initiated on a national basis, e.g. Vårdhandhandboken (www.vardhandboken.se) and Svenskt demensscentrum (www.demenscentrum.se). Finally we searched the Internet for portals initiated on a regional or local level, e.g. Sårwebben (www.vgr.se/skassarwebben), using a snowballing approach. All analyzed portals, 15 in total, contain healthcare knowledge. Swedish healthcare organizations, authorities and associations have created them. The following 15 portals were analyzed:

- Kunskapsguiden
- Vårdhandboken
- Internetmedicin
- Ungdomsmottagningen på nätet UMO.se
- 1177.se
- Svenskt demenscentrum
- IPULS-projektet METIS
- Nationella riktlinjer för Sjukdomsförebyggande metoder: Tobak, alkohol, fysisk aktivitet och matvanor
- Virtuellt Sårcentrum
- Sårvårdsboken Örebro
- Sårwebben
- Föräldrawebb Fyrbodal
- PS Young Support
- Nationellt kkompetenscentrum Anhöriga
- Vårdaktörsportalen i Västra Götaland

Secondly, we documented the selected portals according to the following aspects:

1. Type of content
2. Target group/s
3. Structure of the knowledge content
4. Technical platform
5. Possibilities for communication between users and portal owners
6. Organizational model for maintenance of the portal
7. Model for evaluating the effects of the portal
8. Possibilities and challenges relating to the portal

To collect the data two methods were used: 1) inspection of the portals and 2) telephone interviews with managers of the portals.

Thirdly, we analyzed the data to identify general patterns. All portals were analyzed by the first author of the paper and the overall analysis was made by both authors.

3. Results

The main findings of the analysis are presented organized according to the general patterns that we found.

3.1 Focus

A general pattern among the analyzed portals is that most of them are developed based on the need to disseminate knowledge about a particular medical specialty to particular target groups with particular needs of information, knowledge and learning. Considering an employee that needs to access knowledge about several specialties, i.e. a district nurse, or a patient with several health problems, this situation is suboptimal. A person then has to access several portals. Since there is no standardized way of structuring a knowledge portal this means that knowledge is fragmented and usability on the overall level, over several portals, is low. Also, learning and exchange of experiences is hindered by this fragmented approach. From this situation we conclude two things. Firstly, it is clear that a more conscious strategy is missing in healthcare organizations about how knowledge should be structured and disseminated through knowledge portals. Secondly, portal developers do not properly consider the needs and characteristics and usage situation of the target user group/s. One particular aspect of this is that portal developers in most cases neglect that the users of their portal will most likely use other portals as well.

Among the analyzed portals there is a dominance of portals focusing on mental illness, particularly in young adults. We also observe several portals addressing lifestyle related disease, e.g. related to alcohol. We can only hypothesize the reasons for this focus, but one can be that the Swedish government has prioritized knowledge dissemination in these areas.

3.2 Intended users

Among the analyzed knowledge portal we find three types of intended user groups:

- Healthcare professionals
- Patients and/or citizens
- Both of the above user groups

We believe that the Swedish National strategy for e-health[1], initiated by the Swedish government, has motivated several of the analyzed portals. The strategy focuses on the introduction, use and benefit of information technology in healthcare. The goal is to create actual benefit for three main target groups: the citizen, healthcare professionals and decision-makers in healthcare and social services. Two particular areas in the strategy are related to the analyzed portals:

- Useful and available information – decision support for healthcare professionals, and
- Knowledge management, innovation and learning.

3.3 Structure of the knowledge content – a usability issue

As previously stated, most portals have different structures and they also have a varying degree of usability.

The knowledge is often structured in a hierarchical and linear manner, comparable to that of a book or report. As a consequence, the use of multi-media such as moving pictures (film and animation) and sound is hardly ever seen.

We often find usability problems related to the book type of structure. E.g., when a large amount of information is presented to the user at once, she is often confused and experiences difficulties in filtering unnecessary information, which leads to problems to manage situations when choices need to be made [5]. Also, this type of structure focuses on gathering of information rather than on learning. This problem emphasizes that portals need to be developed using a governing method for how knowledge should be captured and structured. We have found a small number of portals that have a clearly identifiable structure that is systematically implemented throughout the portal, and that truly take the user situation into account, but they are unfortunately a select few.

The target group of some portals is broad, e.g. both healthcare professionals and patients. This is a particular challenge in terms of designing the user interaction and structuring the knowledge content, something that many of the portal owners experience.

3.4 Interaction through knowledge portals

Very few knowledge portals include facilities to support interactive meetings – between healthcare professionals and citizens or between citizens - through the Internet. Several evaluations (see e.g. [6] have concluded that this is a feature that should be prioritized. However, such interaction through the Internet can be sensitive, which requires that personal integrity can be managed in a secure way. On the other hand, security and integrity issues must be balanced with the benefit that the interaction can give the users. Also here it is necessary that there are guidelines and strategies that govern how this interaction can take place. This could be functions for moderating discussion forums, e.g. in order to remove improper material.

3.5 Technical platform

The general patterns is that Internet based knowledge portals are seen as web-pages that are created through a traditional publishing process where texts are produced, reviewed and published. Therefore, the pre-dominant technical platform is traditional web-publishing tools such as Microsoft Sharepoint[2]. One challenge related to this type of platform is to manage overview when the amount of knowledge increases and knowledge "chunks" in the portal becomes increasingly linked, internally and externally to other portals and ources on the Internet.

3.6 Processes and resources for maintaining knowledge portals

One of the problems with knowledge repositories in general is that their use decreases over time, often because their contents become out of date and hence becomes less relevant for its users. A common reason for this is that processes and responsibilities for continuously updating the content do not work in the organization [1].

One aspect of this is that decision-makers may be willing to invest in the creation of a knowledge portal, but fail to see that keeping the portal up-to-date and useful over time requires that more resources are continuously invested.

The majority of analyzed portals follow this pattern. Their owners find it challenging to manage them over time, particularly in terms of resources. E.g. several important and useful portals targeting young adults are at risk since financial resources are lacking.

Situations where several organizations collaborate to create/maintain a knowledge portal are particularly challenging. In these cases it has shown to be very difficult to agree on common standards, e.g. for structuring the knowledge content. This is the same pattern of difficulties that can be observed regarding standardization of IT solutions in Swedish healthcare as a whole.

4. Discussion and concluding remarks

Internet based knowledge portals are becoming more and more common in modern healthcare, not only in Sweden but throughout the world. They have the potential to contribute to both prevention and treatment of health problems by supporting both healthcare professionals and citizens with the knowledge that they need and when they need it. However, in order for knowledge portals to live up to expectations a number of challenges need to be addressed, some of which has been discussed in this paper. These issues have impact on the survival of a knowledge portal over time.

From the implementation projects that we have been involved in (list included in [4]) we conclude that there are critical success factors that can make or break the long-term survival of a knowledge portal:

[1] http://www.nationellehalsa.se/English/Default.aspx

[2] http://sharepoint.microsoft.com/en-us/Pages/default.aspx

[2] http://sharepoint.microsoft.com/en-us/Pages/default.aspx

- The portal is important enough for management to champion it
- The value to its users is high
- The usability of the portal is high
- The knowledge structure is robust but still flexible enough to cater for changes over time
- Processes and resources for maintaining the portal over time is in place
- There is a strategy in place for the future developments of the portal

The portals that we have analyzed have several weak spots related to these factors. From what we see it is quite common that portals are developed and maintained by healthcare professionals, while managing several of the factors (e.g. usability and knowledge structure) is clearly outside their expected expertise. Portal development projects therefore need to also involve other categories of competencies, such as usability experts, experts in knowledge structuring and IT experts.

Acknowledgments

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A Cognitive Walkthrough and Focus Group Study of Nursing Personnel to Improve EHRs Used in Nursing Homes

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Abstract

The use of electronic health records (EHRs) to support health care has dramatically increased in the past several years; however, the efficiency of these systems in supporting nursing personnel's workflow remains unclear. The purpose of this paper is to examine nurses' experiences using an EHR system and how nursing personnel evaluate the usability of the EHR system. Three focus group interviews and a cognitive walkthrough with four nurses were performed in the spring of 2010. A major finding was that the nursing personnel were satisfied overall with the implemented EHR system. The most commonly mentioned problems were lack of training and organizational challenges during implementation. Strategies to improve the efficiency of EHRs were reducing the amount of information displayed and the number of opportunities to perform a certain task in the system.

Keywords: *focus groups, medical health records, nursing evaluation research, nursing staff*

Introduction

Nursing personnel, including registered nurses (RNs) and nursing aides (NAs), are legally required to document the planned and performed care of patients in nursing homes [1]. The patients' electronic health records (EHRs) play a key role in nursing homes when nursing personnel perform the documentation. The EHRs are to support nursing personnel as they carry out their work and assist them in making high quality, evidence-based decisions. The goal of the government is that electronic devices should be used for documentation and communication in all situations in health services to increase efficiency and save money [2]. Understanding nurses' experiences is important in fulfilling the goal of using the electronic devices efficiently and effectively in health services.

Usability is the lack of frustration when using something [3]. Frustration is often caused by a discrepancy between the number of tasks required and the available time to perform them. When there are too many tasks waiting for the nurse's attention, s/he might not want to use the computer if it leads to more frustration. Nevertheless, documentation is necessary, not only because it is legally required but also because it is essential for all involved nursing personnel to know whether the patient's situation has changed.

High usability requires that the product should be useful, efficient, effective, satisfying, learnable and accessible [4]. Usefulness is the most important attribute; if a product is not considered useful, it will not be used at all [3]. The other attributes of usability, such as efficiency, give the user the opportunity to achieve his/her goals in the shortest possible time. This is also quite important in nursing home settings, as are the effectiveness and the learnability of the system. We know that many nurses are not given sufficient time to learn the system but are required to learn while actively performing the documentation. This can be problematic. Satisfaction with a system is often determined by the previously mentioned attributes. Shneiderman and Plaisant [4] claim that in life-critical systems, subjective satisfaction is less of an issue because the users are well-motivated professionals. Nevertheless, this may affect both use and the frequency of use.

Accessibility is a sibling of usability [3], and in healthcare settings there are strict guidelines regarding who has access to information in the EHR. This might be an obstacle, although it is necessary to keep the information about each patient secure. Nevertheless, this is a problem when nursing homes must use temporary staff, which they often do. Temporary staff often lack the necessary usernames and passwords to access the computer. This may be an organizational problem; however, it is closely connected to the user's perception of the computer and therefore must be considered. Because of work pressure, the staff often needs to identify different methods to circumvent these obstacles, and some solutions may not be completely legal. The five attributes of usability mentioned above are the focus of this study.

Background

In Norwegian nursing homes, the main users of EHRs are physicians and nursing personnel. Because the physicians and

the nursing personnel work in different settings and have different needs and nursing personnel complete most of the documentation, this study will concentrate on the nurses' evaluations of the software. The nurses' working conditions in a nursing home setting are quite often characterized by many events and tasks occurring simultaneously. When sitting at the computer documenting the records of different patients, there are usually many interruptions, such as telephones to answer, that occur mid-sentence. People asking questions is another type of interruption that might result in the nurse having to leave the current record incomplete to consult another patient's record. The lack of computers is another challenge to take into consideration; there are seldom more than two computers in each ward; thus, nursing personnel must share.

There are different EHRs, and not all of them are considered beneficial [5] and useful by the users [6]. Nevertheless, nurses must use them because this is the only way to complete the documentation. Experience with certain types of software might influence the user's opinion of a new system before s/he has even tried it.

The participants included in this study had previously used EHR software (EHR 1) before they started to use the current EHR software (EHR 2). EHR 2 was developed by a physician, and the main differences between EHR 1 and EHR 2 were that EHR 2 included decision-support capabilities [7]. EHR 2 has been implemented in three nursing homes in Norway. For two years the nursing personnel in these nursing homes participated in the development of EHR 2 by continuously giving feedback to the software developer concerning areas that required improvement. Despite this involvement, there are nursing personnel who avoid using the EHR 2 documentation functions. More knowledge about nurses' experiences with using the EHR 2 might increase its use. The aim of this study was to examine nursing personnel's experiences with the EHR 2 software and how they perceive its usability in their nursing home.

Methods and Materials

To examine how the EHR 2 supported the nurses' workflow, we chose to conduct cognitive walkthrough observations in real working situations to gain an understanding of the surroundings in which the EHR 2 system is typically used. We chose the cognitive walkthrough observations method to gather information about potential integration problems with the process and use of the system [8]. Alexander and Staggers [9] claim that understanding competing demands in natural settings is important for researchers who want to understand how clinical technology affects nursing workflow, patient care and the efficiency of nursing services. The natural setting cognitive walkthrough observations were conducted when four RNs on four different wards were conducting documentation using the EHR 2.The RNs were asked to perform their documentation in their usual manner and were free to express their thoughts aloud while they were using the EHR 2. They were not asked questions during the cognitive walkthrough observation.

Moving from a cognitive walkthrough observation to a focus group is moving away from realistic usage situations [10]. By using data from the natural cognitive walkthrough observations, the moderator (MB) could help the participants recall how a particular feature was being used. The participants in the cognitive walkthroughs were from four different units in the three nursing homes that had used EHR 2 for two years. The focus group participants were from the same three nursing homes; however, they were not the same nurses who participated in the cognitive walkthroughs. The focus group participants were as homogeneous as possible to make the participants feel comfortable enough to express their opinions during the focus group interview sessions. The moderator led the interviews and used a semi-structured interview guide.

Sample

The participants in the focus group interview were recruited by the managers of the wards. The inclusion criteria were that the participants used EHR 2 on a daily basis and had more than one year of experience working in a nursing home. A total of 19 nursing personnel, twelve RNs and seven NAs, participated in the three focus group interviews. Six from nursing home A, five from nursing home B and eight from nursing home C participated. Table 1 displays the participants' characteristics.

Table 1. Focus group participants' characteristics (n=19)

Characteristics	
Gender, female, n (%)	16 (84)
Male, n (%)	3 (16)
Age (years) n (%)	
20-29	5 (26)
30-39	7 (37)
40-49	1 (5)
50-59	6 (32)
How well do y ou know the system? n (%)	
Very well	4 (21)
Well	13 (68)
Not well	2 (11)
How often do you use the system? n (%)	
Daily	18 (95)
At least once a week	1 (5)
At least once a month	0

Observation and focus group interviews

During the cognitive walkthrough observations, the observer did not participate in any way other than to observe and take notes; the purpose was to understand the setting in which the EHR was being used and the issues that arose and to subsequently use this knowledge to create in-depth questions for the follow-up focus group interviews. The focus was on the use of the computer and not on all the other tasks a nurse performs during her/his shift. During the observation, handwritten field notes were taken. For example, the observer noted when the participant seemed frustrated, expressed positive or negative comments, and when there was missing information or s/he did not know how to use the system.

Focus groups should be as homogeneous as possible (e.g., the same age, the same sex, the same educational level) to make the participants feel comfortable enough to express their opinions on the questions [11, 12]. The questions are preset and should allow enough room for the conversation to flow without deviating from the focus. Focus group interviews are challenging but quite useful in evaluating user interfaces, and as Lazar states [10:178], ”If you don’t listen to your users you might miss some of the most important feedback that you can get.” The moderator included questions that attempted to uncover situations in which the participants had different opinions of the various situations. The questions were open-ended and exploratory to encourage the participants to delve deeply into the questions during their conversations. Brender [13] argues that focus group interviews are especially well suited for evaluating health informatics systems because they can identify possible patterns in nursing personnel experiences using an EHR system and how nursing personnel evaluate the usability of the EHR system. Recording equipment was used when conducting the interviews, and a co-moderator took notes.

Data analysis

Qualitative content analysis [14] was used on the transcribed data from the cognitive walkthrough observation and the focus groups. The analysis consisted of descriptive narratives, which in Sandelowski’s [15] opinion are appropriate for seeing the situation as it is without the need to interpret. This requires that one write down what occurs using natural language. If there is anything in the situations the observer does not understand, s/he must write down what occurred. In this situation the questions were written down and used in the focus groups interviews conducted subsequently.

In analyzing the cognitive walkthrough observations and the focus group data, the researchers coded openly, line by line, and identified and compared categories. The categories were compared to detect similarities and differences among them. This will elicit information about the nursing personnel’s experiences with the EHR 2 software, how they perceived the usability of this new software in their nursing home, and whether the software was used as intended.

Findings

All the participants had experience with EHR software systems other than EHR 2. The nursing personnel stated that after they started to use EHR2, there was no time-consuming duplicate documentation, as there had been previously. Table 2 shows the summary of the six categories from the cognitive walkthrough observations and the focus group interviews, in which issues were identified. We organized the comments into categories that analyzed the usability aspect and suggested implications for practitioners.

Table 2. Experiences reported in the focus group interviews (n=3)

Comments	Analysis	Implication for practice
Login, not available Not enough computers available during peak time	Accessible – Administration problems	Automatic request for login id- and password Approval for guest, temporary 24 hour access
Lack of training	Learnable-Training/education	Tutorial
The software has limited capability for documenting planned interventions	Useful-Software	Add care plan documentation capability
Terminology not consistent or standardized. Problems with different dialects	Effective-Functionality	Interpretation of standardized terms
Documentation may be improved if images could be included (e.g., follow-up wound care)	Usefulness - Visualization	Add opportunity to upload images to include, e.g., progress notes and the care plan in the EHR software
Do not require the nurse to re-enter or use "copy", "cut" and "paste". Opportunities to extract information, search the data (e.g., number of falls on the ward level.)	Efficient-Reuse data	Automatic trend reports for individual report generation. Customized set of parameters, search criteria

The cognitive walkthrough observations revealed that the EHR 2 provides ample opportunities to use free text; however, if the nursing personnel were provided with standardized text, they would prefer to use that instead. Some sections of documentation were still performed using paper notes. One of the nurses summarized her experience as follows: "After we got the EHR 2, we have been better overall at doing documentation."

Findings from the cognitive walkthrough observations showed that EHR 2 provided a good overview of resident data, medical diagnoses, medications and laboratory data for the nurses. We also found that there were many different methods to perform the same documentation task. Different methods altered how much the RNs had to read or browse in the EHR 2 to identify essential data. One nurse said, "EHR 2 software gives a good overview of the residents' data, and we will absolutely not change software again."

Discussion

In this paper we examine how nursing personnel experienced using the EHR 2 software for documentation in nursing homes. Overall, the nursing personnel stated that they better performed documentation when using the EHR 2 software and compared their experiences with using the EHR 1 software. EHR 2 gave the nurses a good overview of patient data, medical diagnoses, medications and laboratory data. Six categories summarize the nurses' experiences using EHR 2 and can be prioritized as areas needing improvement.

First, nursing personnel describe a lack of guest or temporary login capabilities and a lack of computers available at peak times. Because of these problems, some of the nursing personnel (e.g., temporary nurses on weekends) do not document the planned and/or performed nursing care of residents in nursing homes using EHR and instead use paper notes. This lack of documentation may potentially generate safety issues, and parallel documentation causes inconsistencies in both electronic and paper documentations [16]. A recent study has shown that EHRs can increase the quality of care in nursing homes; however, managers and policy makers must be aware of the increased hardware and software expenses [17].

Second, nursing personnel reported that they required more opportunities for training. This concern aligns with findings from other implementation studies [6, 18, 19] that label training as a critical factor to the success of implementation projects. A well-planned, descriptive tutorial may support the training and implementation process.

Nursing personnel noted the inability to document planned interventions as a third category in which the software needed to be improved. This confirms the results from another study [20]. Our results indicate that the nursing process is a part of nursing personnel's daily routine and needs to be incorporated

into the EHR software as a strategy to support nurses' workflow.

As a fourth category, the participants also noted that there is no standardized terminology. However, there seems to be a trend in nursing care to increase the use of standardized terminology to increase resident safety and improve documentation [21, 22]. Category number five recommends including a method to upload images to improve quality and reuse data for visualization.

The theoretical framework that we chose broadens our understanding of the data collected. The positive results align with the findings of other studies that show that less time is spent on documentation when information systems are used [23]. An increased focus on including advanced technology for support and a close collaboration between the vendor and the users create an overall high usability of EHR 2. These implications should, however, be interpreted in light of the limited amount of EHR software and nursing homes included in this study.

Methodological considerations

A limitation of this study may have been that group dynamics play an important role in focus group interviews. Outspoken individuals might sway the group or dismiss the comments of weaker participants [14]. Homogeneity among the participants is preferred because the group dynamics are affected if someone has a higher status or greater expertise than the rest [24]. Elwyn et al. [11] point out that people tend to be more truthful and reveal more about themselves when they are with strangers. In our focus group interviews, the participants were with colleagues, some of whom they knew. Hopefully the discussion in the focus groups made the participants feel safe enough to be honest about how they work with the computers and software even if some might have felt they were revealing their own lack of knowledge.

The findings from these observations and focus group interviews might not be valid for all systems used by nursing personnel. However, in this particular study, the objective was to examine how the user interfaces with EHR 2.

The participants were asked to participate in the study, and the ones who agreed might be the ones performing the best at using the system. Therefore, there may be a bias in the overall positive results; nevertheless, important issues were revealed. People who are not too familiar with a program usually perform worse when they are being observed [10].

Conclusions

This study made several contributions to identifying areas for improving the usability of EHRs in nursing homes. We used a novel data gathering research method: cognitive walkthroughs in a natural setting to frame our questions for in-depth focus group discussions. We suggested viable solutions to improve usability of the EHR and reported the increased satisfaction of nursing personnel who used a newer version of the EHR in their nursing home on a daily basis. Further research that measures the relation between the implemented proposed enhancements to the EHR system and the satisfaction of the nursing personnel would be a good follow-up study.

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GPS for Demented, an Analysis of Success Criteria and of Health and Care Workers` Attitudes to Using Tracking Technology

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Abstract

The demographical development in Norway will lead to a huge increase in the number of elderly by the year of 2050. There will be fewer employees per person in need of care, and this will be a challenge for the health care sector if services are to be kept at the current standard. New technology may help to alleviate this problem. Consequently we carried out a qualitative study focusing on the use of GPS technology as a wander management system in five municipalities in Norway. The data were analyzed with Leavitts diamond and The DeLone & McLean Model of IS Success [1] as reference models. The informants found the GPS`s easy to use. Health workers were able to locate patients equipped with a GPS and the technology was sufficiently accurate to map patients outdoors. Health care workers and relatives experienced increased safety and freedom of movement for all patients. However there were challenges with battery capacity, organization of the services and in securing that the GPS was carried with the patient. Furthermore, the respondents claimed that large scale deployment will require organizational changes, to enable employees to manage the technology.

Key words:

Health care workers, GPS, wander management systems, demented, tracking technology

1. Introduction

The media regularly report on demented not finding their way home and consequently efforts to locate them [3-6]. Most incidents end well, with the missing person being found. However there are also some incidents that end tragically [7-9]. In Denmark 4-5 demented disappear from their homes every day, and on a yearly basis 10-15 persons die because they do not find their way home [10].

At home, relatives take care that demented do not wander off alone. However when they are not capable of doing this anymore, the municipality will have to assist with nursing homes, where doors may be locked [11]. Alarms and wander management systems may contribute to more independence from relatives and health and care workers, and to maintaining freedom of movement [12].

The current demographic development will incur great socioeconomic challenges. There will be a vast increase in the amount of elderly, and relatively fewer employees left to take care of the elderly [13]. Norway will need three times as many employees in 2050, if we do the same tasks with the same quality and in the same ways as today.

Technological appliances may contribute to addressing this challenge. A Danish project showed how use of GPS technology may resources to be allocated differently. The technology allowed demented to remain in average 6 months longer in their own homes, and the municipality of Kolding could save the equivalent of 12 man-years [14].

There are several issues that need to be taken into account when implementing GPS technology as a wander management system for demented. Health- and care workers are expected to play a pivotal role in its success. In this study, experiences of healths care workers and relatives of demented in municipalities that have implemented the technology, were investigated to answer the research question: "*What technological and organizational issues are important for health care workers to succeed in implementing GPS based wander management systems for demented?*».

2. Background

The proportion of people suffering from dementia increases rapidly with age. In the age group 65-69 only 0.9 % is demented, whereas in the age group of 80-84 the proportion is 17.6 %. Among the above 90, as many as 40.7 % have developed a dementia. The number of people above 80 years of age is expected to increase considerably in the Nordic countries in the coming decades, and consequently, a huge increase in the number of demented is expected.

Dementia is caused by a brain disease. The disease affects cognitive functions such as memory, navigation, comprehension, calculations, learning, language and judgement. The loss of memory usually affects registration of new information, but old well known information may also be lost, especially in the later stages [15, 16]. Daily tasks do become more difficult and as time goes by, impossible.

Dementia usually occurs in combination with other diseases and general loss of functions. Sufferers require many different services, and huge resource expenditure from the health services. One common phenomena is wandering, without a clear goal or purpose, more than 60 % of demented develop this behavior [17]. Physical activity may delay development of the disease [18-20].

Wander management systems use GPS technology to track and locate demented. GPS (Global Positioning System) is the most well-known example of absolute positioning, which with

the help of satellites the show longitude and latitude with an accuracy of +/- 10 meter [21]. It is common to use equipment with both GPS and GSM (Global System for Mobile Communications) [22-25]. GPS does not work well indoors, nor in congested areas with tall buildings and narrow streets [21]. Since GPS is the most accessible system for Norwegian users, we will be using the terms wander management systems and GPS interchangeably in this paper.

Users need to carry with them a GPS unit, which enables tracking the user's position via satellite. Care providers or relatives need access to a computer or a cell phone with Internet connection to track patients who may be missing. The GPS tracker can track in real time, or zones can be specified to trigger an alarm if the demented moves outside the zone.

During the last few years a lot of projects have been testing use of tracking technology for demented. GPS works in general well enough, but the tracking units are encountered as big and clumsy, and the battery capacity is not good enough [23, 25, 26]. These findings are somewhat dated, and the technology is constantly developing [27], however low battery capacity [18] and size still remains a problem [25, 27]. Care providers have stressed the importance of units being light and small, at the same time as being comfortable to carry and use [28].

There are several challenges related to implementing wander management systems. Difficulty in training personnel, making sure staff that are able to handle the equipment are on duty, and general lack of basic IT skills among the employees may all pose problems for implementation [29]. Both care providers and relatives are positive to use of GPS units, as long as this is done within acceptable limits [21, 28-32]. Relatives and care providers have in general a positive attitude to use of tracking technology to manage wandering of demented [25, 31]. Relatives are concerned about their family members freedom and possibilities to move around unrestricted, whereas health workers are concerned about the legal ramifications if a user gets injured while wandering on his/her own [27]. However a study carried out by the Norwegian Association of Local and Regional Authorities (KS), showed that health and care workers were concerned that patients might not be able to find their way back home (Holbø et al., 2009) but at the same time, they had ethical concerns with monitoring.

There is limited research on implementations of tracking technology in the health sector; hence we have chosen to see if there is research on implementation of other technologies in this sector which may have implications for our research question. Gagnon et.al [33] recommends active involvement of users in all stages of implementations. The feeling of ownership this creates will contribute to the perceived ease of use and usability. Sufficient training does contribute to the perceived usability and reduces opposition to the system. In implementation of telemedicine there are some very important factors that can affect the process. If health personnel views the technology as useful and as having possibilities for tailoring to the specific group of patients, the implementation will most likely be easier. On the other hand low perceived usefulness, limited possibilities for tailoring to the patient and technical worries will be a barrier for implementation [33].

Based on studies of implementation of electronic patient journal, Ludwick and Doucette [34] point to involvement of top management as important for implementation of new technology.

Experience from a project with 180 users of GPS in Denmark, showed that it was more difficult to implement new technology in large municipalities, both due to the many levels of administrations and a longer decision process. It is harder to reach all parts of the organization and engage everybody. They recommend introducing technology in a limited area in large municipalities to make sure it runs smoothly, before disseminate lessons learned to other parts of a municipality [14]. The biggest challenge is, according to Ausen et al. [18], to establish and maintain routines for use, implementation and maintenance of GPS units as an integrated part of the health- and care services. In order to succeed with GPS technology, it is important that the employees feel ownership, and see the need for the target group [18].

Use of tracking technology does raise issues related to ethics and protection of the individual, especially when used for the most vulnerable groups [12]. Monitoring may contribute to protect a person with dementia, or to being able to move with less restriction. Use of tracking technology opens up for faster reaction if the demented can´t find his or her way. But it may also open up for monitoring, control and registration of data which may be perceived as humiliating. Due to this, ethical reflections are important for health- and care providers with responsibility for managing the technology. They have to decide whether it does benefit the patient, whether their involvement has been taken care of and how they perceive using it. Ethical considerations should focus on the feeling of safety for the relatives of the patients and the employees, and for sense of freedom of movement and needs for activity for the patients, their quality of life. In Norway tracking technology is not allowed if the patient resists. For persons with dementia consent in legal terms is not possible if they do not understand what consent implies.

3. Methods and framework for analyses

In the following we will discuss the research method applied in our research. We will also report on our choice of informants, on how the study has been carried out and how the findings have been analyzed. We will further reflect on the reliability and validity, or to use another term, the trustworthiness of the results.

We have used DeLone and McLean`s model of IS success [1] to understand what health- and care workers view as success criteria for implementation of tracking technology for demented. In addition we have used Leavitts diamond [35] to help in understanding how technology in interaction with structure, organization and tasks can affect a successful change process.

3.1 Research design

Since there is rather limited research on use of tracking technology for demented we need a better understanding of the whole topic area and of instances where health and care providers manage the technology. Qualitative methods are well suited for a deeper understanding of issues related to a limited group of respondents. We collected data through interviewing 11 health- and care workers from 5 different municipalities in Norway. The interviews lasted from 30 to 90 minutes. They all had experience with using GPS units for demented. Since the goal with the research was increased understanding of what technological and organizational issues health- and care workers regard as important for success of implementation of GPS units for demented, it was important to get their perspective.

We initiated the study by contacting the employee in charge of use of tracking technology in the different municipalities. We asked them to recommend employees for interviews that had worked with implementation of the technology and had used it for persons with dementia. There is of course a risk that the employees in charge deliberately selected respondents who were positive to use of tracking technology. But, due to the limited use of GPS it was difficult to set further selection criteria. Prior to the interviews we sent everybody a letter of information and a letter of consent for signing.

3.2 Collection of data

Through interviewing employees we learnt about their experiences, and about their attitudes and expectations to use of GPS for demented. The interviews were designed to be flexible and offered the opportunity for follow-up questions and clarifications. However interviews are time-consuming and hence there were strong limitations in the number of respondents.

The interviews were all semi-structured. Prior to the interviews, the informants were sent a letter with information on the topic for the interview, so they could be prepared. This way we made sure the informants all got the same questions, and that we covered the same issues. They were also told that the results would be treated as confidential, and they all agreed to the interviews being taped.

Objectivity in qualitative research means letting the interviewees talk without researchers influencing them in any way [36]. To achieve this we carried out all the interviews in their own work-place, except for one telephone interview. For all the interviews there were two researchers, to make sure they were carried out the same way. Prior to the interviews we carried out two trial interviews.

3.3 Data analyses

In qualitative research the presentation and interpretation of results is done in one consecutive phase. This is challenging and requires a lot of work, especially because the data is unstructured and diverse. All our interviews were transcribed, and we have tried to preserve as much as possible of what happened in the interviews. Two of the researchers transcribed half the interviews separately, and systematized the material with the interview guide in mind, to see if our interpretation of the interviews were the same. We split the interview texts in smaller and smaller units, to grasp the different parts of what the interviewees had said. The small units were interpreted and then summarized. We based this work on Giorgi´s phenomenological analyses [37]. This work was again carried out by two of the researchers before comparing the results and where there were differences, we worked towards a shared understanding of the material.

3.4 Trustworthiness

Reliability is dependent on what data is used, how they are collected and analyzed. It has to do with whether other researchers can reproduce the results. In qualitative research however, this is not really possible since the researcher is used as an instrument in the data collection and analyzes [38], hence we rather use the term trustworthiness to

We have used conversation in our data collection, and for this reason we describe the research process in detail to increase the trustworthiness of our results. By having two researchers coding the data independently the reliability is increased, and by collecting data from 5 different municipalities, of different size, our findings should be applicable to other implementation of tracking technology in other settings.

3.5 Models for analyses

Organizations can be viewed as complex systems where particular four variables affect each other. The four variables are tasks, structure, technology and organization. Structure, functions, organization and technology exist in mutual interaction [35]. Leavitt diamond is primarily a model for organizational change. Introduction of new technology will affect the employees, their duties and the structure of organization.

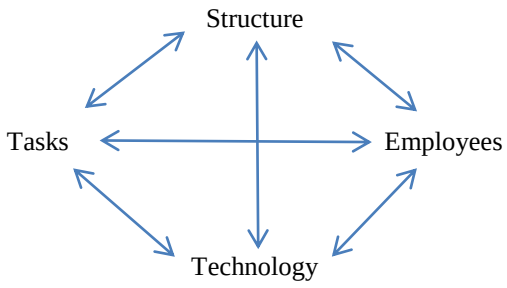

Figure 1. Leavitts diamond, which shows that changes in technology will affect tasks, but also the employees and the structure of an organization [35].

We have to have a system view on organizations to effect changes. If tasks are changed or new tasks added, it is important to see the connection with the existing tasks that the organization already carries out. According to Leavitt [35] ”*most efforts to effect change, whether they begin with people, technology, structure, or tasks, soon must deal with the others”.*

We apply the IS Success Model **[1]** in our study of factors that are important for health and care workers to succeed in implementing tracking technology. The model is based on prior research on how to achieve success from information

systems. It has been tested and verified in a number of studies, and is shown below.

The model consists of six factors which together captures the concept of IS success. There are three dimensions of quality that affects use and user satisfaction. Information quality can be defined as properties of the information that the system delivers. The information must be understandable, complete, relevant, consistent, accurate and secure. Ease of use will also be an important factor.

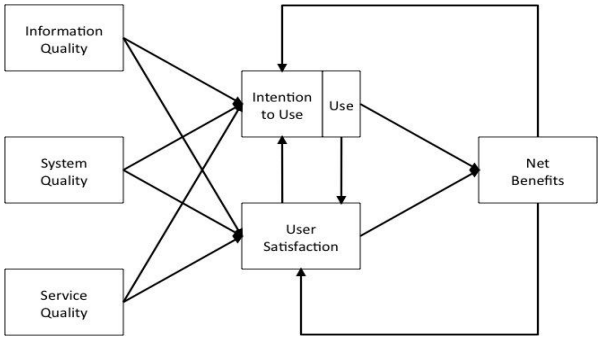

Figure 2. DeLone and MacLeans IS Success Model [1], which shows that information quality, system quality and service quality affects intention to use and user satisfaction of a system, and finally the success (or net benefits) of the system.

System Quality will be an important criterion for users to use the system. It means that the system is user friendly, accessible, reliable, flexible / agile and fast response time is important. System reliability is a factor that means a lot for system quality. If for example, GPS technology has a lot of downtime; it would be irresponsible to rely on when in use, while this in turn will affect the use of the technology.

Service quality is the quality of support that users receive from IT personnel. For example, response time, accuracy, reliability, technical expertise will be important factors in such a situation. If the system would have downtime, you are dependent on help, so that the system as quickly as possible is up and running again. The various dimensions of quality will affect the use and user satisfaction, and increased user satisfaction contributes to increased use. User satisfaction and usage are requirements for a net gain of a system[1].

4. Results

Before presenting our results, we briefly describe the cases the survey was made in. The table below describes what kind of GPS the 5 municipalities used, if they were in a test phase and if it is still used. It also shows whether there was support from the top management in the municipality for the use of GPS. Municipality 1 has tried out the GPS on three users, two of them had dementia and one was a wheelchair user. The project is now finished, and the municipality has two GPS systems available to use for people with dementia living at home or in nursing homes. Municipality 2 participated in a pilot project where they tried out the GPS on three demented people. The municipality will further test GPS on 20-30 people with dementia living at home. The management wants to introduce GPS in a large scale for dementia patients so they can live longer at home and have an active and meaningful life.

	Municipality 1	**2**	**3**	**4**	**5**
Number of inhabitants	6`	100`	15`	170`	25`
Anchored in management	No	Yes	No	Yes	Yes
Test phase	No	Yes	No	Yes	Yes
In use	Yes, for one user	Yes, and increasing	Yes, on one user	Yes, and increasing	Yes, for three users
Still want to use GPS	Yes	Yes	Yes	Yes	Yes
Type of GPS	Safe-tracker	Safe-tracker	Safe-tracker	Safe-tracker	Careto

Table 1. Description of the municipalities involved.

Municipality 3 has completed a project at a nursing home, where they tried GPS for tracking people with dementia. They have used GPS for over three years, and they describe their experiences as positive. Municipality 4 participated in a research project where they tried to use GPS on people with dementia. Their experience is based on using GPS on two people with dementia. The municipality is still running a project and plans to expand the use to 20-30 people with dementia. The management is initiating the use of GPS, and they regard it as necessary to meet the challenges of the future.

Municipality 5 is participating in a pilot project on tracking people with dementia. They participate because they want to collaborate with the university in testing tracking technology. GPS is tested on three people, two of them are living at home and one user is in institution.

Information Quality

For accurate information staff must rely on the technology and they can manage to find the person if the GPS is accurate. The staff in this survey had no trouble finding people with dementia using the map function. This indicates that the information was easy to understand, regardless of whether they used a PC or a smartphone. The staff said it worked regardless of whether patients were in the terrain or in a city. All respondents told us that the computer program worked satisfactory. This is consistent with previous findings, the detection of dementia is described as accurate and they were able to locate them fast [22, 24, 29]. When the map didn't work satisfactorily the respondents experience was that the missing person was inside a house or in a building.

System Quality

The informants pointed out various challenges in terms of using tracking technology. A major challenge is the battery capacity. The battery lasts up to 72 hours, but when it's in active use it must be recharged daily. Searching when a person has disappeared necessitates a charged battery. Ausen et.al [18] and Dale [29] also points out that the battery capacity should be improved.

We know from previous research that technical concerns may be a barrier to implementation of technology[33]. Although it

appears from our results that the battery capacity can be a challenge, the informants didn't see it as a barrier for use. They said good procedures for recharging the battery is sufficient for relying in the technology.

All our informants report an impractical size of the device. They find it difficult to secure fastening of the device to the person with dementia. They have challenges in ensuring that the user actually brings along the GPS. Without the tracking technology, health and care providers are unable to perform a search if a patient disappears. This finding is consistent with previous results [22-27].

Our study also show there is a need for smaller units to trace. Development of small GPS device designed for people with dementia is important in order to extend the use to a greater extent. Another possibility is to use the devices today, but knowing the user's behavior patterns so well that one is able to ensure that the GPS is brought along with the demented when he / she goes. The approach is however much more difficult for employees, and may not be realistic if there are many users of GPS. One other important criterion for GPS units is robustness. They should be used outdoors under all weather conditions.

In spite of the experienced challenges the system was perceived as easy to use by as many as 9 of our 11 informants. Those who found it more difficult were using the more advanced features of the GPS. One of the reasons why the respondents thought it was easy to use is that most of them only used the simple features of the GPS.

Three of the respondents tested other features in the GPS. They used geofencing, where the carrier of the tracking device can move freely within a given area. Once the user moves outside the predefined area, the staff is notified through an SMS alert on their smartphone. This turned out to be difficult, and they received several error messages. But with help from the providers they solved the problem, so the system worked as intended. However, one municipality had inadequate follow-up from the supplier, and they stopped using geofencing. Cooperation with the supplier seems important for use of the more advanced functions.

Service Quality

There were differences in experiences both between and within municipalities in relation to cooperation with the supplier. One health worker stated that there had not been any need for cooperation with the supplier, while another felt that there was a big need, and that the cooperation wasn't good enough. Different roles and positions within the municipality were probably one of the main reasons for that. According to Holbø et.al [21] one should not underestimate the need for education when introducing new information technology, ICT projects have stranded due to inadequate education. One municipality felt that the education was a bit limited, but they said the use of GPS was very simple. There was support from the company when they connected, and it was also supported by an electrical company that promotes this product.

We may anticipate that the need for closer cooperation with the supplier will increase, if we use GPS units on a larger scale. Possibly those who are good on computers and can master the technology have been assigned the responsibility when only a few employees are involved. When the numbers of GPS increase and more employees get involved, the need for training will increase drastically. Already today some employees say they get too little training.

Use and user satisfaction are closely related. And as mentioned previously, health and care providers want to use GPS on demented. This is reflected in terms of satisfaction with the system, which in turn will have an impact on net benefits. The fact that employees and their families see the benefits of use of GPS on demented is important. This contributes to achieving the goals such as increased activity, and helps demented in living longer at home before entering nursing homes. Technology helps in making health workers, relatives and users feel safe. Health and care providers do also experience respect for the individual user's integrity. Table 1 below gives a summary of the most important technological issues:

Battery capacity
Bulky / low aesthetic
The GPS function is not good enough indoors
Good mapping, easy to find a person with dementia
Ensure that the GPS is carried with the person

Table 2: Technological issues affecting implementation of tracking technology

Leavitt`s diamond

An attempt to change one part of the organization through introducing GPS, will lead to changes in other parts of the organization [35]. If one fails in implementation in terms of one or more components in Leavitt diamond, the result may be lack of use the GPS and hence less benefits. We found in this study that grounding in management can be important when implementing new technology. Five of eleven respondents said that the use of GPS was not rooted in the administrative management and in these municipalities there are no preliminary plans to increase the use of this technology. Six of the respondents said that in their municipality the decision to use GPS is rooted in the leadership, and these municipalities have further plans use GPS on larger scale. Eight of the eleven respondents believe that it is important for a successful implementation that use is rooted in the management. This is consistent with previous findings [39], they point out that involvement of management is an important factor in implementation of new technology. Our results indicate that without support from top management, a greater prevalence of GPS is not possible. The table below shows some important organizational issues:

Involvement of employees early in the process of using GPS
The technology should be rooted in organization
Training of personnel and procedures
Organization of tasks such as how to handle alarms from the GPS
Competence use of personnel

Table 3: Organizational issues affecting implementation

Conclusions

Municipalities have to innovate to meet the challenges that come with an increasing number of people with dementia. We need to work in different ways to meet the needs of this rapidly growing group. We will not be able to provide everybody in need with nursing homes and will be forced to look for other solutions. GPS technology alone will not solve this challenge, but it can be a help for health and care providers and for relatives, and the demented may be able to live at home longer. There is little knowledge about the use of tracking technology among health professionals today and there are obstacles in the legislation that must be resolved before one can start with using GPS on a bigger scale. We have used a qualitative approach and our findings are therefore not possible to generalize. But even with such a small sample, we believe our findings to some extent may be possible to transfer and give value for other municipalities starting similar projects.

Our findings confirm previous research, but also show an increased interest in using this technology. Tracking technology may help healthcare professional, their families and the demented, and increase their safety. Increased freedom for the ones with dementia does also contribute to the intention to use this technology.

Our analysis is conducted on the basis of the theoretical framework. We can see that information quality is good enough for health professionals and they should be able to use the technology. They can easily use the map function to find the demented. System quality is also demonstrated as good enough, they find best practices to ensure that the battery at any time is charged, and the demented brings along the GPS when he or she goes out. System Quality is not shown as a barrier for the technology to be used.

Service quality is also regarded as good enough, but it appears that the ideal would be to have local suppliers who are available to health professionals when needed for support. Support of senior management also emerges as a key success criterion for a successful implementation of new technology on a large scale.

There were both positive experiences and challenges with use of GPS. The main challenge has been the battery life and how to ensure that the GPS unit is brought along when the person with dementia goes out. Through the interviews we found that only the most basic features of the GPS was used. The use of GPS was not rooted in the management in all municipalities. Municipalities where they lacked top management support, only has sporadic use of the technology, and there were no plans to increase the number of users with GPS.

Organization issues are also important for health personnel. Widespread use of GPS requires some type of monitoring center to receive alarms and tracks the person with dementia.

The technology must be adapted to the individual user by mapping of the individual movement patterns and habits. Examples here could be to attach the GPS to the keychain if this is something that a user has to adopt out on a trip. This is time consuming and requires detailed knowledge of user's daily patterns and habits.

Further research on health personnel`s management of technology for demented is needed. We need quantitative research collecting experiences from health professionals who have used GPS units for some time, and where there are more users of technology with dementia. We also need to know more about the needs of the users. What do they need, how much battery capacity is “good enough” and how should the design be to ensure that the user brings the GPS with him? Further knowledge on these issues is important for acceptance from demented, to avoid some of the problems we are experiencing today.

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Towards Requirements for Telementoring Software

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Abstract

The current situation in the domain of telementoring was analyzed in order to extract a basic set of guidelines and principles for building software for medical mentoring needs. The guidelines represent an initial attempt to define boundaries for the telementoring software in a globalizing health care system, where compatibility and flexibility questions come first into consideration. We employed a reverse requirements engineering technique, which resulted in definition of current guidelines for requirements looking from the implementation perspective. Moreover, interviews with potential users of the software (surgeons) enabled testing of initial requirements as well as appending some new domain specific features. The combination of reverse engineering and user interviews techniques allowed defining up to date boundaries for developing telementoring software.

Keywords: telementoring, guidelines, telestration.

Introduction

Since the first attempts to use telemedicine[1] techniques in 1960's, the domain has expanded significantly. The rapid development of information communication technologies (ICT) resulted in affordable hardware and software solutions, making the spread of technology more feasible. Growing data transmission bandwidth enabled the technology to overcome local area networks (LAN) eliminate (or minimize) distance and delay related issues. A decreasing ratio of general practice surgeons per population is reported by Williams et al. Moreover, the studies predict even higher shortage of surgeons in the future [1]. Therefore, we hypothesize, that telementoring systems could offer a direct solution to this problem, as well as promote international cooperation and education of surgeons and help to lower rapidly increasing costs of health care services [1] , [2].

As telemedicine is gaining in popularity and respect from medical personnel, new software and hardware solutions are being developed to support the increasing demand. Cases of success in using telemedicine tools are being reported [3], but Bashshur et al. raise another important question: do we have enough evaluation results to consider the cases of success as a right direction for telemedicine? To form a contribution to producing sufficient amount and quality of evaluation results two ways of assessing research in the domain of telemedicine are offered [4]:

- Testing efficacy, effectiveness and safety;
- Assessing the program according to achievement of goals and objectives **[**4**]**.

The first criterion is usually reflected in the reports of tools used, while the second one usually requires a more global outlook, which is difficult to define in a scope of a single project or usage report of a tool, therefore global assessment of goals is usually left behind. It proves the fact, that telemedicine software lacks a global direction and global requirements for the technologies under development **[**4]. Our aim is to define the fundamental principles (guidelines) for developing telementoring software using telestration[2] as a case study. Looking from software engineering perspective, the guidelines would help to understand the environment of the software without directly interfering with medical personnel. Having the background knowledge would standardize the initial requirements for the software to be developed, leaving only solution specific requirements to be defined. As the software would be built having the same basic assumptions and principles in mind, it would definitely improve compatibility and flexibility properties.

The paper is structured as follows: we firstly give a brief introduction about current problems telementoring systems are facing. As our aim is to define a set of guidelines for developing telementoring software, a methodology is represented in the next section. Moreover, the paper also gives a review of related works in the field as well as an introduction to regulatory requirements for developing software for medical needs. The paper is concluded by a set of guidelines, laying the basis for better understanding of the environment of the

[1] Telemedicine - society of American Gastrointestinal and Endoscopic Surgeons (SAGES) defines telemedicine as a set of medical practices without direct physician-patient interaction via interactive audio-video communication channel [20].

[2] Telestration – a technique, enabling drawing of freehand commands over still image or video. In this research we focus on using telestration as a tool for helping less experienced specialist perform an operation under mentorship of remote expert.

software, providing a starting point for requirements engineering process of telementoring solutions.

Method

For extracting the guidelines a combination of reverse engineering approach and user centered design based interviews were employed.

Reverse Engineering Approach

Reverse engineering is a common approach in redesigning legacy information systems, which usually provide critical information dealing with business processes. Sometimes it may be difficult to obtain this information directly from stakeholders, while business processes are self-evident to them and they naturally forget to mention some important details. Liu analyzed possibilities to apply reverse engineering techniques in requirements engineering process **[**5]. The author represented a model for deriving software requirements when only running software and its current stakeholders are available. The performance of the model was proven by employing it in a case study of recovering requirements for a university library system. A detailed schema of a model is depicted in Figure 1.

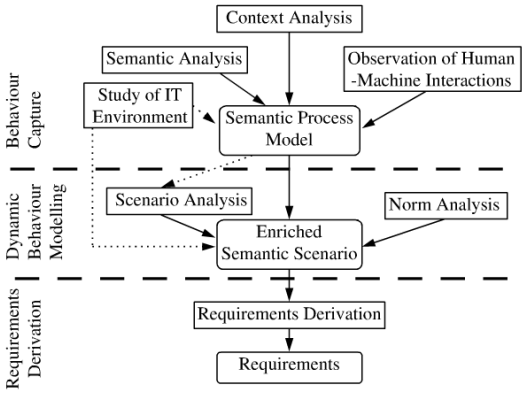

Figure 1 - Reverse requirements engineering **[**5**]**

The process of requirements recovery occurs in three stages: Behavior Capture, Dynamic Behavior Modeling and Requirements Derivation (see Figure 1). The first phase mainly deals with describing the environment as a main source of requirements. Moreover, a semantic analysis is also performed to gain a better understanding of the meaning of terms, concepts and functions. A basic comprehension of terms and relationships among them leads to the phase of Dynamic Behavior Modeling, concerned about modeling scenarios, rules and constraints. A representation of human computer interaction and functional requirements of the system is modeled as a Dynamic Behavior.

Looking from a modeling perspective, the first two phases yield a descriptive model. What is left, is to use the model to formalize the requirements and "validate them against the running system in a form of user acceptance testing" **[**5**]**.

Nevertheless Liu defined a part of methodology for our research [5], we were not able to fulfill it completely and reflect the outcomes in this paper. We are still lacking results from applying reverse engineering technique to fully operational telemedicine software. To compensate that, we analyzed a set of technology usage reports and papers identified in a systematic review performed by Augestad [6] instead of applying this method directly.

User-Centered Design Approach

User-Centered Design (UCD) was selected as a basic approach for requirements elicitation from stakeholders. The main idea is to place the users of the product in the center of design process (from planning, requirements engineering to implementation and testing phases) [**7**]. We firstly aimed to identify the users of the product and define their roles in using the software. Moreover, we discussed the context (environment) of product, as a source of requirements. By interviewing the users, we defined software usage scenarios, keeping the end user in the center of the process (UCD) and minimizing possibilities of cardinal changes of requirements during software life cycle. According to the supporters of the method, active involvement of users into software process (UCD) increases the utility and usability of computer systems **[**8**]**. A basic scheme of User-Centered Design is depicted in Figure 2.

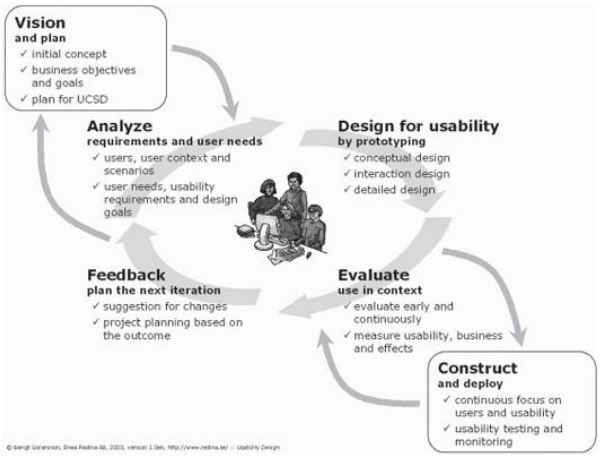

Figure 2 - Basic scheme of User-Centered Design **[**8**]**

Interviews were used as a main technique for requirements elicitation. Domain experts from The Norwegian Centre for Integrated Care and Telemedicine (NST) and end users (surgeons) from University Hospital of Northern Norway, Tromsø were involved in the requirements engineering process. All selected stakeholders had previous experience in using and participating in the development of tools for telemedicine. A set of interviews enabled validation of the guidelines from Reverse Engineering study and resulted in definition of ground rules for developing remote mobile telestration tools.

Related Works

For a long time requirements for medical solutions were considered to be unique for every single implementation. But the overall globalization is making this opinion change, especially in the field of telemedicine. Therefore, we tried to identify the cases of defining the requirements in a broader sense.

The survey of related researches was performed towards finding attempts to define requirements for telementoring

software. The attention was paid to telestration related requirements. The field of telestration was chosen because it combines the majority of requirements for telementoring domain, therefore guidelines for other solutions (for instance remote care) can be derived with slight additions and adjustments. The search for references was performed following the guidelines by Kitchenham [9]. After conducting the search we discovered that the majority of papers in this field are technology usage reports, mainly dealing with medical outcomes (how many patients were treated, what was the duration of the procedure, what is the ratio of success and details of the operation). Moreover, the outcomes were reflected according to different criteria, preventing generation of a global view. The most of the identified papers used similar telementoring systems resulting in overlapping sets of requirements. Therefore only the most distinctive approaches representing the most of extracted assumptions are represented in this section. As we were looking towards defining requirements in a wider scope, the reports helped identifying the most common technological solutions used for telestration. In addition, researches exploring particular software/hardware in more detail provided the contribution which was necessary towards the definition of the guidelines for telementoring software.

The closest attempt to define basic low level requirements for telemedicine software was presented by Zhang et al. **[**10]. For simplifying the process, authors aimed to distinguish the main components of the systems used for telementoring (see Figure 3). This division enabled defining requirements for every section separately. Moreover, separate sets of requirements ensured reusability properties.

As it is indicated in Figure 3, Zhang et al. focused on lower level requirements, concerning data collection, processing and transfer. Four main steps defined in Figure 3 represent the basic scheme of telemedicine solution: collection of particular data from the sensors, preprocessing, transferring to the remote location and recovering the data in an informative form for the analysis of physician. Zhang et al. were mainly concerned about modeling data transmission channel, but all other higher abstraction layer and more domain specific requirements were not represented. These requirements may look sufficient while only dealing with remote care solutions, focusing on analyzing data from a set of sensors situated in the living area of a patient. We were not able to deny the necessity to define any of the requirements discussed in **[**10**],** but in addition to that, we replenished the set by the results from reverse engineering approach employed to analyze some well-known software and hardware in telemedicine domain, while our goal is to analyze and define the guidelines in a much broader scope.

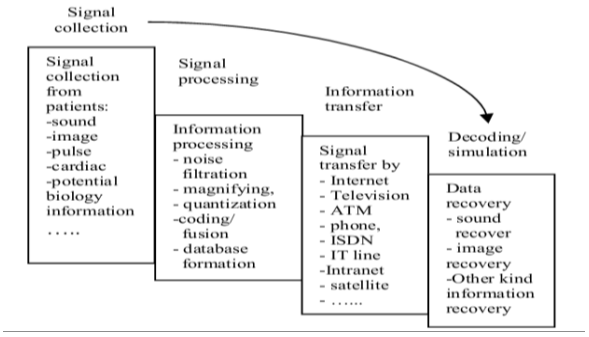

Figure 3 - Telemedicine information systems **[**10**]**

An Overview of Current Solutions and Technologies

N-Way Telestration

One of the most important recent works **[**11], introduced a new approach to visual content sharing and telestration. It contrasted traditional telestration technologies (combining video stream and markups from mentor to one stream and transmitting it to the recipient) by offering an idea of overlaying contents one over another. Conventional systems usually require dedicated hardware, limit the number of participants and file formats, geometry, distance and do not include concurrent users. Moreover, every session alters the initial video stream by adding markups made by users [11]. Therefore Zhou et al. presented a novel approach, overcoming these limits. Figure 4 illustrates the technology.

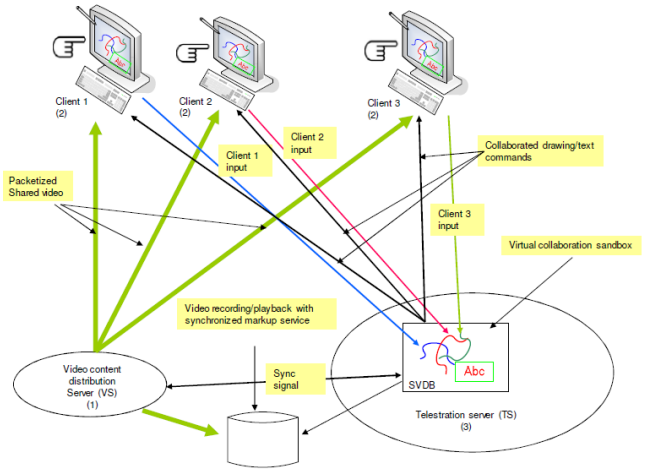

Figure 4 - N-way telestration system prototype **[**11**]**

The solution employs a combination of two synchronized servers: a video streaming server and a telestration server, responsible for overlaying commands on video. Client side software renders the video stream including commands coming from telestration server. Moreover, inputs from the side of the mentee[3] are also captured as telestration commands and represented on a shared video stream, making a session two- (or even n-) way interaction [11].

The main strength of the model is support for heterogeneous environments, including multi resolution screens and a variety of operational systems. These characteristics enable employing tablet computers, cellphones and PDA for developing mobile telemedicine solutions. Moreover, the solution does not pose any specific hardware requirements, making the final solution more affordable and customizable.

Video Object Anotation, Navigation and Compossition

An even more sophisticated solution was presented by Goldman et al., offering the ability to attach telestration commands to the moving objects in addition to the functionality of N-way telestration, mentioned before [12]. For

[3] Mentee – a person who is being mentored. In the domain of telemedicine it usually defines a local less experienced specialist remotely mentored by an expert.

example, symbols can be placed on the doors of a car, passing the street. The technique ensures that the symbols stay in the same position looking from the perspective of the car (see Figure 5). This functionality is a necessity while implementing telestration solutions for telemedicine, to ensure the commands are fixed to the object in a case of camera movement.

Figure 5 - Symbols attached to a moving object **[**12**]**

Notwithstanding some elaborate features of the used algorithms and implemented software, the main limitation comes with frame preprocessing speed and possible delays while working with live video stream. Goldman et al. tended to deal with attaching the markups to a moving object as a main goal, but expanding more on live video processing was left behind **[**12**]**.

Surgical Robot Approach

In comparison to the techniques mentioned earlier, which can be applied not only for medical use, we analyzed a few technological examples better known to advanced surgeons. We summarize some experiences of using Da Vinci (Intuitive Surgical, Sunnyvale, CA) and RemotePresence-7 (InTouch Health, Sunnyvale, CA) robots designed to satisfy requirements of telesurgery **[**13**]**, **[**14**]**.

Both robots were employed in the context of telestration and remote presence during surgical procedures. Live video and audio conferencing services, accompanied by real-time telestration and remote control of robots were exploited. Only minor problems of both technological solutions were reported, proving the feasibility of using telementoring technique towards improving health care services **[**13], [14].

Notwithstanding the fact, that this sophisticated equipment performed as it was expected, we would like to emphasize a few characteristics, waiting to be improved. The mentioned solutions lack flexibility in employing mobile devices, therefore users are expected to have fixed positions for mentoring. Moreover, an extremely high price is also a case for consideration.

The overview exploited a set of technologies used in medical domain related to remote presence approach. The features and characteristics, regarding future works and requirements engineering for telementoring systems were highlighted. The review gave a brief introduction to the domain and some ideas for further development and improvement projects.

Regulatory Requirements

To form a solid basis for our assumptions, standardization related documents, dealing with medical software and hardware requirements were also included as references. As no particular documents were directly reasoning with the guidelines in telemedicine domain, we aimed to analyze, extract and adopt them to support the development process of telementoring software. It resulted in contribution to the guideline derivation.

Design Control Guidance for Medical Device Manufacturers

The regulations were introduced by the U.S. Food and Drug Administration Center for Devices and Radiological Health. The document established a framework for designing medical devices, providing flexibility for manufacturers to adapt the framework to current business processes. The main goal of techniques is to alter initial design process making systematic assessment of the design an integral part of development (see Figure 6) to ensure the deficiencies are corrected in the early phase.

Looking from the point of requirements, the framework focuses on the development process and defines some basic guidelines for every step of waterfall life cycle model depicted in Figure 6. In fact, the framework adds an extra layer of review to every step in the model, ensuring that outcome of preceding phase forms appropriate input for the next one. Extra verification of design output enables assessing if the output of design phase meets the requirements posed by inputs. Moreover, validation activities ensure that devices comply with user needs and its intended use policies. Validation should also include testing in actual (if possible) or simulated environment, reassessment of risks and possible changes. All the results of validation, verification and review processes are thoroughly documented providing a contribution to quality assurance process **[**15**]**.

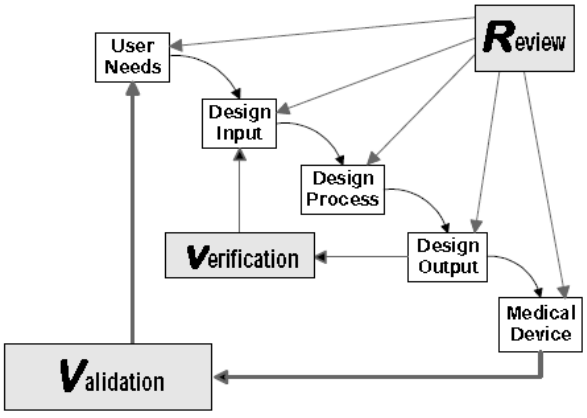

Figure 6 - Design Control for Waterfall Design Model [15]

ISO IEC 62304:2006 Medical Device Software - Software Life Cycle Processes

Another of a few established regulations dealing with ensuring proper quality and reliability of medical device software was introduced by International Standardization Organization (ISO). It does not advocate any of software life cycle models, but provides a framework of processes (including activities and

tasks) necessary for a safe design and maintenance of medical device software [16]. The framework can be easily adapted to supplement the software process that is being used. The standard uses criticality measure to divide final products into classes and proposes different set of practices for every class. The main idea of ensuring high quality and reliability of software is mainly based on verification procedures integrated into the software process. The standard also improves Risk Management process addressed by the International Standard ISO 14971 by adding factors related to hazards [16]. The proposed improvements of software process give detailed direction how to develop and maintain safe software systems.

Telestration Systems. Reverse Requirements Engineering

Telestration is a critical functionality for medical mentoring applications. Moreover, as it was mentioned before, it encompasses the majority of requirements for software in telementoring domain. We see telementoring as a branch of teleconsultation discipline, providing extra functionality, adapted to ensure guidance, n-way interaction and utilization of extra features (for instance telestration) and represent immediate response. However, only a few attempts to implement and use this kind of software were identified during the review. While the majority of the papers were dealing with the transmission of still images between patient and medical personnel or representing patient's health conditions according to a set of remote sensors, our aim was to apply a reverse engineering technique to the telestration solutions discussed earlier to extract a basic set of guidelines for developing remote presence software.

Behavior Capture

We analyze a behavior of the system and its environment using a schematic view, depicted in Figure 7. The initial purpose of the telestration solution is helping a less experienced specialist to perform an operation, considering that a local mentor (expert) is unavailable. Looking from the point of environment, the operating theater is an especially stressful place, posing requirements of reliability as of critical importance. On the other end, a remote expert on his portable device, dependent on possibly unreliable Internet connection, mainly concerned about the quality of video and audio to ensure accuracy. The description of the environment draws some guidelines for requirement definition which will be summarized in the next section.

Dynamic Behavior Modelling

After describing the environment, we continue to look at the system from the scenario perspective. As it is very specialized software, therefore only a single scenario of successful operation can be defined. Any other scenario, resulting in non-fully functional interaction has to be treated as failure, as we are dealing with a reliability-critical system.

For a schematic view, we used an operation theater equipped with 2 cameras, 2 monitors and a video streaming server. The (possibly wearable) cameras are situated in a way to create a representation of a scene as similar as possible to the one that is

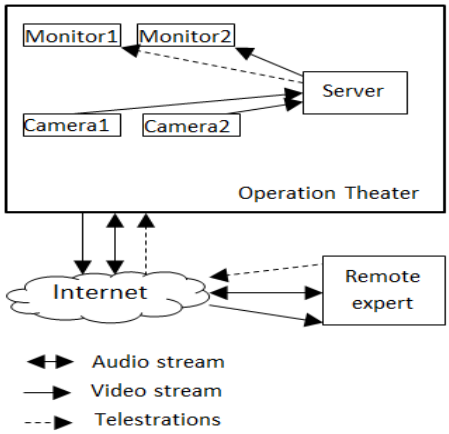

Figure 7 - Schematic view of telestration software

observed by the local surgeon. This ensures that the remote surgeon follows the same content as the local one. As both ends of the link are able to observe the same situation, the remote expert is able to produce telestration commands on the live video stream, which appears on the second monitor in the operation theater (see Figure 7). The telestration commands are fixed to the object in case of camera movement. Both ends of the link are able to modify the telestrations, ensuring two-way interactions, as video is not always enough to convey the current situation including exceptions.

An introduction of dynamic behavior of the system leads to emphasizing a set of requirements concerned about delay of the transmission. Moreover, usability is also a case, as we are dealing with strictly predefined procedures and we do not want the technology to influence them in an unexpected manner. As it was already mentioned above, we will summarize all the guidelines for requirements engineering in the next section.

Results

In this section we will try to generalize all the mentioned issues towards the guidelines to be taken into consideration while designing a specific tool for telementoring. We define a guideline as a high level recommendation type input for further requirements engineering procedures. Our assumptions are based on reverse engineering approach, stakeholders' interviews and literature review in telemedicine domain. Related Works as well as Overview of Current Solutions and Technologies sections stands for the initial source (we were not able to analyze running telementoring software) for extracting and defining guidelines for the software development process. Stakeholders' interviews were mainly used as an evaluation mechanism minimizing the gap between reverse engineering based guidelines, extracted from the research papers, and current end users' needs for telementoring software. We did not go into detail in discussing functional requirements in this paper, as they are dependent on a particular product and its functionality. We only lay a basis for the requirements engineering process of telementoring software.

Flexibility

Rapid development of technologies introduced capabilities which were not available earlier. But it also presented new challenges not only for newly developed, but also for legacy

solutions. A lack of flexibility is often a case preventing applying new technologies in companion to existing infrastructure. For example, two instances of medical robots were mentioned earlier [13], **[**14**]**. Both of them were developed for stable environment configuration, which has not changed a lot from the design phase. Notwithstanding the improved data transmission bandwidth, these gadgets are not able to utilize it for better outcome. Moreover, a working position of proctoring expert is still fixed (a particular desktop computer, equipped with particular hardware) [13], **[**14**]**, nevertheless mobile technologies and devices are able to offer sufficient characteristics for a moving mentor to ensure a shorter response time in emergency cases.

While speaking about flexibility, support for different platforms should not be omitted. As we are aiming to build flexible software, ensuring high satisfaction of global goals, a platform should not become a bottleneck, limited to only predefined environment conditions. However, enhancing flexibility tends to reduce reliability, highlighting the interconnection of the properties. Therefore, Mahinda and Witworth proposed a questionnaire for evaluating the combination of flexibility and reliability (robustness) allowing to define distinct requirements that "neither overlap not contradict". The main idea is to analyze flexibility and reliability together, as the properties are in tension – "one creates change and the other resists it" [17].

It may look like we want to be prepared for every future technology change in a term of flexibility. In fact, we aimed to highlight, that flexibility in interfaces, possibility to add newly developed modules, sometimes overriding the old ones, assists adaptation to changing environment. Of course, newly developed add-ons escalate an issue of reliability requirements, which is of critical importance and will be discussed in the next section.

Reliability

The discussed software will be used in an environment dealing with the health of the patient. As any moment can easily change the situation from stable to critical, ensuring highest level of reliability is the first priority. The success of the procedure may be dependent on the combination of remote and local surgeon knowledge, therefore the full functionality of the software must be available at any given moment. To make the guidelines closer to the term of requirement, we offer to use a common approach of metrics for measuring reliability. Considering fully functional software as a goal, a probability of becoming not fully functional during operational period can be used as a metrics for reliability.

One of the techniques to reach a high level of reliability is to follow the regulations, discussed in earlier sections. The proposed adjustments of software process ensure a positive impact on the final quality of the software product. Moreover, continuous validation and verification activities enable easier inclusion of end users to the development process (User-Centered Design), promising higher user acceptance and meeting actual needs.

Usability and Integration

Operating theater is an environment having strictly predefined rules and work flows [18]. It poses a necessity of integrating software and hardware without changing established procedures significantly. An introduced solution is highly influenced by existing conditions, therefore integration guidelines must be taken into consideration in the very beginning to reach the improvement without changing workflow model. Hardware positioning can be used as an example to illustrate the situation. Operating room already contains a considerable amount of equipment, having default positions. To ensure that no changes to the workflow are made, default positions must be maintained, while newly introduced hardware is being added. Looking from the perspective of software, platform independence, mentioned in flexibility section, minimizes integration related problems, leaving hardware positioning and compatibility as the main issues.

Risk Assessment

Risk assessment process is an integral part of software development. It usually includes identification of potential hazards and software items that could contribute to hazardous situation, calculation of probabilities of hazardous situation to occur and severity level definition [16].

Looking from the point of mobile telementoring software, some of the hazards were already mentioned before. Dealing with mobile hardware, unreliable Internet connectivity and limited battery power can be identified as main hazards. Moreover, while performing risk assessment procedure, the possible hardware faults on the both sides of the link should be evaluated. Human factor is also responsible for creating hazardous situations while interfering with technology. Therefore, risk control measures should be established enabling evaluation of possible occurrence of hazardous situation, as well as actions that should be taken to avoid it or mitigate the consequences.

Data Transmission

In this section transmission delay related guidelines are discussed. It may become a problem, to ensure a considerable delay time, while one end of the link is possibly mobile, dependent on potentially unreliable Internet connection and limited battery power. These are just a few of the challenges for developing mobile telemedicine solutions, which must be taken into consideration. To summarize data transmission related guidelines, Zhang et al. approach **[**10**]**, depicted in Figure 3, can be applied. As described in earlier sections, the approach offers dividing the system into four parts and defining requirements separately (see Figure 3) to ensure separation of different categories of requirements [10]. We did not expand on this level of abstraction in data transmission, as detailed description of data transmission requirements was discussed by Zhang et al. [10]. Looking from higher level of abstraction, the main interest is towards minimizing frame transmission delay, to ensure smooth video streaming and telestrations.

Conclusions and Future Works

Specifying requirements is one of the most important phases of software life cycle. Its significance can be proved by lots of successful and failed projects [19]. Moreover, huge costs of changes in further phases are often a result of improperly performed requirements engineering process [19].

This paper provided a basic overview of software requirements in telementoring domain. Contradicting arguments about current situation were presented, pointing out the need of changes **[4]**. As telemedicine is gaining in recognition, it is quickly spreading globally, overcoming boarders and distance. The paper escalated a problem of defining a basic set of guidelines for software and hardware products for guiding developers towards one direction. Telestration software was used as an example representing a wide spectrum of requirements in telementoring. The defined guidelines support our hypothesis that having the same initial assumption as the initial point for development process should increase the compatibility of the final solutions. The paper also introduced some new features for telementoring software. We focused on the idea of introducing mobility to medical mentoring, allowing more flexibility in working conditions and ensuring higher reachability of domain experts. In addition, by performing this research, we were also looking forward to a possibility to use more common hardware (including personal computers and mobile devices), while current telemedicine tools are usually limited to equipment by a particular vendor. Changing to regular hardware would have an impact on extremely high prices of the overall product, resulting in faster spread of technology.

We admit the weaknesses of the research, as the results were stated with no direct analysis of telemedicine software. However, the opinion of actual stakeholders, we interviewed, was highly appreciated and allowed drawing the guidelines for the research to improve telementoring software.

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Outbreak detection based on a tree-structured anatomic model for infection

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Abstract

When designing an outbreak detection system, it may be preferable to use existing medical data as input instead of requesting additional date from medical professionals. In this paper we propose using existing symptom data and reported immunological reactions in EPRs in combination with a model based on the anatomy of disease. We argue that these data for all patients in a geographical area are sufficient to indicate the increase in incidence of infectious diseases. We transform lexical patient data in a seven-step algorithm to a two-dimensional space representing the medical anomalies in a geographical area.

Keywords*: Epidemiological research, population surveillance, algorithms, syndromic surveillance, symptom model, patient clusters, immunological reactions*

Introduction

An infectious disease can potentially cause an increase in incidence over a period of time in a geographical area. To determine whether such an increase is indeed the result of an infectious disease, we need to identify which patients are afflicted by any anomalous infection, and what these patients have in common. To search for a common cause we need to examine the essence of the infection; i.e., the type of immunological reactions (IRs) caused by it, the body parts affected and the microorganism causing it (determined later by laboratory research). These basic elements of an infectious disease are represented in Figure 1 as introduced by Bassøe [1].

The elements that can be detected by the patient in an early stage of disease are affected body parts and immunological reactions. In recent years electronic patient records (EPRs) have be mined for symptoms, signs and laboratory results [2, 3]. In an EPR, we will find symptoms and immunological reactions reported by the patient or found by their medical contact person. From the symptoms we can deduce which body parts are likely involved. By collecting this information for all patients living in an area, we can calculate which patients display related symptoms and are potentially afflicted with the same infection.

In this paper we will demonstrate seven steps to transform symptom data into evidence for possible disease outbreaks, with the model that closely mimics the effect of disease on human anatomy [4].

Materials and Methods

From lexical data representing symptoms and IRs, extracted from EPR we build a map containing clusters in seven steps. Each step has an algorithm associated with it. Note that the correctness of these algorithms is not taken into account here, as it exceeds the scope of this paper. The steps are presented below.

From symptoms to EPR (1)

Symptoms will be added into a patient's EPR based on that patient's statement of symptoms to a medical professional. Alternatively, a social networking site such as Facebook could be used as a source for symptoms.

For each symptom a timestamp will be added to the symptom to distinguish time of onset. This will give us the possibility of discarding symptoms that are likely not topical anymore for any current infectious disease outbreak.

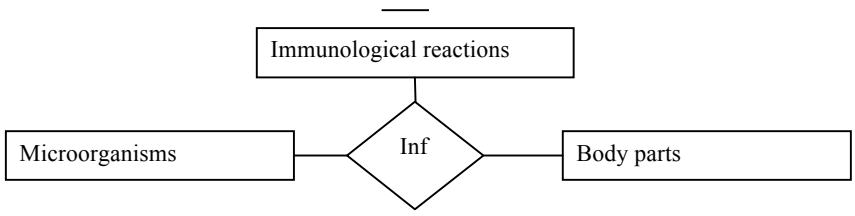

Figure 1 – General model of infections.

The EPR in use will be a problem-oriented like PROMED, which is described elsewhere [5]. This facilitates data extractions by eliminating all notes on other problems than infections. Direct access to signs of infection and immune reactions are obtained automatically [6, 7].

From EPR to tree (2)

Lexicographical analysis will be used to extract a patient's symptoms, reported over a certain time period from the EPR. We locate the body part(s) and the disorders associated with each of the symptoms. We have a predefined tree organizing all organs based on their hierarchical place in different systems within the human body. Based on this tree, we create a new tree to represent the organs likely involved in our patient's symptoms. Each node represents a body part and will get a label $\in\{0,1,2,\ldots\}$ based on the number of symptoms reported associated with that body part by that patient.

As a result we have a collection of trees representing the medical status of all patients in an area. Any trees containing only a root represent healthy patients

From tree to distance measurement (3)

For each new patient, or patient reporting new symptoms, we calculate the distance to other patients, based on the tree created in step 2. The distance between patient A and patient B is estimated by calculating how many steps (deletion, insertion, change of label) are necessary to change the tree representing patient 1 into the tree representing patient 2. This is called the Levenshtein distance between trees [8].

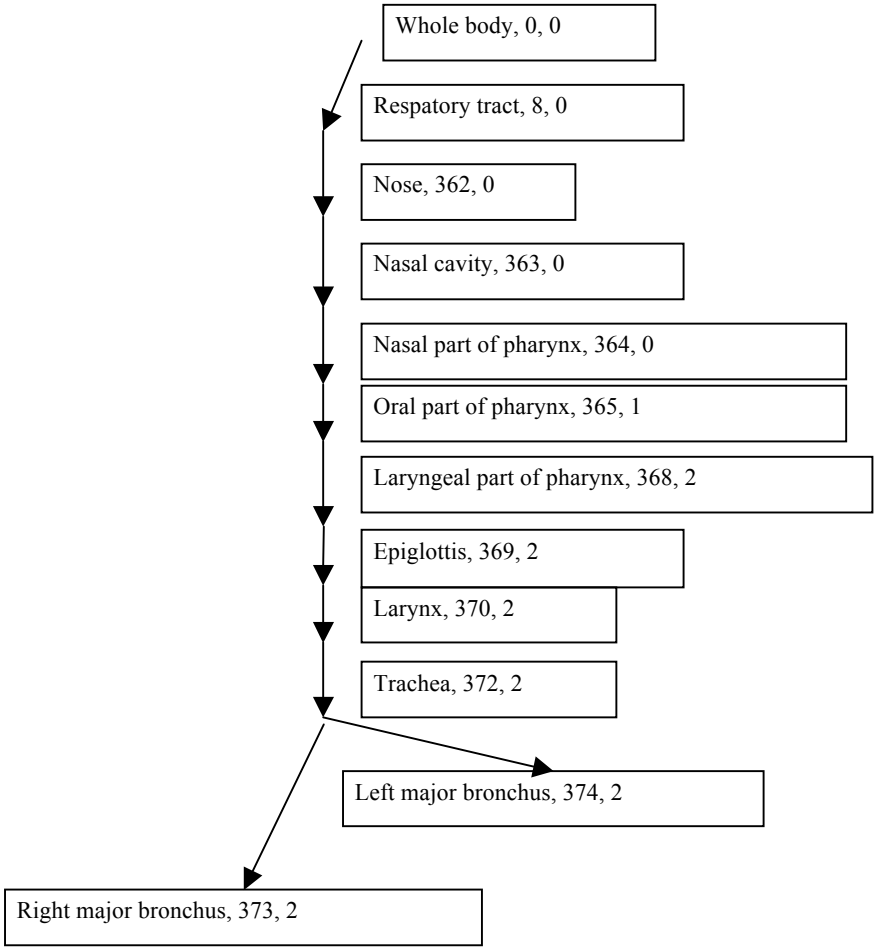

Figure 2 - Tree representation of patient with influenza pneumonitis

From distances to map (4)

After calculating all distances between all patients, we have attained a matrix of distances. We use an iterative push-and-pull algorithm to create a map of patients, approximately representing the relative similarities between their conditions. We create this map by randomly distributing points over a two-dimensional space, and adjusting for relative distances between points by push-and-pull operations [9]. This is an important step, since it facilitates a way to visualize the patient data of an entire geographical area.

Adjust map for additional data (5)

We then adjust the position of the patients on the map, based on data on additional symptoms reported in the EPR, that cannot be directly related to a specific body part (such as fever or high body temperature), their geographical proximity, family relation to one another and whether they belong in the same age group.

From map to layered map (6)

For each patient, we determine if they have experienced any immunological reactions. All groups of data points representing immunological reactions of the same type (e.g. type 3 for bacterial infections and type 4 for viral infections) can be represented in separate maps. The overlap of these maps will be the map from step 5.

From layers to clusters (7)

For each layer created in step 6, we detect clusters. If any of the clusters contains more than a predefined number of patients, there might be reason to believe that there is an outbreak of an infectious disease in the geographical area we are analyzing.

At this point the cluster of patients can be further analyzed, to determine overlap in symptoms and immunological reaction, to make a prediction about the nature of the outbreak, and take actions accordingly.

We suggest either k-means cluster [10] or visual detection. In the first case, visual detection can be done to crosscheck the result.

Summary

We have identified seven steps to transform symptom data into evidence for possible disease outbreaks. The model mimics the effect of disease on human anatomy. The steps are as follows: (1) From symptoms to EPR; (2) From EPR to tree; (3) From tree to distance measurement; (4) From distances to map; (5) Adjust map for additional data; (6) From map to layered map; (7) From layers to clusters.

In future work, we will add an eighth step in which we will study the source and direction of the outbreak after its existence has been established.

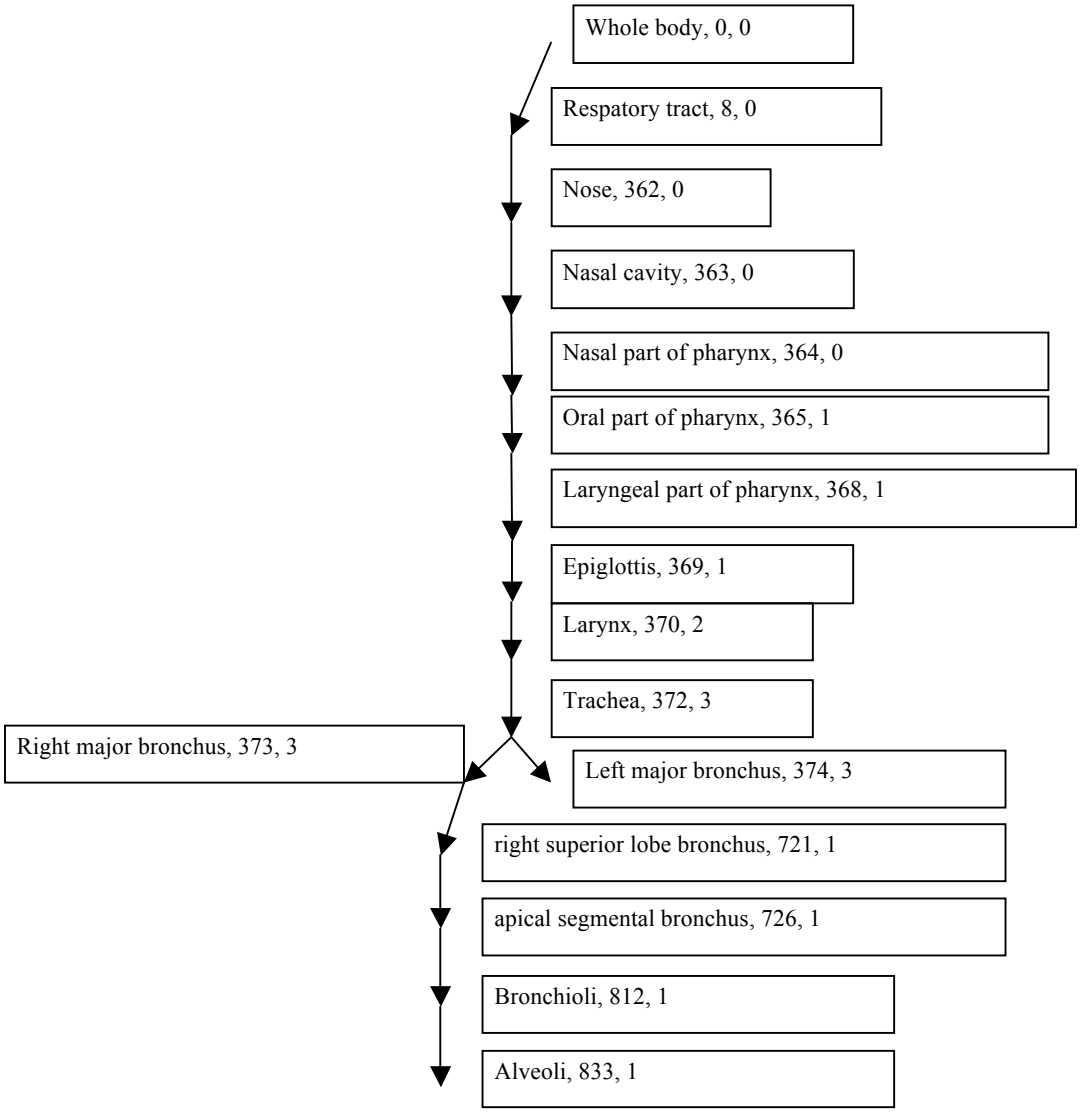

Figure 3 - Tree representation of patient with pneumococcal pneumonia.

Results

To demonstrate the seven steps of the algorithm, we implemented a basic version using Python. As examples for illustrating the system we have used the likely symptoms of patients with influenza pneumonitis, pneumococcal pneumonia, *E. coli* pyelonephritis and *E. coli* cystitis. The first two diseases primarily affect the respiratory tract. The latter two diseases affect the urinary tract. A virus causes the first disease, while bacteria cause the latter three. Patients infected with these diseases will therefore likely experience different IRs and symptoms affecting different body parts.

Examples of trees representing the affected organs of the patients with the first two diseases are shown in Figure 2 and 3. In these figures, the affected organs are followed by their code in our system and the number of symptoms likely affecting them.

When we transform data for patients with these four diseases, using algorithm 1 through 4, we arrive at a two-dimensional map visualizing how closely the medical status of the patients is related.

Since this data is random and any additional medical data describing direct similarities between patients will be arbitrary, we have not included step 5 in this example. Furthermore, we have not included a layered map of immunological reactions in this paper. However, it can easily be derived from Figure 4; taking into account that only Influenza pneumonitis gives IR reactions indicating a virus infection. The others indicate a bacterial infection. We can visually divide the two types of infection.

In figure 4 we can also visually identify approximate clusters for the different diseases.

Discussion

The results presented here strongly suggest that with minimal medical knowledge, clusters of patients can be detected and a prediction of types of infectious diseases with high incidence can be made. Due to the two-dimensional structure of the output data, a quick visualization can be made, which opens for the possibility of rapid surveillance of infectious diseases in clinical practice.

Since the input data represents the anatomical structure of disease concisely and objectively, only a few parameters are needed as input, and all parameters are readily available in an EPR. In particular, it is unproblematic to automatically extract data on immunological reactions [6]. The simplicity of the combined algorithms seems promising.

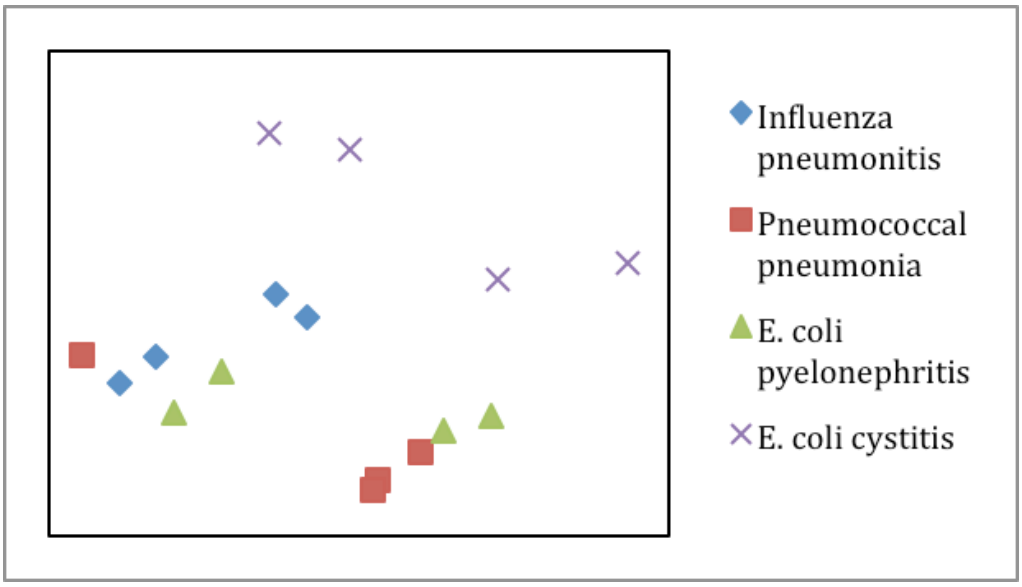

Figure 4 - Example of a two-dimensional map of patients.

Figure 4 shows correlation between data representing patients with similar health profiles. More correlation will likely be found if step 5 of our algorithm is taken into account, where other important overlapping health data will push the points together. However, the data used for this paper is simulated and adding further similarities between patients would be trivial.

In a follow up of this research, we will include real data and integrate an automatic mapping from symptoms to likely affected organs.

Conclusion

The development of strategies for the detection of infections before the onset of the symptoms is critical, especially given the limitations of the current disease surveillance systems that are based only on people's awareness of their health status. This is particularly important for vulnerable population groups, such as people with diabetes, that their health status is altered significantly when they are infected. Here, we highlighted the lessons learned in our project, the difficulties of this approach as well as our future plans. We hope that this work will provoke the thoughts for new directions within the disease surveillance field.

Acknowledgments

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Initial Experiments of Medication Event Extraction Using Frame Semantics

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Abstract

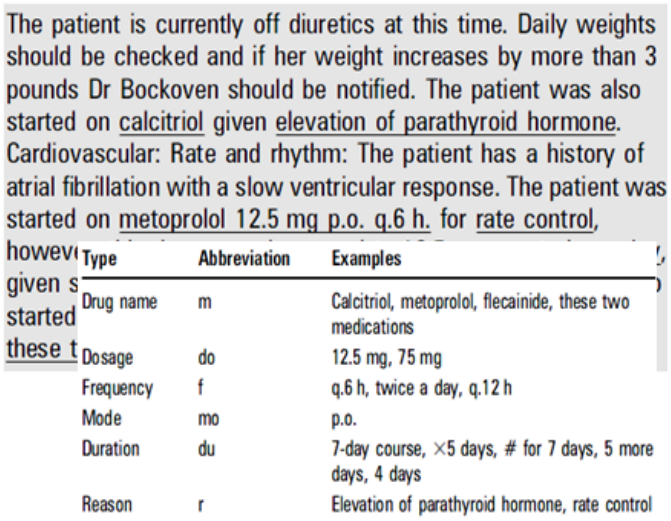
Semantic annotation of text corpora for mining complex relations and events has gained a considerable growing attention in the medical domain. The goal of this paper is to present a snapshot of ongoing work that aims to develop and apply an appropriate infrastructure for automatic event labelling and extraction in the Swedish medical domain. Annotated text samples, appropriate lexical resources (e.g. term lists and the Swedish Frame-Net++) and hybrid techniques are currently developed in order to alleviate some of the difficulties of the task. As a case study this paper presents a pilot approach based on the application of the theory of frame semantics to automatically identify and extract detailed medication information from medical texts. Medication information is often written in narrative form (e.g. in clinical records) and is therefore difficult to be acquired and used in computerized systems (e.g. decision support). Currently our approach uses a combination of generic entity and terminology taggers, specifically designed medical frames and various frame-related patterns. Future work intends to improve and enhance current results by using more annotated samples, more medically-relevant frames and combination of supervised learning techniques with the regular expression patterns.

Keywords:

Natural Language Processing; Automatic Data Processing; Semantics; Medication Extraction; Chemicals and Drugs; Dosage.

Introduction

Semantic annotation of text corpora for mining complex relations and events is a challenging research topic that has gained a considerable growing attention in the medical domain [1,2]. The goal of this paper is to present a snapshot of ongoing work that aims to develop and apply the appropriate infrastructure for automatic event labelling and extraction in the Swedish medical domain. Our approach is closely related to information extraction (IE), a technology that has a direct correlation with frame-like structures as described in the FrameNet (see below and also Appendix A). Templates in the context of IE are frame-like structures with slots representing event information. Most event-based IE approaches are designed to identify role fillers that appear as arguments to event verbs or nouns, either explicitly via syntactic relations or implicitly via proximity. As a case study, the paper presents an approach to automatically extract detailed medication information/events from medical texts (scientific papers, clinical records etc.) based on the theory of frame semantics. Medication information is often written in a narrative form and is therefore difficult to use in computerized systems or acquired by mining technologies.


The patient is currently off diuretics at this time. Daily weights should be checked and if her weight increases by more than 3 pounds Dr Bockoven should be notified. The patient was also started on calcitriol given elevation of parathyroid hormone. Cardiovascular: Rate and rhythm: The patient has a history of atrial fibrillation with a slow ventricular response. The patient was started on metoprolol 12.5 mg p.o. q.6 h. for rate control,

Type	Abbreviation	Examples
Drug name	m	Calcitriol, metoprolol, flecainide, these two medications
Dosage	do	12.5 mg, 75 mg
Frequency	f	q.6 h, twice a day, q.12 h
Mode	mo	p.o.
Duration	du	7-day course, ×5 days, # for 7 days, 5 more days, 4 days
Reason	r	Elevation of parathyroid hormone, rate control

Figure 1. Example of discharge summary (left) and extracted information on drugs (bottom-right); figures taken from [7].

Our approach uses a combination of adapted entity and terminology taggers, specifically designed medical frames and various frame related regular expression patterns.

Several systems for medication event extraction have been reported in the last couple of years [9]. However, the most relevant research initiatives with respect to the presented work is the third i2b2 Workshop on NLP Challenges for Clinical Records (designed as an information extraction task; see <https://www.i2b2.org/NLP/Medication/>) which focused on the extraction of medications and medication-related information from discharge summaries [4-8]. Medication extraction has numerous applications in e.g. pharmacovigilance, pharmacogenetics research, medication surveillance, clinical decision support, biomedical research and as an input or pre-processing step for medical language processing tools intended for data mining and knowledge discovery. Figure 1, taken from [7] shows an example of underlined medication-related information from narrative discharge summaries (left) and how structured extraction of the targeted categories of information on drugs might look like (right). In the near future we intend to

improve and enhance the extracted results using (larger) manually annotated samples and supervised learning in a much larger scale than we have been able to do so far [3] and particularly for all other types of medical-related frames.

Theoretical Background

The FrameNet approach is based on the linguistic theory of frame semantics [10] supported by corpus evidence. A semantic frame is a script-like structure of concepts, which are linked to the meanings of linguistic units and associated with a specific event or state. Each frame identifies a set of frame elements, which are frame specific semantic roles; both so called core roles, *arguments*, tightly coupled with the particular meaning of the frame and more generic non-core ones, *adjuncts* or *modifiers* which to large extent are event-independent semantic roles. Furthermore, roles may be expressed overtly, left unexpressed or not explicitly linked to the frame via linguistic conventions (null instantiations). Here, we only deal with the first type of such roles. FN documents the range of semantic and syntactic combinatory possibilities of frame evoking lexical units (LU), phrases and clauses by abstracting away from syntactic differences. A LU can evoke a frame, and its syntactic dependents can fill the frame element slots. Since a LU is the pairing of a word with a meaning, each sense of a polysemous word belongs to a different semantic frame, Moreover, since a single frame element can have different grammatical realizations it can enhance the investigation of combinatorial possibilities more precisely than other standard lexical resources such as WordNet.

Materials and Methods

The Swedish FrameNet

This paper deals with the "`Administration_of_medication`"-frame, part of the Swedish FrameNet (SweFN). SweFN is a lexical resource under development, based on the English version of FrameNet constructed by the Berkeley research group. The SweFN is available as a free resource and its latest version can be found here: <http://spraakbanken.gu.se/swe/forskning/swefn/>. The SweFN frames and frame names correspond to the English ones, with some exceptions, as to the selection of frame elements including definitions and internal relations. The meta-information about the frames, such as semantic relations between frames, is also transferred from the Berkeley FrameNet. Compared to the Berkeley FrameNet, SweFN is expanded with information about the domain of the frames, at present: general language, the medical and the art domain. The frames also contain notation about semantic types. FN facilitates modelling the mapping of form and meaning within these structures in the medical discourse through manual annotation of example sentences and automatic summarization of the resulting annotations.

Since frame classification is based on general-domain frame semantics, several efforts have been described to domain adaptations [11]. For instance, the `Cure` frame describes a situation involving a number of core roles such as: `Affliction`, `Healer`, `Medication`, `Patient` etc., and is evoked by lexical units such as *detoxify*, *heal*, *cure*, *surgery*, *treat*, *recover*, etc. The word in bold face below evokes the `Cure` frame: "`[Steloperation av fotleden`$_{\texttt{TREATMENT}}$`]` **`lindrar`** `[smärta-`$_{\texttt{AFFLICTION}}$`] [väl`$_{\texttt{MANNER}}$`] men medför en del komplikationer`" (litt. 'Lumbar fusion operation of the ankle reduces pain well, but entails some complications'). Medical frames in SweFN include: `Administration_of_medication`; `Cure`; `Addiction`; `Recovery`; `Experience_bodily_harm`; `Falling_ill`; `People_by_disease` etc.

Relevant resources

The following resources (textual, terminological, etc.) have been used for both extracting relevant text samples and also aiding the recognition of relevant frame elements in the samples:

- All text samples are taken from the MEDLEX corpus [12] using key word searches and selecting random sentences.
- The FASS, which is the Swedish national formulary: FASS contains a list of medicines that are approved for prescription throughout Sweden. The FASS version of November 2011, which contains over 12.500 names of registered drugs, was used in this work. For example:

tradename/substance	form	atc
Alvedon forte	Filmdragerad tablett	N02BE01

- The Swedish SNOMED CT's hierarchies, particularly the *substance* hierarchy (including *products*) which contains "concepts that can be used for recording active chemical constituents of drug projects, food and chemical allergens, adverse reactions, toxicity or poisoning information, and physicians and nursing orders" <http://www.ihtsdo.org/snomed-ct/snomed-ct0/snomed-ct-hierarchies/substance/>. Moreover, the `Administration_of_Medication` frame states that, if possible, the `Purpose` of the medication is also required to be identified, usually a disease; in the same manner also `Body_System` is required to be identified if explicitly stated in a medication event context), Examples of SNOMED CT:

term	hierarchy	concept-id
kadaverin	subst.	68837002
Azitromycin	product	96034006

- The Swedish MeSH's category D, Chemicals and Drugs which contains ca 5.900 terms. MeSH is a good source of synonymous terms, since the Swedish SNOMED CT contains no synonyms.

term	MeSH hierarchy
Paracetamol	D02.065.199.092.040
Antibiotika	D27.505.954.122.085

- Semi-automatic acquired drug/substance lexicon extensions (e.g. generic expressions of drugs, misspellings) and a few relevant affixes as well as names of drug classes/types than drug names, such as `antibiotica`, `antipsychotics`, `antidepressants`, `steroids`, `analgesics`, `anticoagulants`, `contraceptives`, `hormones` etc.

  `artotec` vs artrotec, *`b-blockerare`* vs beta-blockerare, *`diklofinak`* vs diklofenak

- List of drug forms, such as: `pill, tablet, capsule, liquid solution, suspension, injection, cream, gel, liniment, lotion, ointment, suppository` etc.
- List of drug administration paths, such as: `intranasal, intravenous, intravesical, subcutaneous` etc.
- List of volume units such as: `g, mg, milligram, mcg, mikrogram, MU, mmol, millimol, ml` etc.
- List of relevant abbreviations and variants commonly used in prescription of drugs (e.g. shortened drug administration paths) and other drug-related information, such as:

  `iv, i.v., im, i.m. sc, s.c., po, p.o., vb, v.b., V b, T, inj., tbl, …`

Method

We manually annotated a sample of 106 sentences with all possible frame elements [14] and *cf.* Appendix B. Administration of medication events were also annotates for negation and speculation. In appendix B there is an example of such construction (the first example shown is negated, i.e. crossed annotation on the interface). Through manual analysis of the annotated examples we get an in-depth understanding of how medication events can be actually expressed in real data in order to be able to model rules (regular expressions) to be used for the task and also have available training data for future planned supervised learning extensions. Annotated example sentences are shown below, the XML-like labels should be self-explanatory, see also table 1 and Appendix (B).

We generally followed similar methodology described in [5,7,9]. We applied an existing Swedish named entity recognizer (NER) which (among other entities) identifies and annotates time expressions (marked as TIMEX) as well as various types of numerical information (marked as NUMEX) with appropriate labels in the attributes TYPE and SuBType (*cf.* [13]). These annotations are important since they are both required by the frame and are very common in the context of medication event expressions. The following example illustrates how the NER-tagger annotates occurrences of time ("TIMEX/TME"); frequency ("NUMEX/FRQ") and dosage ("NUMEX/DSG"): `Åtta patienter erhöll Recormon före operationen, i dosering 2 000 IE subkutant tre gånger per vecka under tre veckor` (litt. 'Eight patients received Recormon before surgery, dosage 2000 IU subcutaneously three times per week for three weeks') is annotated by the NER as "`Åtta patienter erhöll Recormon före operationen , i dosering` *<NUMEX TYPE="MSR" SBT="DSG">2 000 IE</NUMEX>* `subkutant` *<NUMEX TYPE="MSR" SBT="FRQ">tre gånger per vecka </NUMEX> <TIMEX TYPE="TME" SBT="DAT">under tre veckor</TIMEX>*"

In total, 136 `Administration_of_Medication` events could be found in the whole sample. As expected, `Drug_name` (the trigger element) and `Dosage` had most occurrences in the whole material, 100 and 66 respectively. These sentences were used for making the rules described below. All annotated samples are available from: <http://demo.spraakdata.gu.se/brat/#/sweFNAdminOfMed_dk/adminOfMedication>.

- `<Drug_name>Kåvepenin</Drug_name> <Drug_strength>1 g</Drug_strength> <Frequency>x 3 </Frequency> och <Drug_name>Mollipect </Drug_name>.` (litt. 'Kåvepenin 1 g X 3 and Mollipect.')
- `Lugnande besked , rec <Drug_name>Tradil</Drug_name> <Drug_strength>400 mg</Drug_strength> <Frequency>1 x 1-2 </Frequency>` (litt. 'Reassurance, rec Seractil 400 mg 1 x 1-2')
- `Förnyat E-rec <Drug_form>T</Drug_form> <Drug_name>Stesolid</Drug_name> <Drug_ strength>5 mg </Drug_strength> <Frequency>½ x 4</Frequency>, 100 st 4 uttag <Duration>1 mån intervall</Duration>` (litt. 'Renewed E-rec T Valium 5 mg x 4 ½, 100 pcs 4 during 1 month intervals')
- `<Drug_name>Ventoline Diskus</Drug_name> <Drug_strength>0,2 mg</Drug_strength> <Time_of_the_day>morgon , kl 11</Time_of_ the_day> , <Time_of_the_day>kvällen</Time _of_the_day> samt ibland <Time_of_the_day>nattetid</Time_of_the_day>.` (litt. 'V entolin Diskus 0.2 mg morning, 11 o'clock, evening and sometimes at night.')

Table 1 - Frame Elements of the "Administration_of_Medication" frame

FrameElement	Definition / Example
Drug_form	pill, tablet, capsule, injection, gel, ...
Drug_name	Abboticin, Aberela, Abilify, Absenor, ...
Drug_strength	strength of the active ingredient(s)
Body_system	the part or area of the body affected by the administration, condition or disease
Dosage	the amount of a single medication used in each administration
Drug_type	a very general or generic name of a substance, such as antidepressants, steroids, analgesics, anticoagulants, hormones,...
Duration	the amount of time for which the activity / the medication is to be administered
Frequency	the number (or description of the number) of times a medication takes place over a period of time
Manner	usually various adverbials, such as slowly, fast, p.r.n. (Latin "pro re nata"), periodically, ...
Purpose	the medical reason for which the medication is stated to be given (often) a medical problem
Circumstance	the existing conditions or state of affairs surrounding and affecting an event
Route_of_drug_administration	path by which a drug, poison, or other substance is taken into the body, i.e. intranasal, intravenous, intravesical, ...
Time Time_of_the_day Time_elapsed_between_administration	various time related frame elements

The following steps have been used for the automatic annotation of the frame elements of the Administration_of_medication frame. These steps are applied at the sentence level only:

- start by identifying and annotating drug names (e.g. FASS) or drug name classes according to SNOMED CT or MeSH. These drug names are used as triggers for continuing the following processing steps.
- the NER-tagger is then applied and potential time, frequency or other important numerical entities are identified and annotated.
- SNOMED CT is applied once again in order to identify potential Purpose (e.g. Disorders) and Body_system.
- lexical rules based on lists of drug forms, administration path etc., implemented as regular expressions are applied for the recognition and annotation of relevant frame elements. It has been hypothesized that medication-related information is most often found in the portion of text following a drug name [5] --- in the sample we have observed some similar patterns that we also try to model in the rules, such as the most frequent: "<Drug_name> <Drug_strength> <Frequency>" (10 occurrences).
- in the same manner as previously, we prepared some data (40 sentences annotated and evaluated by the author) for testing the different steps. Nevertheless, it would have been advantageous if (trained) experts, e.g. physicians, could annotate the test data but that was prohibitive at the moment but will be considered in the future.
- normalizing the labels from the different processes, processing and scoring of the results, i.e. precision and recall for each frame element is calculated.

Results

Table 2 shows the evaluation results for each frame element that had more than 10 occurrences in the test data. Here *Precision* measures the amount of elements correctly labeled out of the total number of all elements labeled by the rules; while *Recall* measures the amount of elements correctly labeled given all of the elements in the sample. The evaluation results are based on 40 sentences that were annotated separately from the annotated sample used for the creation of the pattern matching rules.

Some of the frame elements could not be found in the limited test sample, while some had very few occurrences and we chose not to formally evaluate at this stage of the processing, for instance Body_system. In the test sample the most frequent elements were Drug_name with 53 occurrences and Drug_strength with 36. The vertical level evaluation assess the extraction of each frame element individually. So far, the extraction of Purpose and Circumstance seem the most problematic since these elements shows great common language variability, such as long phrases, vague expressions, acronyms etc. For instance: <Circumstance>Vid klart skyldig blindtarmsinflammation av varierande grad upp till kraftigare inflammation med tecken på vävnadsdöd i blindtarmen</Circumstance> administreras antibiotika Tienam 0,5 g x 3 (litt. '*In clear-cut case appendicitis of varying degree up to stronger inflammation with signs of necrosis in the cecum* antibiotics Tienam 0.5 g x 3 is administered') and Om misstanke att <Purpose>ITP</Purpose> föreligger, ge Prednisolon [...] (litt: 'If suspicion of *ITP* exists give Prednisolon'). Therefore using a simple pattern matching approach is rather insufficient for most of the cases encountered so far.

Table 2 - Evaluation results (# occurrences in the test sample)

Frame Element	#	Precision	Recall
Drug_name	53	93.8%	83.6%
Drug_strength	36	94.4%	85%
Route_of_drug_administration	27	100%	96.2%
Dosage	21	88.2%	80.9%
Frequency	19	84.2%	80%
Drug_form	19	100%	94.4%

Another problematic aspect is observed on many cases where there is an ellipsis, that is clauses where an overt trigger word (often a verbal predicate belonging to the frame) is missing. In appendix B there is an example of such construction (the second example shown in which the given event lacks an overt trigger; i.e. samt med kinidin tabletter (litt. '[...] and with kinidin tablets').

Conclusions

We have outlined an approach to medication event extraction using frame semantics. Extraction of event information is a hot topic in medical research [15,16]. The driving force for the experiments is the theory of frame semantics, which allows us to work with a more holistic and detailed semantic event description than it has been previously reported in similar tasks or in efforts using for instance most traditional methods based on binary relation extraction approaches. Moreover, event extraction is more complicated and challenging than relation extraction since events usually have internal structure involving several entities as participants allowing a detailed representation of more complex statements.

Preliminary results suggest that SweFN++ seems a good start for annotating corpora. The role set described is general enough to capture a wide range of phenomena that characterize the majority of semantic arguments of medical events. The motivation for the technique used so far is simplicity. There are a number of improvements and extensions envisaged for the near future. For instance, we intend to annotate more sentence samples, and in particular on different frames. Therefore, as an immediate next step we intend to apply supervised learning as a complement to the current approach which is based on pattern matching using regular expression patterns: Patterns are manually produced and their adaptation requires time and expensive human resources so the application of supervised learning methods are considered the most appropriate alternative technique that can be used, most probably in a close interplay with regular expression patterns that are

suitable for matching with high accuracy short numerical and abbreviated patterns, such as dosage. Finally, a further goal we have in mind with our current work is to use such an approach for the extraction of medication events from clinical texts i.e. medical records, where a patient's medical treatment plays an important role during the patient's medical diagnosis, treatment, etc. a critical piece of information for healthcare safety and quality.

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Appendix A

The "Administration_of_medication"-frame taken from <http://spraakbanken.gu.se/swe/forskning/swefn/utvecklingsversion> (version of September 2012). In the picture below, the left column is provided in Swedish (*ram*: frame; *domän*: domain; *semantisk typ*: semantic type; *kärnelement*: core elements; *periferielement*: non-core elements; *exempel*: examples; *sms*: compound construction; *sms-exempel*: examples of compound constructions; *saldo*: relevant lexical units taken from the Swedish lexical resource 'saldo').

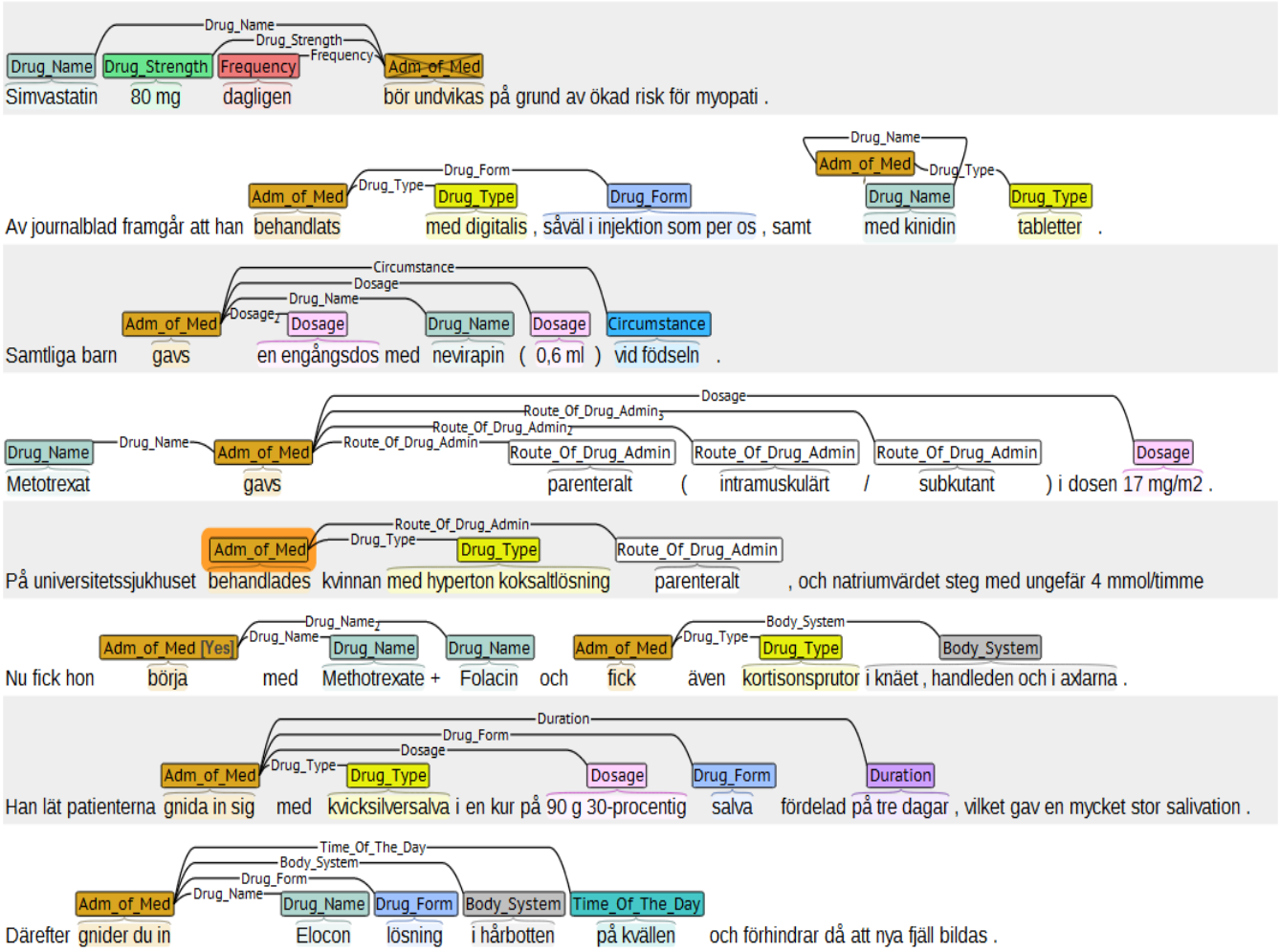
Administration_of_medication

ram	**Administration_of_medication**
domän	Med
semantisk typ	
kärnelement	**Drug_form**, **Drug_name**, **Drug_strength**
periferielement	**Body_system**, **Circumstances**, **Depictive**, **Dosage**, **Drug_type**, **Duration**, **Frequency**, **Manner**, **Purpose**, **Route_of_drug_administration**, **Time**, **Time_of_the_day**, **Time_elapsed_between_administration**
exempel	Behandlas med **T Vibramycin 200 mg x 1 i 14 dagar**. **T Sumatriptan 50 mg œ-1**. **T. Suscard 2,5 mg kl. 13.10** **Tramadol 50 mg 1 tabl 2-3 ggr dagl** **Tegretol 20 mg/ml, 30 ml x 1** **Inj Diamox 250 mg x 1 iv** **inj Fluarix 0,5 ml im i höger arm** **Benzatinpenicillin 2,4 milj IE im dag 1** Åtta patienter erhöll **Recormon före operationen, i dosering 2 000 IE subkutant tre gånger per vecka under tre veckor** Normalt ska en **salva** eller **kräm strykas på tunt**. Modern hade under graviditeten medicinerat med **klomipramin 50 mg dagligen**. Barnets moder hade under graviditeten medicinerat med **klomipramin 60 mg x 1**. Modern hade under graviditeten medicinerat med **klomipramin 75 mg /dag**. **Läkemedlet** kan **administreras peroralt**, **rektalt** och **på huden som gel**.
sms	
sms-exempel	
saldo	**nn:** applicering..1 drog..1 glidkräm..1 glidsalva..1 herpessalva..1 hudkräm..1 injektion..1 injicerande..1 injicering..1 insprutning..1 kräm..1 läkemedel..1 medicin..2 piller..1 påläggande..2 påläggning..2 salva..1 tablett..1 ögondropp..1 ögondroppar..1 **vb:** applicera..2 gnida..1 injicera..1 **vbm:** droppa in..2 lägga på..1 stryka på..1

Appendix B

Part of the annotated data with the frame elements of the `Administration_of_Medication` frame. The BRAT system [14] has been used for the m anual annotation of the frame elements.

The first example shown below is actually annotated as "Negated" (crossed annotation) i.e. `bör undvikas` (litt. 'ought to be avoided'). The second example illustrates an elliptic annotation, where the second event lacks an overt trigger; i.e. [...] `samt med kinidin tabletter` (litt. '[...] and with kinidin tablets').



Applying visualization to support coherent terminology implementation

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Introduction

In every corner of the health sector there is a need for information to be captured, shared and retrieved. A wide range of information is to be exchanged between the various IT-systems within the health sector, such as information concerning the patient's medical case history, information's from other departments and cross sector information. The accessibility of information is important for the treatment and care of a patient. Further, the ability to compare clinical information is a necessity for generating clinical overviews and statistics.
However, one of the greatest challenges when considering data communication in health care is multiple definitions of the same concept. [1] Therefore, use of standardized clinical terminologies is a prerequisite in the quest of achieving semantic interoperability.[2] However, ambiguous and inconsistent use of terminology can hinder data for being shared and therefore to be reused.
It is a fact, that the IT-systems are continuously adjusted and refined. Concepts are being added end resigned to fit the current information needs. Therefore, it is of great importance to maintain a reliable overview of the concepts within the systems to know what concepts are already being used so that added concepts conform to the existing.
The objective of this study is to clarify the needs for a tool that can support a coherent SNOMED CT implementation and to specify these needs in a system design.

Materials and Methods

This paper is based on results from a clinical implementation of SNOMED CT. The terminology was implemented alongside the configuration of an EHR system in the Northern Jutland Region in Denmark. The point of departure is the configuration of two EHR- templates "nursing status" and "physical examination".
Alongside with the implementation process the authors of this paper manually developed visualizations of the concepts involved in the respective EHR-templates. The visualization was based on the concept structure of SNOMED CT. The visualization was then used as underlying basis for terminological discussions between the end-users (clinicians) and the implementation team, leading to content-refinement for the respective EHR-templates.
The experience from this work was evaluated by the authors and system demands was clarified and specified in an implementable system design.
The basic idea is to visualize a set of concepts included in a set of EHR- templates and to illustrate their relationships relative to the complete SNOMED CT structure.

Results

The result of this project is a system design and a software prototype that support a SNOMED CT implementation process.
It is found that visualization can support the terminology implementation in clinical IT-systems at different levels. It provides an overview of the concepts applied in the clinical IT-systems, thereby giving an overview of the options available to make specific filtrations (data requests). Also, it can support the selection of concepts that is applied to the IT-system.

Conclusion

This work is about how to approach SNOMED CT implementation in clinical information systems to facilitate reuse and comparability of information across systems.
To rely on a common terminology system is of course the first step towards facilitating clinical data exchange between IT-systems. However, it is necessary to approach the terminology implementation coherently and with consistency to obtain comparability of information. Also, the IT-systems should apply mechanisms that conform to the reference model of SNOMED CT. Otherwise, the relational properties of the concepts cannot be maintained, and thus complicating the possibility to create advanced retrieving functionalities.
Future work is to validate the system design and to test the potential of terminology-visualization in different scopes of SNOMED CT- implementation.

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Performance of XML Databases for Epidemiological Queries in Archetype-Based EHRs

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Abstract

There are very few published studies regarding the performance of persistence mechanisms for systems that use the openEHR multi level modelling approach. This paper addresses the performance and size of XML databases that store openEHR compliant documents. Database size and response times to epidemiological queries are described. An anonymized relational epidemiology database and associated epidemiological queries were used to generate openEHR XML documents that were stored and queried in four open-source XML databases. The XML databases were considerably slower and required much more space than the relational database. For population-wide epidemiological queries the response times scaled in order of magnitude at the same rate as the number of records (total database size) but were orders of magnitude slower than the original relational database. For individual focused clinical queries where patient ID was specified the response times were acceptable. This study suggests that the tested XML database configurations without further optimizations are not suitable as persistence mechanisms for openEHR-based systems in production if population-wide ad hoc querying is needed.

Keywords: Medical Record Systems, Computerized; Database Management Systems, Archetypes, XML Databases, openEHR

Introduction

An electronic health record (EHR) is a computer processable repository of information regarding the health status of a subject of care [1]. Much has been published about the potential use of EHRs to support healthcare, clinical-epidemiological studies, decision support systems and healthcare services management. International Standards have been proposed to establish the EHR definition, context and scope [1], the requirements of the EHR architecture [2] and models to communicate EHR extracts [3]. Despite all this, electronic health records are usually non interoperable, hard to evolve and do not fully meet the proposed requirements.

Health care is an area with some features that make it very complex for the development of EHR systems. For instance: there is a large number of evolving concepts and it is hard to achieve a consensus regarding comprehensive models for the EHR. To reduce the need for constant changes in the system persistence models, [4–6] propose the separation between the domain model and the reference model.

This separation of responsibilities is refined in the specifications developed by the openEHR Foundation [7], a multi level modelling approach, designed in order to build future-proof systems. The approach uses a stable reference model (RM) that can be implemented in software, and a flexible domain model expressed in "archetypes" and "templates"; these concepts are well explained in [8]. The RM is the model whose classes will be persisted and tends to be stable, i.e., its classes are intended not to change frequently. The archetypes give the semantic meaning to the objects that are persisted via reference model. OpenEHR's proposal is that structural changes and business rules are reflected in the archetypes rather than in the RM; this way there is no need to make changes in the persistence mechanism, be it relational, object-oriented, XML, etc. Furthermore the archetypes are created and edited primarily by domain experts, not programmers or informaticians.

The archetype-based multi level approach has opened a new horizon for research in medical informatics, besides inspiring standards development organizations [3] Several research groups have been working on several issues raised by the approach, for instance, representation of clinical guidelines [9], conversion of data stored in legacy systems to archetype-based systems [10,11], implementation of the specifications as open source [12], among others.

An important decision to be taken when developing systems based on the multi level modelling approach is the choice of persistence mechanism, so that performance and query requirements are met. Since the RM has a large set of classes that can form relatively deep hierarchies, a pure object-relational mapping may not be an efficient solution, this is suggested by the literature and discussions in the openEHR community [13,14]. Some openEHR-based open-source implementations have been made public recently [15–17], but their performances using realistic epidemiological data and queries have not been described.

The EHR data, generated according to the RM, can be serialized in several formats: JSON, XML, and others. Since there are several XML databases available, they can be used to store openEHR compliant XML documents. But in

order to be used in production, they must have good performance not only when querying for data about an individual (clinical query) but also for data about a whole population (epidemiological query), e.g., follow up or research. This is one of the most important secondary uses of electronic healthcare records and to the best of our knowledge, no study has been published with this kind of evaluation.

This paper addresses the performance of XML databases that stores openEHR compliant documents in terms of size and response times to epidemiological queries.

Materials and Methods

Test database

This study used the database of the National Cervical Cancer Information System – SISCOLO – for the State of Rio de Janeiro, Brazil, from June 2006 to December 2009 that was subjected to a process of record linkage in order to identify records that belong to the same patient [18]. Through this process, all records belonging to the same patient were given the same integer identifier (uid field in the database) that was unique for each patient. Data for this database are collected from standardised forms for two ambulatory procedures requests: cervical pathological examination and pap smear. These forms generate two main tables in the SISCOLO database which contain respectively the results of histological and cytological examinations of women. Those tables, which from now on will be called "histology" and "cytology", were exported into corresponding tables in a MySQL [19] schema.

The cytological exam comprises the following sections:

- anamnesis;
- clinical examination
- cytological exam results
  - reasons for the rejection of the slice
  - type of epithelium in the sample
  - material adequability (true or false)
  - reasons for inadequability
  - benign cellular alterations
  - microbiology
  - atypical cells of indeterminate meaning
  - atypias in scamous cells
  - atypias in glandular cells
  - other malign neoplasias
  - presence of endometrial cells

Depending on the results of the cytological exam, the woman may be referred to perform a histological exam which is comprised of the following sections:

- cytological exam results;
  - atypical cells of indeterminate meaning
  - atypias in scamous cells
  - atypias in glandular cells
- colposcopy
  - result
  - procedure
- type of surgical procedure
- macroscopy
- microscopy
  - benign lesions
  - neoplasic or pre-neoplasic lesions
  - differentiation degree
  - tumour extension
  - surgical margins

The histology table has 7,477 records belonging to 6,238 patients. The cytology table has 2,471,088 records, belonging to 1,679,801 patients, and 5,316 of them have also records in the histology table. All identifying demographic data of patients, health professionals and organizations were removed from the database. In addition to this, the date of birth and the date of exam were modified by adding or subtracting a random number of days (in the intervals ±912 and ±100 respectively). This was done in order to obtain a virtually anonymized set of data without impacting the representativeness of the set.

OpenEHR XML documents

A set of 10 archetypes and 3 templates was designed from scratch in order to represent the contents of the SISCOLO database schema using the Ocean Informatics Archetype Editor and Template Designer [20,21]. Then the contents of the SISCOLO database was mapped to openEHR XML documents, according to the following steps:

1. XML files (EHR data instance examples) corresponding to each of the compositions: histological exam, cytological exam and administrative data were generated using LiU-EEE [22] that exposes the example instance skeleton generator from the openEHR Java reference implementation [12].
2. An XML document that represented a patient record with those compositions was generated using LiU-EEE.
3. This XML document was used as a basis for a Freemarker [23] template in order to map all records in the SISCOLO database to openehr XML documents. One XML document was created for each patient and it contained all histological and cytological exams for that patient.

Of the 6,238 women who have histological exams, 5,281 performed only one exam, 779 performed two exams, 138 performed 3 exams and 40 performed 4 or more exams. Of the 1,679,801 women who were submitted to cytological exams, 1,135,726 had one exam, 363,357 had 2 exams, 132,438 had 3 exams and 48,280 had 4 or more exams. Each exam generated one composition in the EHR. It can be seen then that the majority of women have only a few exams. In the very few cases where women have more than ten exams of each type, this may be due to errors in the probabilistic record linkage process.

For women who have histological exams, the openEHR XML documents vary in size from a minimum of 30 KBytes to a maximum of 606,2 KBytes, depending on the number of cytological and histological exams they were submitted to.

Evaluated Databases

Four XML database systems were evaluated in this study and compared with the performance of the original database in

MySQL (version 5.5.24): eXist (version 1.4.2) [24], BaseX (version 7.3) [25], Sedna (version 3.5) [26], and Berkeley DB XML (version 11g) [27]. This selection included the major actively maintained open source XML databases with XQJ and XQuery java interfaces.

Evaluation setup

The evaluation was done in terms of storage space and response times to a series of queries against each of the databases. Three datasets were built as subsets of the original SISCOLO database:

1. all EHRs containing both histological data and associated cytological data (6,238 records) - *siscolo6k*;
2. the same records as in 1 plus around 60,000 EHRs containing only cytological data (66,070 records) – siscolo60k;
3. the same records as in 1 plus around 600,000 EHRs containing only cytological data (604,367 records) - siscolo600k.

Each of these datasets were stored in each of the XML database systems. Then a set of population-based queries were created in SQL and equivalent ones in the Archetype Query Language (AQL) [29], which were translated to XQuery [30] through the LiU-EEE software.

In order to be realistic, the population-based queries were created following the analysis performed in an epidemiological study that evaluated the effectiveness of the SISCOLO screening programme [30]. In addition to the population-wide queries, three clinical queries were created to access, for each of a set of randomly selected EHRs, the whole content of the EHR, one *composition* section and one *evaluation* section within each EHR.

AQL does not yet have aggregation functions. Therefore all population-based queries were framed to return all record Ids that satisfied the query criteria. All epidemiological queries included a time interval in their selection criteria. The response times were evaluated both for an interval of four months and for a period of three years which included most of the data in the database. Box 1 shows an example of an AQL query and its corresponding translation to XQuery.

Box 1: A query example is to return all record ids that had a histological exam result indicating neoplastic lesions between 2006-01-01 and 2006-05-01.

In AQL it is expressed as...

```
SELECT e/ehr_id/value as ehr_id
FROM Ehr e
CONTAINS VERSION v
CONTAINS COMPOSITION c [openEHR-EHR-COMPOSITION.histologic_exam.v1]
CONTAINS OBSERVATION obs [openEHR-EHR-OBSERVATION.histological_exam_result.v1]
WHERE (EXISTS obs/data[at0001]/events[at0002]/data[at0003]/items[at0085]/items[at0033]/items[at0034] OR
EXISTS obs/data[at0001]/events[at0002]/data[at0003]/items[at0085]/items[at0033]/items[at0035])
AND c/context/start_time/value >= '2006-01-01T00:00:00,000+01:00'
AND c/context/start_time/value < '2006-05-01T00:00:00,000+01:00'
```

...which when translated to XQuery results in:

```
declare namespace v1 = "http://schemas.openehr.org/v1";
declare default element namespace "http://schemas.openehr.org/v1";
declare namespace xsi = "http://www.w3.org/2001/XMLSchema-instance";
declare namespace eee = "http://www.imt.liu.se/mi/ehr/2010/EEE-v1.xsd";
declare namespace res = "http://www.imt.liu.se/mi/ehr/2010/xml-result-v1#";
<res:xml-results>
<res:head><res:variable name="ehr_id"/></res:head>
<res:results>
{let $ehrRoot := //eee:EHR
for $e in $ehrRoot
for $v in $e/eee:versioned_objects/eee:versions
for $c in $v//*[@xsi:type='v1:COMPOSITION' and @archetype_node_id="openEHR-EHR-COMPOSITION.histologic_exam.v1"]
for $obs in $c//*[@xsi:type='v1:OBSERVATION' and @archetype_node_id=
 "openEHR-EHR-OBSERVATION.histological_exam_result.v1"]
where
(exists($obs/data[@archetype_node_id = 'at0001']/events[@archetype_node_id = 'at0002']/data[@archetype_node_id =
'at0003']/items[@archetype_node_id = 'at0085']/items[@archetype_node_id = 'at0033']/items[@archetype_node_id = 'at0034'])
or exists($obs/data[@archetype_node_id = 'at0001']/events[@archetype_node_id = 'at0002']/data[@archetype_node_id =
'at0003']/items[@archetype_node_id = 'at0085']/items[@archetype_node_id = 'at0033']/items[@archetype_node_id = 'at0035'])) and
$c/context/start_time/value  >= '2006-01-01T00:00:00,000+01:00' and $c/context/start_time/value < '2006-05-
01T00:00:00,000+01:00'
return
<res:result><res:binding name="ehr_id">{$e/eee:ehr_id/value}</res:binding></res:result>}
</res:results>
</res:xml-results>
```

The queries were executed ten times in MySQL in all three datasets. Due to their slow response times, the number of times the queries were executed in the XML databases was reduced. For BaseX, they were run three times for siscolo6k, two times in siscolo60k and siscolo600k. For Sedna, they were run two times for siscolo6k, a subset of the queries were run two times in siscolo60k and only once in siscolo600k. For Berkeley DB XML, the same subset of the queries was run three times in siscolo6k and only once in siscolo60k and siscolo600k. All databases were queried through the Java API for each database and the execution time was measured from the moment the query was sent to the database until the result set was returned. No display of or navigation through the results was performed.

The MySQL database was indexed by the EHR id. No indexes besides those that are already built-in in the XML databases were created, because we were most interested in ad hoc queries for which it is not known in advance which indexes should be used, and which is a very common use case in health care research. Thus, in the XML databases, no assumptions were made about the kinds of query that would be made. The evaluation was performed with a single user accessing the stand-alone database.

The evaluation was performed in a DELL desktop with an AMD Athlon 64X2 dual-core processor 5600+x2 with 3.9 GB RAM running Ubuntu 12.04 LTS.

Results

The sizes of each database in MySQL and in the four XML databases are shown in Table 1 for the three datasets described above and also for the complete dataset, described by "FULL" in the table. Besides requiring much more space than the relational database, it can be observed that there is a large discrepancy among the XML databases, with BaseX being the least demanding and Sedna the most space consuming.

Table 1 – Databases' size in GBytes according to the database system and the number of records it contains.

Database	Size (Number of Records)			
	6,238	**66,070**	**604,367**	**FULL**
MySQL	0.013	0.052	0.41	1.1
Generated XML files	0.56	2.8	23	60
BaseX	0.38	1.9	15.7	42
eXist	0.72	3.9	31.27	70
Sedna	1.7	8.4	70.9	181
Berkeley DB XML	1.5	7.0	57.4	137

The response times for each of the databases are shown in Figure 1.

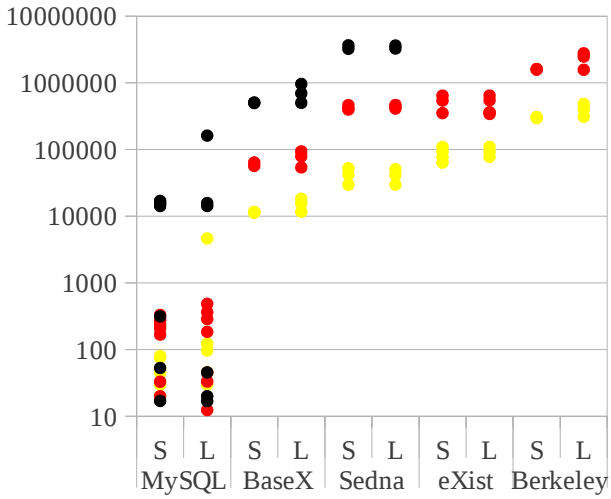

Figure 1 - Response Times for the epidemiological queries.
Yellow: siscolo6k, Red: siscolo60k,
Black:- siscolo600k,
S, L - short and long time intervals respectively
Y axis - Time in milliseconds and logarithmic scale

All XML database systems perform poorly compared to the relational database for the epidemiological queries and there is also a large discrepancy among them as far as the response time goes. MySQL has response times varying from µs to hundreds of ms with one query reaching a peak of 100s one time for the larger dataset. BaseX has the best performance of all XML databases in all datasets but the response times are around 10s for the 6k , 60s for 60k and 500s for 600k dataset for the short time interval. The response times increase significantly for the long time interval. Sedna comes second in the rank of XML databases with similar response times for both the short and long time intervals, but much slower response times than BaseX in all datasets. eXist is slower than Sedna for the smallest dataset, but with comparable response times for the 60k dataset. Berkeley DB XML was the slowest of all with response times two orders of magnitude higher than BaseX. No data was obtained for eXist and Berkeley DB XML for the 600k dataset because the response was taking too long and the program was aborted.

The average response times for the clinical queries were between 10 and 200ms for the BaseX, eXist and Berkely DB XML, as well as for MySQL. The response times depended on the sizes of the individual records.

Discussion

The openEHR XML documents are very verbose; this is caused by the inherent verbosity of XML and by the openEHR RM. The RM has a deep tree structure and it stores both codes and description for terminological entries. More information is also added to the openEHR data such as context, auditing, archetype ids an so on, which was not present in the anonymized SISCOLO database. The size of

the three sets of XML documents are respectively 556 MBytes, 2.8 GBytes and 23 GBytes. Therefore it is not a surprise that the sizes of the XML databases are much larger than the corresponding SQL database. However it is interesting to notice that the XML database systems differ greatly in the size of the generated databases with BaseX being the most space saving of all and Sedna and Berkeley DB XML requiring around 3 times more space than BaseX. eXist ranks second in this aspect.

The response times of the XML databases for the epidemiological queries leave much to be desired as compared to the sql database. This is in accordance with the results from the literature [31]. There are also large differences among the XML databases, being BaseX again the most responsive of all and eXist the least responsive. The response times are very high, even for the smallest dataset. In a realistic scenario with concurrent access to the databases, the response times would be even worse.

Each XML database has its own built-in indexing mechanism. With Sedna the query syntax should be modified to indicate which index to use. In the epidemiological scenario, this is not useful because usually it is not easily known in advance which index would be most helpful to the query execution.

The way the openEHR archetypes are designed and the nature of data values that are stored in the database make the automatically generated indexes in the databases inefficient. The archetypes usually have many attributes with the same value, for instance almost all archetypes have an archetype node id equal to “at0001” and the database used in this study has mainly coded values with few options to choose from. This makes xml text and attribute indexes point to a huge number of entries in the database, leading to long inspection of documents in order to return the results. How to best handle querying of the relatively deep openEHR tree structures, often with repeated path segment identifiers, is an interesting topic for future research.

The XQueries were not handwritten but produced by LiU-EEE AQL parser. Possibly these queries could be rewritten so that better response times could be obtained, but this is open to investigation.

It would be better to run each of the queries the same number of times for each scenario but, due to the slow response times, the number of repetitions was reduced and, in some cases, some queries were omitted. However, it has been observed that the response times do not change very much for successive runs of the same queries and the order of magnitude of the response times is not lost when we limit the number of repetitions. Besides the queries that were left out had response times similar to the queries that remained.

Although useful as an educational tool for teaching the openEHR specification and implementation to students and newcomers, the results of this study put into question the usability of XML databases as a persistence mechanism for openEHR-based systems intended for ad hoc population queries. Even in the clinical scenario, it is common to perform population-based queries, for instance, a doctor that asks for the records of all patients that he/she is going to attend that day. Therefore other alternatives should be investigated, such as the one proposed by Beale [32], Arikan [15] XML shredding [33] or other architectures such as Column stores, e.g. Hadoop/Hbase (hadoop.apache.org), Cassandra (cassandra.apache.org); Document store, e.g. Terrastore (code.google.com/p/terrastore); Key Value or Tuple stores, e.g., AmazonSimpleDB (aws.amazon.com/simpledb), Graph Databases, e.g., Neo4j (neo4j.org), InfoGRID (infogrid.org); and RDF triple stores e.g. Allegro Graph (www.franz.com/agraph/ allegrograph).

It is important to point out that the Archetype Query Language does not provide constructors for creating aggregation queries. In the clinical-epidemiological context this is an essential requirement and the Archetype Query Language needs to be enhanced in order to enable interoperable such queries. It is also necessary to add the “Distinct” construct so as to avoid the return of the same values more than once in the query results.

Conclusions

The XML database systems were considerably slower and required much more space than the relational database. For population wide epidemiological queries the response times scaled in order of magnitude at the same rate as the number of records (total database size) but were orders of magnitude slower than the original relational database. For individual focused clinical queries where patient ID was specified the response times were acceptable. This study suggests that the tested XML database configurations without further optimizations are not suitable as persistence mechanism for openEHR-based systems in production if population-wide ad hoc querying is needed.

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Web-based support in long-term illness – a person-centred care approach

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Introduction

The poster outlines a research project that aims to develop and evaluate a person-centred model of web-based learning and support for people with long-term illness. Departing from the widespread use of the internet in modern society and the emerging use of web interventions in healthcare [1-3] the multi-case project captures persons' needs and expectations in order to develop highly usable web recourses. To support the underlying idea to move beyond the illness, we approach the development of web support from the perspective of the emergent area of person-centred care (PCC).

Materials and Methods

The research design uses a meta-analytical approach through its focus on synthesizing experiences from four Swedish regional and national studies/cases of design and use of web-based support in long-term illness. The cases include children (bladder dysfunction and urogenital malformation), young adults (living close to persons with mental illness), and two different cases of adults (women with breast cancer and childbearing women with type 1 diabetes). All of the cases are ongoing, though in different stages of design, implementation, and analysis.

An inductive approach characterizes the analysis of the results of the cases. By means of a step-wise analysis a shared knowledge and understanding of each separate case is created followed by the development of central categories (such as types of needs and expectations, types of theories, conceptual framework, etc).

Results

To allow valid comparisons between the four cases we explore and problematize them in relation to four main aspects: 1) The use of people's experiences and needs; 2) The role of use of theories in the design of person-centred web-based supports; 3) The evaluation of the effects of health outcomes for the informants involved and 4) The development of a generic person-centred model for learning and social support for people with long-term illness and their significant others.

Discussion

Person-centred web-based support is a new area and no available study focus on how web-based interventions can contribute to the further development of PCC. In the four cases within this project the evaluation model is characterized by evaluation of web support in real settings, and data will be analysed using both within-case and across-case statistical analyses. Therefore, our multiple-case method, in which overlapping results from different contexts will provide comprehensive experiences, will contribute to the design of a more generally applicable, individually modifiable model. However, the multiple case method is also a challenge of validity, as the use of different case experiences and environments, involves an endeavour to understand what types of experiences are actually being captured in the process of developing a web-based support and what this means in relation to PCC. In summary, the main intention of the project outlined here is to contribute with both a synthesis of results on meta-level from four cases and a substantial contribution to the field person centred care.

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Pre-defined Headings in a Multi-professional Electronic Health Record System

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Introduction

Applying multi-professional electronic health records (EHRs) is expected to improve the quality of patient care and patient safety. Both EHR systems and system users depend on semantic interoperability to function efficiently. A shared clinical terminology comprising unambiguous terms is required for semantic interoperability. Empirical studies of clinical terminology, such as pre-defined headings, in EHR systems are scarce and limited to one profession or one clinical specialty. The aim was to study pre-defined headings applied by users in a Swedish multi-professional EHR system.

Materials and Methods

This was a descriptive study of pre-defined headings (n=3 596) applied by 5 509 users in a Swedish multi-professional EHR system. When the EHR system was implemented headings predefined by each profession based on their perceived clinical-specific or profession-specific needs were developed. Predefined headings in an EHR system in a county council, applied by health care professionals obligated to document according to the Swedish Patient Data Act, were included. Pre-defined headings applied by dieticians, medical social workers, occupational therapists, physicians, physiotherapists, psychologists, registered nurses, and speech and language pathologists were included. The pre-defined headings were classified into categories to reflect the ambiguity of each heading. The headings were classified by the first author according to three categories, employed by Melander Marttala in a study of mutual understanding between physicians and patients, and an additional category. Pre-defined headings that occurred in the Swedish Academy Glossary (SAG) without any explanation were classified as "common words". "Terms for specific purposes" had one or more explanations in SAG. Pre-defined headings not found in the SAG, but in a medical health care dictionary, were classified as "specialist terms". Pre-defined headings not found in the SAG or in a medical health care dictionary were classified into an additional fourth category; "unclassified headings".

Results

Less than half of the pre-defined headings were shared by two or more professional groups. All eight professionals groups shared 1.7% of the pre-defined headings. The distribution of pre-defined headings across categories yielded 46% "terms for specific purposes" 28% "common words", 13% "specialist terms", and 13% "unclassified headings"

Discussion

Nearly 60% of the pre-defined headings were not shared at all. It indicates that each professional group had incorporated their own specific clinical terminology as pre-defined headings into the multi-professional EHR system. However, registered nurses and physicians, and medical social workers and psychologists, pair wise mutually shared more than 50% of their pre-defined headings between themselves. There is a conflict between ambiguity and comprehension of terms and words used as predefined headings. "Specialist terms" can, because they are unambiguous, support mutual understanding within a professional group or a specialty. At the same time they can be incomprehensible and thus exclusionary to patients and other professional groups. Whereas "common words" can, despite the fact they are ambiguous, be inclusionary because they are comprehensible and familiar to patients and all professional groups. The pre-defined headings in the multi-professional EHR-system studied did not constitute a joint language for specific purposes. The improvement of the quality and usability of multi-professional EHR systems requires attention.

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Standardiserat fackspråk för dietister

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Introduktion

2003 bildades en arbetsgrupp kring etik och terminologi inom Dietisternas riksförbund (DRF) med fokus på terminologi, då det sakandes definierade termer för nutritionsbehandling. Arbete har utmynnat i flera olika delar med både nationell- och internationell koppling. Syftet med detta abstrakt är att kort beskriva denna utveckling.

Material och Metod

Arbetet inleddes med att beskriva de olika stegen i nutritionsbehandlingsprocessen samt identifiera centrala begrepp som används inom nutritionsbehandling. I huvudsak tillämpades befintliga definitioner från olika källor men i några fall har egna definitioner varit nödvändiga att ta fram och i det arbetet har Terminologiskt centrum (TNC) medverkat.

Ganska tidigt identifierades den standardiserade arbetsprocess (NCP[1]) som The Academy of Nutrition and Dietetics utarbetat med tillhörande standardiserad terminologi (IDNT[2]), specifikt utarbetad för de fyra stegen i nutritionsbehandlingsprocessen. Nutritionsbehandlingsprocessen består av fyra olika steg; nutritionsutredning, nutritionsdiagnos, nutritionsåtgärder samt nutritionsuppföljning och utvärdering. Det som framför allt är nytt för dietister är nutritionsdiagnostiken vilken bygger på ett s.k. PES-uttalande (problem, etiologi samt symtom/tecken).

2010 fick Utvecklingsgruppen på Dietistkliniken vid Karolinska Universitetssjukhuset i uppdrag att i samarbete med Dietisternas Riksförbund översätta NCP och IDNT till svenska. Parallellt med detta har DRF aktivt deltagit i arbetet med Nationell informationsstruktur (NI) och Nationellt fackspråk (NF) samt översättningen av SNOMED-CT.

Resultat

I samband med DRF:s kongressen våren 2011 var översättningen klar och mötet fokuserade på att introducera nutritionsbehandlingsprocessen och IDNT för Sveriges dietister. Dietistklinikerna vid Karolinska- och Sahlgrenska Universitetssjukhuset var då redan igång med implementeringsarbetet. Ett tjugotal olika utbildningar har därefter arrangerats, vilket uppskattningsvis nått ungefär 2/3 av samtliga dietister verksamma inom hälso- och sjukvård samt kommunal omsorg. DRF har där till arrangera nationella användarkonferenser samt bistått medlemmarna med löpande information genom återkommande artiklar i dietisternas egen yrkestidning. Sedan svenska dietister påbörjat implementering av IDNT/NCP har intresse också väckts i Norge och Danmark. Norska kollegor har deltagit i användarkonferenser och planerar nu sin första egna utbildning.

Ett antal magister- och doktorandarbeten har också initierats, bl.a. har ett kvalitetsgranskningsinstrument för dietistens dokumentation av nutritionsbehandlingsprocessen validerats och reliabilitetstestats. Dietisternas riksförbund ingår i det internationella utvecklingssamarbetet kring NCP och IDNT och för närvarande pågår arbetet med införande i SNOMED-CT.

Genom NCP tydliggörs om problemet ska adresseras till dietisten och kan behandlas med hjälp av nutrition samt vilka variabler som kan användas för att utvärdera effekten. Modell har bemötts positivt av andra yrkesgrupper, då dietistens ansvarar för nutritionsbehandlingen förtydligas samt åskådliggör patientens nutritionsrelaterade problem.

De svårigheter som identifierats handlar om att intresset är mycket större än kapaciteten att utbilda. Arbete har hitintills skett med ideella krafter, vilket utgjort en mycket stor begränsning. DRF saknar resurser att anlita någon som specifikt arbetar med utbildning. Ett annat problem är att de elektroniska journalsystemen är svåra att ändra i, så som att byta ut sökord eller lägga in en rullist för nutritionsdiagnoser. Därtill är nuvarande beskrivningssystem undermåliga för att beskriva och utvärdera dietistens arbete. Slutligen uppmärksammas begränsningar i att integrera IDNT med ICF, vilket är den struktur som införs inom kommunal äldreomsorg.

Diskussion

För att nå framgång med ett implementeringsarbete behövs resurser som kan utbilda och understödja förändringsarbetet. NCP och IDNT är viktiga delar i det standardiserade arbetsätt och språk i vilket dietister bidrar till en ökad patientsäkerhet samt ett bättre beskrivningssystem med möjligheter till systematiks uppföljning och utvärdering. Nuvarande KVÅ måste också vidareutvecklas för att bättre beskriva vilka relevanta åtgärder som utförs kring respektive nutritionsdiagnos. Vidare måste strukturer som överensstämmer med intentionerna i den nationella informationsstrukturen skapas, vilket möjliggör integrationer intressanta för journalleverantörer.

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[2] International Dietetics & Nutrition Terminology

Session-based Ontology Alignment

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Introduction

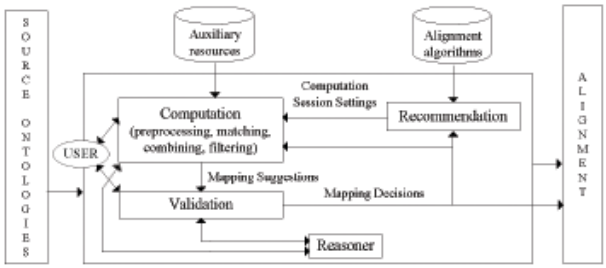
In recent years many ontologies have been developed. The benefits of using ontologies include reuse, sharing and portability of knowledge across platforms, and improved documentation, maintenance, and reliability. Ontologies lead to a better understanding of a field and to more effective and efficient handling of information in that field. Many of the currently developed ontologies contain overlapping information. For instance, Open Biological and Biomedical Ontologies lists circa 40 different ontologies in the anatomy domain (April 2012). Often we want to use multiple ontologies. For instance, applications may need to use ontologies from different areas or from different views on one area. Further, the data in different data sources in the same domain may have been annotated with different but similar ontologies. Knowledge of the inter-ontology relationships would in this case lead to improvements in search, integration and analysis of data. It has been realized that this is a major issue and much research has recently been done on ontology alignment, i.e. finding mappings between terms in different ontologies.

In this poster we tackle the problem of aligning large ontologies where the mappings suggested by the ontology alignment system need to be validated. In contrast to the case of small ontologies, the computation of mapping suggestions can take a long time and therefore, we would like to be able to start the validation before every mapping suggestion is computed. Further, it is clear that for large ontologies, in general, there are too many mapping suggestions to validate in one time. Therefore, we want a system that allows to partially validate the mapping suggestions and resume the validation later. However, whenever validation decisions have been made, they increase our knowledge about the ontologies and mappings and this knowledge can be used to provide better mapping suggestions.

Results

In the poster we present an iterative alignment framework that introduces the notions of computation, validation and recommendation sessions. During the *computation sessions* mapping suggestions are computed. During the *validation sessions* the user validates the mapping suggestions generated by the computation sessions. During the *recommendation sessions* the system computes recommendations for which algorithms may perform best for aligning the given ontologies.

Further, we implemented a prototype based on this framework. To our knowledge, this is the first implemented ontology alignment system that allows a user to interrupt and resume the different stages of the ontology alignment tasks. It also provides solutions for several of the main challenges in ontology alignment, i.e. large-scale ontology matching, efficiency of matching techniques, matching with background knowledge, matcher selection, combination and tuning, and user involvement. The system has been tested using Anatomy ontologies used in the Ontology Alignment Evaluation Initiative.



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Debugging is-a structure in and mappings between taxonomies

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Introduction

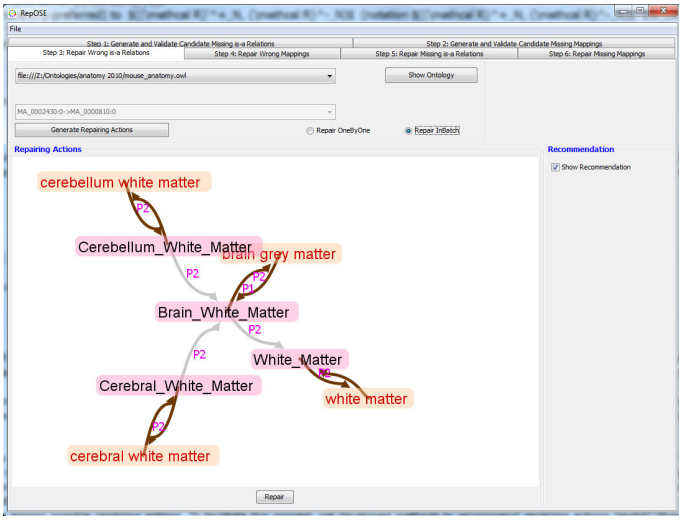
In recent years many ontologies have been developed. The benefits of using ontologies include reuse, sharing and portability of knowledge across platforms, and improved documentation, maintenance, and reliability. Ontologies lead to a better understanding of a field and to more effective and efficient handling of information in that field. Often we also want to be able to use multiple ontologies. In these cases it is important to know the relationships between the terms in the different ontologies and much research has recently been done on ontology alignment, i.e., finding mappings between terms in different ontologies.

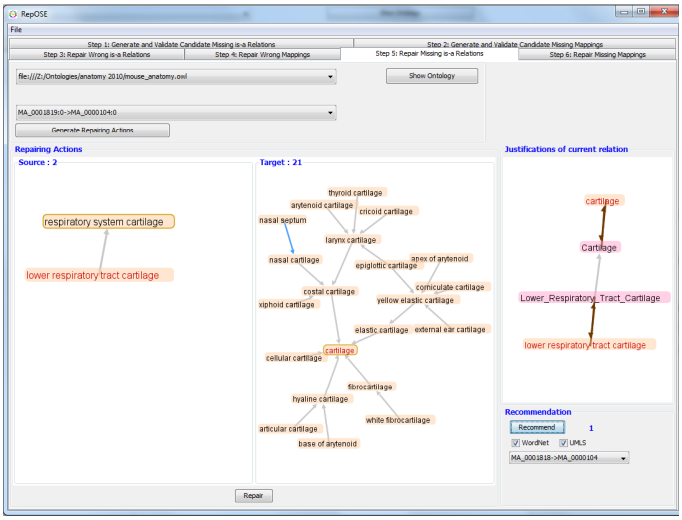
Neither developing ontologies nor aligning ontologies are easy tasks and often the resulting ontologies and mappings are not consistent or complete. With the increased use of ontologies and ontology mappings in semantically-enabled applications such as ontology-based search and data integration, the issue of detecting and repairing defects in ontologies and ontology mappings has become increasingly important. These defects can lead to wrong or incomplete results for the applications.

Results

We have developed a theoretical framework for debugging the is-a structure of and mappings between taxonomies, the most used kind of ontologies. In the poster we show an implemented system, RepOSE, that supports a domain expert to detect and repair missing and wrong is-a relations and mappings [1,2].

Using this system a domain expert has debugged the anatomy ontologies and their mappings that are used in the 2010 Ontology Alignment Evaluation Initiative. The Adult Mouse Anatomy Dictionary (AMA) contains 2744 concepts and 1807 asserted is-a relations, while the NCI Thesaurus Anatomy (NCI-A) contains 3304 concepts and 3761 asserted is-a relations. There are 986 equivalence mappings and 1 subsumption mapping between these taxonomies. Using RepOSE, we detected 102 missing is-a relations and 21 wrong is-a relations in AMA. For NCI-A we detected 61 missing is-a relations and 19 wrong is-a relations. To repair these defects 85 is-a relations were added to AMA and 57 to NCI-A, 13 is-a relations were removed from AMA and 12 from NCI-A. Further, 12 mappings were removed. In 22 cases in AMA and 8 cases in NCI-A a missing is-a relation was repaired using is-a relations that could not by derived from the original taxonomies and mappings.





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Centrala begrepp inom bild- och funktionsmedicin

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Bakgrund:

Klinisk fysiologi är en inriktning inom medicinen som bygger på tolkning av fysiologiska mätningar i kliniskt perspektiv, i praktiken med viss övervikt för hjärt- och kärlsjukdomar. Detta område har inte blivit föremål för systematik och begreppslig standardisering på samma sätt som laboratoriemedicin, kirurgi med flera områden. Jag vill här presentera ett embryo för sådan systematik, som underlag för diskussion.

Resultat

En kliniskt fysiologisk undersökning kan konceptuellt illustreras så här:

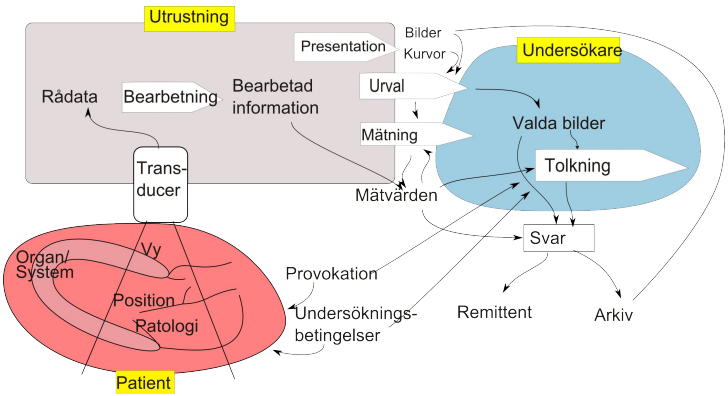

Fig 1: Begrepp inom bild- och funktionsmedicin

Förklaring:
För att belysa förekomst av en viss **patologi** i ett **organ** eller **system** hos en **patient** väljer man en eller flera bildgivande metoder, som bygger på detektion av vissa fysiska egenskaper i någon **vy**/anatomisk **position** hos patienten, under vissa **undersökningsbetingelser** och ibland med **provokation** (yttre kompression, arbete, kontrastmedel, radioaktivitet etc). Genom en **transducer** konverteras fysikaliska fenomen till elektriska signaler i form av **rådata**, som kan bearbetas och presenteras i form av **bilder**, **kurvor**. Ofta gör man även **mätningar** i bilder/kurvor, vanligen med interaktion från användare. Ett urval av bilder, kurvor och **mätvärden tolkas** och sammanfattas som ett **svar**, vilket sänds till **remittent** och **arkiveras**, tillsammans med vissa bilder o kurvor.

Bedömningar inom klinisk fysiologi bygger på mätningar och registreringar av olika "patofysiologiska tillstånd" (PPT), i vissa fall även reaktion på yttre provokationer.
Ett sådant PPT kan språkligt beskrivas som bedömning av ett tillstånd hos ett kroppssystem : "vänster kammare är förstorad", ibland med ytterligare specifikationer "vänster kammares anteroposteriora diameter mätt via transthoracal ultraljudsundersökning befinnes måttligt ökad", och språkliga beskrivningar kan ofta ordnas på olika sätt - "vänster kammare måttligt dilaterad" eller "måttlig vänsterkammardilatation" eller "måttlig dilatation av vänster kammare".
För att beskriva samma sak mer formellt vill jag utgå från modell ovan (Fig 1), med inspiration även från klinisk kemi och främst Clinical LOINC [1-3] – jag föreslår att en PPT-typ kan beskrivas som en kombination av system, komponent, storhetsslag, tidsaspekt, mätmetod och mätbetingelser

Exempel: "viloblodtryck (liggande, vänster arm) 120/80 mmHg"

- system — artärer, vä arm
- komponent — intraarteriellt
- storhetsslag — tryck (mätenhet mmHg)
- tidsaspekt — två tillfällen i hjärtcykeln : systole och diastole
- mätmetod — indirekt mätning med armcuff, auskultatoriskt
- mätbetingelse — liggande patient

Diskussion

Mätvärden resp tolkningar av dessa är exempel på PPT, och är även instanser av mer abstrakta **storheter** (t.ex. viloblodtryck: systoliskt respektive diastoliskt tryck i artärsystemet i en extremitet, indirekt mätt med cuff) – jmf skillnad mellan mätstorhet och mätvärde. Genom att systematisera mätstorheter kan de "katalogiseras", vilket har mycket stort värde för att hitta och jämföra referensvärden, utforma bättre metodbeskrivningar och bättre beskriva sortiment av undersökningar vid jämförelser av vårdresultat och val av vårdgivare.

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