Ontology as Boundary Object

Abstract
A lack of semantic interoperability in the multidisciplinary delivery of health care leads to poor health outcomes. This paper describes research that has lead to the development of an ontology based on SNOMED CT®. The ontology functions as a boundary object to bridge the semantic interoperability gap between members of multidisciplinary health care teams caring for patients with chronic diseases. Overall, there was strong agreement among the clinicians on the usefulness of the boundary object.

Introduction
The sharing of representations for cooperation between information systems or between humans and information systems requires “interoperability”, i.e., the ability of one system to communicate and interact with another system. For semantic interoperability, the data in the messages have meaning only when they are interpreted in terms of the subject domain of the system. However, users do not always know the model of the subject domain of a system. Semantic interoperability problems arise when user subject domain models differ from the system subject domain model. (Pokraev, 2005).

Among humans, the meaning of any set of terms, and the significance and utility of any taxonomy, can be evaluated only in the context of a community whose members are involved in similar activities and share similar values. (Wenger, 2002) In short, semantic interoperability among humans is tied directly to communities of practice, and to the negotiation of meaning that occurs within them. (Friesen, 1999) The question for semantic interoperability is how to communicate across these communities of practice.

One solution to the semantic interoperability problem is the introduction of boundary objects that serve as an interface between different communities of practice. (Bowker and Star, 1999) Boundary objects are shared by different communities but viewed or used differently by each of them and contain sufficient detail to be understandable to both parties, yet neither party is required to understand the full context of use by the other. (Denim, 2003)

An example of a boundary object is an electronic health record. It is used by doctors, nurses, hospital administrators, insurers, government, etc. Each community of users will have a slightly different view of and understanding of the health record, but the health record serves as an interface among these communities.

In this research, we created and evaluated a boundary object to interface among different communities of practice in the treatment of chronic diseases that require multidisciplinary care teams. These multidisciplinary care teams may consist of doctors, nurses, physiotherapists, dieticians, psychologists, etc. Each of these disciplines represents a community of practice that must work effectively with the other disciplines (communities) in order to deliver appropriate health care. The approach taken in this research was to develop an ontology, based on the SNOMED CT® vocabulary that encompassed the specialized vocabulary of each of the disciplines. The resulting ontology serves as a boundary object that maps from one specialized vocabulary to the others.

The Need for Semantic Interoperability in Multi-disciplinary Care
Multiple Chemical Sensitivity (MCS) and chronic pain are examples of complex chronic medical conditions for which there is growing evidence of the benefits of multidisciplinary
care management (Clark, 2000; Fox et al., 2007). Patients with these conditions exhibit a wide range of symptoms from physical to psychological (Dysvik et al., 2005; Kolstand et al., 2006). The nature of the multifaceted symptoms requires a multidisciplinary management approach with a comprehensive assessment of all factors affecting the individual’s health such as physical, psychosocial, economic, nutrition and medical areas of health focus. The increasing occurrence in primary care, of medical errors, repeated medical tests and poor understanding of the health conditions has made it critical to improve communication among clinicians involved in the care management of such diseases (Dobscha et al., 2009).

**Boundary Objects to Address Communication Gaps**

The intention of using a boundary object approach was to enhance collaboration among multidisciplinary care providers across communities of practice in the heterogeneous domain of complex chronic conditions (Star and Griesemer, 1989). This research has considered the heterogeneous domains of two complex chronic conditions, Multiple Chemical Sensitivity (Fox et al., 2007) and chronic pain (Clark, 2000) to investigate, develop and evaluate the boundary objects approach to improving collaboration. The characteristics of the boundary objects developed in the study had to fulfill certain requirements in order to overcome the challenges of heterogeneity in the domain knowledge. Using the boundary objects approach, we have developed a pragmatic level of interoperability as outlined by Carlile (2004) for clinicians collaborating in the care management of complex health conditions. We have also applied standardized forms of boundary objects taking into consideration the issues raised by Fujimura (1992) around too much flexibility leading to loss of identity. We have also designed the boundary objects such that they have the capacity to maintain a dynamic nature to enable the growth of new knowledge (Gal et al., 2005).

**SNOMED CT®**

SNOMED CT® or Systematized Nomenclature of Medicine SNOMED CT® (2005) is a comprehensive, multilingual, controlled clinical reference terminology, with comprehensive coverage of diseases, clinical findings, etiologies, procedures, living organisms, and outcomes used for recording clinical data. It is a relational, concept-based system with more than 300,000 unique concepts and more than 900,000 descriptions. Concepts are organized by defined relationships and organized in 19 hierarchies or facets. The main advantages of SNOMED CT® are that it is multiaxial, hierarchical and has the provision to express the underlying knowledge. In addition to clinical terms, SNOMED CT® includes general concepts such as occupation, social concept, physical object, lifestyle, physical force, etc., which can be captured as well.

SNOMED CT® can be characterized as a multilingual thesaurus with an ontological foundation. Thesaurus-like features include concept–term relations such as the synonyms. It is a class hierarchy with extensive overlap of classes. The superclass (IS_A) Relation relates classes in terms of inclusion of their members. (Wikipedia, 2010) For example, the concept *Fibromyalgia* IS_A “disorder of skeletal muscle” IS_A “Disease”. A concept or class may have multiple parents. For example, the class *Vulvodynia* has two parents (*Disorder of Vulva* and *Disorder characterized by pain*).

SNOMED CT®’s relational statements are basically triplets of the form Concept₁ - Relationᵦ - Concept₂, with Relationᵦ being from a small number of relation types (called linkage concepts), e.g. *finding site*, *due to*, etc. The interpretation of these triplets is (implicitly) based on the semantics of a simple Description logic, which lends itself to the OWL language for ontology representation. (Wikipedia, 2011)
The structure of SNOMED CT® lends itself to the creation of a boundary object among multiple communities of practice through its class hierarchy with overlapping classes and its thesaurus-like features.

**Standardizing the Medical Chart Terminology**

SNOMED CT® was used as the reference terminology to standardize the terms retrieved in the chart audit process and in the representation of concepts in the ontology. One hundred patient charts were audited and the standardization of the chart audit concepts included the following steps.

- A clinical term was identified for standardization from the chart audit process when the term is a recurring term used to describe a patient profile.
- A manual search for an identical match to the source term was made using a SNOMED CT® browser.
- A search was made for alternative terms / synonyms when an exact match is not found with the same clinical meaning (i.e. concept match) to the source term.
- Terms with no matches in SNOMED CT® were identified.
- The multidisciplinary team reviewed the standardized terms for accuracy and completeness.
- A controlled vocabulary with the relevant grouping of standardized concepts in the patient profile domain was created.

Table 1 shows examples of inconsistent chart terminology from various areas of health and their standardization using SNOMED CT®. The number of standardized terms in each field (community of practice) developed for the terms extracted from the Multiple Clinical Sensitivity charts, were 356 medical, 136 physical, 122 psychosocial, 118 rehabilitation, and 80 nutrition.

The multidisciplinary team of clinicians re-coded 3 prototypical patient charts using the new vocabulary. The clinicians used a web-based form to generate the profiles for patients using the controlled vocabulary. The domain experts tested the accuracy, completeness and relevancy of the standardized concepts included in the controlled vocabulary.

<table>
<thead>
<tr>
<th>Terminologies in clinical notes</th>
<th>SNOMED CT® concepts (hierarchy) and concept ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue, low energy, very tired, extremely tired, heavy feeling</td>
<td>Fatigue (finding) 84229001</td>
</tr>
<tr>
<td>Light sensitivity, hypersensitivity to light, intolerance to light</td>
<td>Light intolerance (finding) 62481005</td>
</tr>
<tr>
<td>Fibromyalgia, FM, Myalgia</td>
<td>Fibromyositis (disorder) 24693007</td>
</tr>
<tr>
<td>Poor balance, balance impairment, loss of balance, unsteady</td>
<td>Poor balance (finding) 249985001 Impairment of balance (finding) 387603000</td>
</tr>
<tr>
<td>Poor sleep, sleep problems, sleep issues, unrefreshed sleep, non-restorative sleep</td>
<td>Unrefreshed by sleep (disorder) 248260009 Poor sleep pattern (finding) 314938000</td>
</tr>
<tr>
<td>BMI</td>
<td>Body measure (observable entity)</td>
</tr>
<tr>
<td>SCL-90R</td>
<td>Symptom checklist (assessment scale) 273859002</td>
</tr>
</tbody>
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**Creating the Ontology**

The second stage of the two-staged approach was the creation of an ontology in the heterogeneous domain. This consisted of 3 phases: Development, testing and evaluation. The development phase included the experts in the domain specifying and organizing the
knowledge in the domain. This phase primarily drew the knowledge from the controlled vocabulary. The key concepts were explicitly related by establishing relationships and attributes in the domain. Multidisciplinary interactions in the management of symptoms were specified in the ontology through relations and attributes. Multidisciplinary classes were also created in the ontology that showed the involvement of various grouping of clinicians in the management of a specific grouping of multidisciplinary symptoms for patients. The knowledge in this phase was derived from the patient charts and from the domain experts. Instances from one hundred patient profiles were populated in the ontology.

The testing phase included the clinicians browsing the profile ontology developed in this research to examine the concepts in the ontology, the relationships between concepts, concept attributes and the individuals populating the ontology. Following this was an evaluation phase that included feedback from the domain experts on the overall usefulness of the ontology in patient care with emphasis on usefulness from a health discipline perspective, from other health disciplines and the multidisciplinary nature of interactions captured in the ontology.

The MCS Ontology

The ontology was created in Protege 3.4.2. Figure 1 shows the top level classes developed for the ontology. The Patient Profile has five different subprofiles representing five different disciplines (communities of practice) involved in delivering of health care to a patient with MCS.

**Fig. 1: Top level of ontology.**

![Class Browser and Class Editor](image)

Figure 2 is a graphical representation of two communities of practice (Psychosocial and Rehabilitation) having the common concept, *Education and or school finding*. This is an example of the ontology acting as a boundary object between different communities of practice.
Fig. 2: Two communities of practice having a common concept

Evaluation
Seven domain experts were recruited to participate in the review of the ontology. Clinicians used the Google ontology browser to navigate through the ontology and were given an option to query the multidisciplinary interactions and the patient profile knowledge that exists in the populated instances of the ontology. Clinicians then used a survey questionnaire to provide feedback on the usefulness of the ontology. They provided feedback on the overall usefulness of the ontology, relevance of the ontology to their health discipline, usefulness of viewing information generated from other health disciplines and the usefulness of viewing multidisciplinary interactions.

A strong level of agreement was obtained among the domain experts (Fig. 3). The highest level of strong agreement was obtained in the overall usefulness category. The highest level of agreement was obtained on the usefulness of the multidisciplinary classes. A small amount of disagreement was obtained in the category of usefulness of the information from other health disciplines.

Fig. 3: Feedback on the MCS profile ontology
Figure 4 shows the evaluation breakdown by individual clinicians. Over half the clinicians showed a strong level of agreement on the overall usefulness of the ontology and most categories of the survey questionnaires. There were no specific trends by a health discipline or by a category in the survey questionnaire.

![Fig. 4: Feedback on the MCS profile ontology by clinician.](image)

**Conclusions**

This research has shown that an ontology, based on a controlled vocabulary, can effectively act as a boundary object among multiple disciplines of care (communities of practice). The methodology was created for Multiple Chemical Sensitivities and validated for Chronic Pain, both complex chronic diseases. Overall, there was strong agreement among the clinicians on the usefulness of the boundary object.

A long-term evaluation to determine the effect of such a boundary object on health outcomes is being planned.

**References**


