

Towards a Pattern-Driven Topical Ontology Modeling Methodology in Elderly Care Homes

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Abstract. This paper presents a pattern-driven ontology modeling methodology, which is used to create topical ontologies in the human resource management (HRM) domain. An ontology topic is used to group concepts from different contexts (or even from different domain ontologies). We use the Organization for Economic Co-operation and Development (OECD) and the National Vocational Qualification (NVQ) as the resource to create the topical ontologies in this paper. The methodology is implemented in a tool called PAD-ON suit. The paper approach is illustrated with a use case from elderly care homes in UK.

1 Introduction and Motivation

In the EC Prolix project¹, we need to calculate competency gaps between a learning module (such as a learning material or a course), a person's profile (such as his Curriculum Vitae), and the descriptions of a job in the human resource management (HRM) domain.

In this project, a tool called *Competency Analyzer* is designed and implemented for supporting a simple calculation method, which computes a competency gap based on *scores* (e.g., by comparing a competence score in a person's profile with the score of the required competence) and *syntactical structures* (e.g., by comparing the document tree structure of a person's profile with the required competence tree structure).

We observe that the simple matching algorithm in the competency analyzer is not sufficient to meet user's needs in a complex setting. We are required to enrich the comparison power of the competency analyser. As modern ontology engineering technologies provide insights and design/implementation possibilities of semantics

¹ **This paper is supported by the EC Prolix project.** The EC Prolix (FP6-IST-027905, Process-Oriented Learning and Information Exchange, <http://www.prolixproject.org/>) is project co-funded by the European Commission under the Sixth Framework Program. It is to align learning with business processes in order to enable organisations to faster improve the competencies of their employees according to continuous changes of business requirements.

and its usage, we need to create ontologies as a knowledge base to enhance the competency analyser.

There exist several competency ontologies, such as [3, 7, 9], served for different purposes. For instance, the competency ontology in [7] is designed for competency-driven e-learning system. Harzallah et al. [9] use a competency ontology to analyze an implicit competency structure behind a Curriculum Vitae. The application purpose is an important² factor that affects the content and the structure of resultant competency ontologies.

In this paper, we will illustrate a pattern-driven topical ontology creation methodology (PAD-ON) for creating topical ontologies used for the competency matching. The paper is organized as follows. Chapter 2 is the paper background, which includes a use case in the field of elderly care homes in UK and the related work. We present PAD-ON in chapter 3. Chapter 4 presents the result of the paper. We conclude, compare our work to others' and illustrate our future work in chapter 7.

2 Background

In this chapter, we will discuss the paper background, which includes three parts. The first part is a use case, with which we use the methodology to create competency ontology. The other parts are the theoretical background of this chapter, which cover the discussions on ontology, the DOGMA approach to ontology engineering, and the related work.

2.1 SCIE Use Case

The Social Care Institute for Excellence (SCIE³) was established by Government in 2001 to improve social care services for adults and children in the United Kingdom. SCIE's core business is to advice old care homes for providing better services to elderly people.

There are two kinds of people in SCIE concerning competency issues: 1) workforce, including carers (e.g., doctors and nurses) and administrative personnel (e.g., managers), 2) elderly people (cared objects). In the Prolix setting, we study competency issues only for the former group. The workforce members are responsible to accomplish different tasks, each of which requires a set of skills, knowledge and background. A task can also contain subtasks and a subtask may belong to different tasks. The tasks are accomplished to fulfill the needs of old people. Old people have a set of well beings, such as the emotional well being and intellectual well being. These well beings eventually form different goals of corresponding tasks.

A use case from SCIE is as follows. In UK, every elderly care home (for instance, Risby Hall Nursing Home⁴) is evaluated periodically by Care Quality Commission

² However, it is not the only factor that affects the content and the structure of a resultant competency ontology. The members of the domain expert community, for instance, are another factor. The discussion is out of the paper scope, we refer to [10] for the details.

³ <http://www.scie.org.uk/>

⁴ Risby Hall Nursing Home is a private care home in Suffolk for the elderly who suffer from Alzheimer's, Dementia (Elderly) and physical disability.

(CQC⁵), which is responsible for the registration and inspection of social care services in England. Before taking an official evaluation, Risby Hall asks SCIE for a virtual evaluation and consulting its employees (in this case, nurses) on how to improve the unqualified competences.

SCIE evaluates Risby Hall based on the Health and Social Care (HSC) competence specification provided by the National Vocational Qualification (NVQ⁶). Risby Hall provides the profiles of its nurses in terms of competences. Note that the competences specified by NVQ cannot be always mapped to Risby Hall's competences. The problem scales down into: how we can find the similarities between an NVQ competence and a Risby Hall's competence.

Current competency analyzer can calculate the competence similarities if these two competences point to the same concept, or contains the same sets of concepts. It fails otherwise. We observe that in the SCIE use case, unfortunately, there do not exist two competences (one from NVQ and the other from Risby Hall) that point to one concept (set). Hence, a competency ontology and a semantic matching engine in the domain of elderly care home are required to enhance the competency analyzer.

2.2 Ontology and DOGMA

The essential points in the **definition of ontology** are discussed by Gruber [8] as follows: 1) an ontology defines (specifies) the **concepts, relationships**, and other distinctions that are relevant for **modelling a domain**; 2) the specification takes the form of the definitions of representational vocabulary (such as lexons and commitments in DOGMA, see the following paragraphs), which provide meanings for the **vocabulary and formal constraints** on its **coherent use**.

In Prolix, we can benefit many advantages of using ontologies as below: 1) Ontology can improve the **reusability** of the logics of applications. The issue of reusability is addressed at both operational/functional level and static inference knowledge base level. Ontology can be **architected and abstracted** in such a way that different applications can use the same ontology. For instance, not only Risby Hall's applications but also the tools from other customers from SCIE can use the competency ontology in this paper; 2) Ontology offers an **interoperability** solution to the applications so that they can communicate with each other in a seamless way. With the competency ontology for elderly care homes, the competence terms provided by Risby Hall can be interpreted in terms of NVQ standardized concepts. 3) Ontology can improve the **analytical performance** of applications. Modern ontology engineering approach, such as ontology reasoning engines and algorithms, bestows ontology based applications on analysing benefits; 4) Ontology provides a **portable, scalable and extensible** solution to knowledge base design. An ontology, by default, can be enriched by different organisations from different communities in different application domains. Our particular work is to explore the ontology of workplace individual competences for enriching the analysing power of the matching mechanism in the competency analyzer.

In the DOGMA (Developing Ontology-Grounded Methods and Applications, [11, 13,14]) framework, one constructs (or converts) ontologies by the *double articulation* principle into two layers: 1) the lexon base layer that contains a vocabulary of simple

⁵ <http://www.cqc.org.uk/>

⁶ http://www.direct.gov.uk/en/EducationAndLearning/QualificationsExplained/DG_10039029

facts called *lexons*, and 2) the *commitment* layer that formally defines rules and constraints by which an application (or “agent”) may make use of these lexons.

A lexon is a quintuple $\langle \gamma, t_1, r_1, r_2, t_2 \rangle$, where γ is a context identifier, within which the terms t_1, t_2 are defined. The role r_1 and co-role r_2 refer to the relations that the concepts share with respect to one another. For example, a on $\langle \gamma, \text{driver's license, is issued to, has, driver} \rangle$ states a fact that “a driver’s license is issued to a driver”, and “a driver has a driver’s license”. The context identifier may refer to a URI where driver’s license and driver are defined.

A *commitment* contains a set of rules in a given syntax, and describes a particular application view of reality, such as the use by the application of the (meta-) lexons in the lexon base. Suppose we apply the *uniqueness* constraint on the lexon in order to have has the constraint as “one driver’s license is issued to at most one driver”.

Ontologies modeled in DOGMA can be further implemented in an ontology language, such as OWL⁷ and RDF(S)⁸.

2.3 Related Work

Pattern-driven methodologies for creating domain ontologies are used to (semi-) automatically create ontologies by populating concepts in patterns. A related work of this paper is OntoCase [2], which retrieve and select patterns from a set of ontological patterns. The patterns that get high ranks are further used by ontology-based applications, such as search engines.

Chenine et al. [4] use context based ontology design architecture in the form of Principle-Subject-Support (PSS) pattern, for creating distributed, heterogeneous and multi-functioned, application ontology. It is applied to create a military domain ontology.

Presutti and Gangemi [12] discuss how to extract and describe emerging content ontology design patterns (CP), and how to compose, specialize and expand them for ontology design. They illustrate two CPs and apply them in the music industry domain. Other related work can be found in [1, 6, 13].

3 PAD-ON

We create ontologies based on the structure of *topical ontology*.

3.1 Structure of Topical Ontology

Based on the DOGMA framework (section 2.2) and the application rationale of the competency analyzer, we further divide an ontology into five blocks of specifications (Fig. 1). They are the basis, assertions, topics, applications and instances described as below.

- The specification of **Basis** identifies the conceptual objects and their typological relationship. In DOGMA, the basis is a lexon set that only contains lexons with “is-a” (or “part-of”, “subtype”, “subclass” etc.) relationships, for

⁷ OWL Web Ontology Language: <http://www.w3.org/TR/owl-features/>

⁸ RDF(S) Resource Description Framework (Schema): <http://www.w3.org/TR/rdf-schema/>

instance, lexon $\langle \gamma, \text{employee}, \text{is a}, \text{is}, \text{person} \rangle$. This kind of lexons can be represented graphically as a hierarchical, acyclic tree.

- The **Assertions** asserts how the conceptual objects interact with each other. It contains the lexons that have “free” relations or playing “free” roles with each other, e.g., lexon $\langle \gamma, \text{trainer}, \text{teach}, \text{is taught by}, \text{course} \rangle$. This kind of lexons can be represented graphically as a non-directed network.
- The **Topics** groups the relationships and assertions into a topical map of larger reusable units. We consider a topic as a collection of lexons. Although the theoretical basis for topics is different from that of a context, a topic can sometimes play the role of a context.

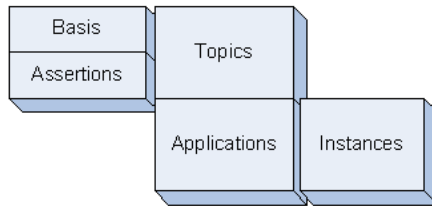


Fig. 1. Ontology building blocks

- The **Applications** select, constrain and contextualize topics, relationships and assertions to formulate abstracts about business data and processes in view of specific application semantics. It is a set of ontological commitments that contain constraints and axioms.
- The **Instance** lists concrete references or values about conceptual objects, relationships and assertions. For example, an instance of “skill level” in the lexon $\langle \gamma, \text{skill}, \text{has}, \text{is of}, \text{skill level} \rangle$ can be “good”.

Note that a lexon in the block of *Instance*, *Applications* and *Topics* needs to be defined in either the block of *Basis* or the block of *Assertions*, or both. The principle of double articulation in DOGMA (section 2.2) still holds in Fig. 1. One can consider that *Basis*, *Assertions* and *Topics* contain lexons. *Applications* and *Instances* bear both lexons and commitments.

In order to create the patterns for generating the ontologies, we need to study the ontology resource – materials used to create the HRM ontology in the field of elderly care homes.

We need to create such a competency ontology that contains concepts at two sharing levels: one is the cross-domain level, which can be used as HRM ontology in a general sense; the other is domain specific level, which defines “local” concepts in the domain of elderly care homes (section 2.1). The former is considered as the vocabulary or basis for the latter. The latter has a closer link with a domain.

The cross-domain competency ontology is created based on the Organization for Economic Co-operation and Development (OECD) and the National Vocational Qualification (NVQ). The domain specific ontology is modeled and abstracted from Risby Hall’s input.

We will illustrate the patterns for creating ontologies and describe how to use these patterns to create the ontology in the flowing section.

3.2 Pattern-Driven Topical Ontology Modeling Methodology (PAD-ON)

A topical ontology is an ontology organized by topics [15]. This methodology contains five steps: 1) create pattern(s); 2) create ontological basis (subtypes of each element in the patterns); 3) create ontological assertions; 4) group lexons in the ontological basis and the ontological assertions into topics; 5) model ontological commitments for the applications and populate the instances of some concepts.

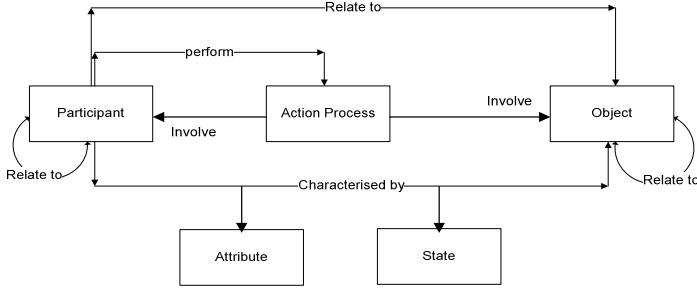


Fig. 2. Pattern used for HRM ontology

The design pattern is an extension to the design pattern discussed in [15], which consists of five elementary elements: Participant, Action/Process, Object, Attribute and State (Fig. 2). It has its basis in *linguistics*.

We extend this pattern with the OECD key competence framework, the conceptualization of which focuses on the person and his action, the manner and means. It stresses the interaction between individuals at work. We refine Participant into Person. The State of the action is further detailed into the *Instrument* and *Manner*. Accordingly, we have a pattern as below.

Persons Act or Interact on Objects by Instruments in Manners

In the SCIE domain, the view of competences focuses on the carer and the cared person. A cared person is the beneficiary of the competent HSC service. The Participant/Person in the design pattern is thus refined into Actor. An active participant performs the action, and the Patient, the passive participant that is affected by the action. Accordingly, the elements in the above pattern are specified as below.

- **Person/Actor:** an initiator of an event or performer of an action, it is a Participant or Person
- **Patient:** an affected, advantaged or disadvantaged participant in the action or event. It is a Participant or Person.
- **Object:** an affected or resultant entity in an action, event or process. It has no volition and is inanimate.
- **Instrument:** a means with which an Actor causes an event or performs an action. It pertains to the State of an action, process or event.
- **Manner:** a state or form of an action, process or event. It pertains to the State of an action, process or event.

On step 1, our task is to define the patterns as illustrated above. Note that OECD is not the only source we use to create the patterns. We also use The *Individual Performance Quality Ontology* (IPQO) to define the patterns. IPQO makes use of NVQs and NVQ levels defined in the National Qualifications Framework. Below is a simple pattern from IPQO.

Persons accomplish Tasks of Levels

It can be extended by adding the categories from WICO as:

Persons accomplish Tasks of Levels by Acting on or Interacting with Objects or Persons with Instruments in Manners

On step 2, we define the subtypes of each element in the above pattern. For instance, we specify “nurse” as a subtype of “Person” and “interpreter machine” as a subtype of “Instrument”.

On step 3, we create lexons that does not contain hierarchical relationships as roles. For instance, “assemble” is specified as “Interact” for the lexon

(γ , nurse, assemble, is assembled by, interpreter machine).

On step 4, we create ontological topics. The topics are considered as *freely combined* contexts, each of which accumulates lexons that are described at the basis level and assertion level into a set. For instance, *(γ , nurse, is a, is, Person)* belongs to the topics of “cleaning” and “HSC21”. The topics are defined based on users’ needs. A topic can be a skill, a competence (a set of skills) or a learning course.

On step 5, ontological commitments that make use of the lexons created in the previous steps are modeled. Note that these commitment models need to be further implemented and integrated into the real application – DMatch [5].

4 Result

The methodology is implemented in a tool called PAD-ON Suite (Fig. 3), which is developed in MS Access 2007⁹. Users are able to create the patterns and specify the elements with concepts defined in the ontological basis and ontological assertions.

Table 1. Number of lexons in different topics for SCIE (data is collected on June 6, 2009)

<i>Ontological topic name (selected)</i>	<i>Number of lexons</i>
B1.1	68
B1.2	79
B1.3	70
Nurse routine task	20
SCIE-manager level 1 – basis	32
SCIE-manager level 2 – basis	102
SCIE-manager level 3 – basis	178
SCIE-manager level 4 – basis	237
...	...

⁹ MS Access is a relational database management system from Microsoft.
<http://office.microsoft.com/access>

With PAD-ON suite, we have created in total 1054 lexons, which are used and grouped in different ontological topics (including 161 HSC topics and 72 Risby Hall's topics). The example topics and their lexon numbers can be found in Table 1.

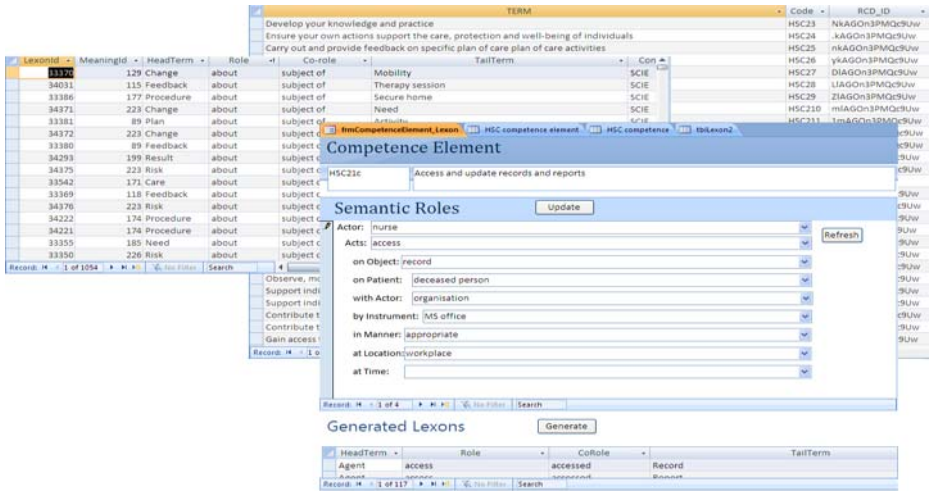


Fig. 3. PAD-ON Suit (screenshots)

We have also tested the resultant ontology and the topics in DMatch with simple set comparison algorithm. The result of comparing topic pair is recorded in Table 2. We are now using the same ontology for a more generic matching framework, which is still under development.

Table 2. Similarities of topic pairs with simple set comparison algorithm

Topic pair	Similarity
B1.3, nurse routine task	0
B1.3, B1.1	65.7%
B1.3, B1.2	52.85%
B1.1, B1.2	73.5%
Nurse routine task, B1.1	10%
Nurse routine task, B1.2	0

5 Conclusion, Discussion and Future Work

In this paper, we have discussed the design of a pattern-driven topical ontology modeling methodology (PAD-ON), which is supported by a tool called PAD-ON suit. The resultant ontology is used by the semantic matching engine called DMatch for the competency analyzer, which provides competence gaps in HRM domain. Elderly care homes are the HRM domain of our ontology.

As discussed in chapter 2, there exist pattern-driven ontology creation methodologies, such as [1, 2, 4, 6, 12, 13]. Blomqvist's work [2] focuses on how to discover and rank ontology patterns amongst many. In her problem setting, there already exists a

domain ontology that contains many ontological patterns. Our work is concentrated on how to use a pattern (or several patterns) to generate an ontology.

Chenine et al. [4] design a PSS pattern for domain ontologies. The particular pattern provides relationships between general concepts, which are principles, subjects and supports. It adopts the perspectives from the applications and software engineering. It covers the contexts and sub-domains that are related to the ontology usage and designing ontology based applications. Our work is more specialized in describing a domain; hence the resultant ontology can be used for different kinds of applications (although we use it for semantic matching in the project).

The resultant ontology of this paper is now used by DMatch, which contains very simple algorithms, such as the set comparison and a matching algorithm supported by terminology data base. In the future, we will design and implement a more generic matching framework, which contains many matching strategies from different perspectives, such as linguistic, relational database modeling and graph theory.

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