Ad-Hoc And Personal Ontologies: A Prototyping Approach to Ontology Engineering

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Abstract. Large scale or common ontologies tend to be developed using structured and formal techniques that can be equated to the Waterfall system development life cycle. However, in domains that are not stable or well-understood a prototyping approach may be useful to allow exploration and communication of ideas. Alternatively, the ontology may be part of an intermediate step or representation that provides structure, organization, guidance and semantics for another task or representation. Given that the ontology is not the end goal and possibly not reusable, the overhead of developing or maintaining such ontologies needs to be minimal. This paper reviews some of the research using ad-hoc, one-off and, sometimes, throw away, personal ontologies and provides an example of a simple technique which uses Formal Concept Analysis to automatically generate an ontology as needed from a number of data sources including propositional rule bases, use cases, historical cases, text and web documents covering a range of applications and problem domains.

Keywords: Personal Ontology, Formal Concept Analysis, Ontology Engineering.

1 Introduction

Agile software development techniques such as Rapid Application Development (RAD) and extreme programming (XP) have become an accepted way of developing software systems where requirements are not well understood and where evolution and change are the norm for that application domain. Elements of these techniques include: short cycles and continuous integration to produce and refine one or more prototypes; a failure-driven approach involving test-first programming and design; refactoring to improve structure and the use of collective ownership which is achieved by ongoing collaboration between stakeholders and pair programming [26]. Agile software development offers a major alternative to the traditional Waterfall system development life cycle model and process. While some fear that agile methods may not scale up or may result in build-and-fix models, some organisations and/or development teams clearly prefer the flexibility and speed offered by agile methods even where the requirements are well understood up-front.

Similarly in knowledge engineering a case can be made for using techniques which develop ad-hoc and personal ontologies, which can be likened to an evolutionary or even throwaway prototype, as an alternative or exploratory precursor to the development of large-scale and/or common ontologies. This is almost the opposite to approaches which use personal ontologies to extract, restrict or guide an individual's usage or access to a larger ontology. For example, the work of Haase et al [18] allows the user to interact in *usage* or *evolution* mode with the ACM Topic Hierarchy, a domain ontology in Bibster. Usage mode restricts the user's view of the domain ontology to the topics the user has chosen to include in their personal ontology, while evolution mode allows the ontology to be extended for the individual. As [18] points out, this raises issues of management of the changing ontology and thus their work provides various change and alignment operations.

Approaching from the other direction, Chaffee and Gauch [7] ask the user to build a personal ontology in the form of a tree containing at least ten nodes and five pages per node (the goal of the ontology is to assist with web navigation) to represent their view of the world. The personal ontology is then mapped to a reference or upper level ontology. Similarly, the SemBlog personal publishing system uses a "loose and bottom-up ontology" based on a hierarchy of categories defined by the user on the basis that "everyone has those categories" which they "routinely [use to] classify … contents to the category" [28, p. 601].

Some approaches provide technical assistance for personal ontology development. Carmichael, Kay and Kummerfield [5] use the Verified Concept Mapping technique based on concept mapping commonly used in education and for knowledge elicitation. The system contains a number of semantic concepts. These concepts are shown to the user and may be used as building blocks to develop a personal ontology. Additionally the system allows the user to define their own concepts and add these to the model, but the system will not understand the semantics of user-defined concepts. Likewise, OntoPIM [21] uses a personal ontology to assist the user to manage their personal desktop information. The personal ontology is developed by providing a Semantic Save function which allows capture of domain independent as well as domain specific metadata when an object, such as a picture or a document, are saved. Following this step, concepts are automatically mapped into the personal ontology by the system.

Sometimes adhoc and temporary ontologies are used for translating from one representation to another. For example, Moran and Mocan [27] created an adhoc ontology equivalent to an XML schema to be used by a Web Service Description Language (WSDL) description to translate from XML and the Web Services Modeling Language (WSML).

In contrast to all of the aforementioned research, this paper looks at the use of personal and ad-hoc ontologies to enable understanding of the domain to be gained and enhanced, just as one would build a throwaway or evolutionary prototype to better or incrementally understand the system requirements, application domain or test a design solution. In knowledge engineering, repertory grids [36] and Protégé [14] have been used to aid the user to discover and develop their own knowledge in a domain. In some cases the systems built acted as a communication channel to share knowledge even though the end product may have never been deployed. Personal systems, and this includes ontologies, are often more acceptable to users as they tend to be more relevant and meaningful for the individual and allow the user to use their own terminology and structure according to the users context and preferences. However, unlike the use of Protégé or repertory grids, the ontology development approach described in the next section automatically generates ontologies from other sources. When changes to the sources occur, the ontologies are simply regenerated. Such a strategy is acceptable if maintenance and ongoing reuse of the ontology is not required, as in the case of a throwaway or exploratory prototype or model.

In various projects over the past decade, Formal Concept Analysis (FCA) [40] has been used to build domain specific, personal and/or shared, ad-hoc and usually throw away ontologies from a number of alternative sources including propositional rules, cases, use cases, software specifications, web documents and keywords. FCA achieves this through the notion of a concept as a basic unit of thought comprising a set of objects and the set of attributes they share, thus providing an intensional and extensional definition for each primitive concept. FCA then applies various algorithms based on lattice and set theory to generate new concepts and allow visualization of the consequences of partial order. Section 2 of this paper provides an example of the technique. Section 3 introduces some of the applications. Conclusions are given in section 4.

2. Automatic Generation of Ontologies

FCA generally relies on the definition of exemplars or stereotypical cases to find concepts. A crosstable where each object is a row and each attribute is a column can be created to provide a formal context for the cases. The notion of a formal context reflects the view that knowledge only holds within the context it is defined. An object which has a particular attribute is marked with an "X" in the corresponding cell, see the representation in Table 1. Using FCA we are able to perform a closure operation on each object to automatically find all formal concepts for a given formal context.

What constitutes an object or an attribute depends on the data to be explored. An object could be a sentence, with the attributes comprising of the (key)words and word phrases found in a use case description or a web-based document. In the following example, a rule base has been used as input. A benefit of starting with rules is that the attribute space has been reduced to the salient features in the cases. With this input type, the rules are the objects where the rule conditions are the attributes and the rule conclusion provides the classification or label for the object. As shown in Table 1, the rules relating to the Cendrowska's contact lens dataset [6] have been used as input to the formal context. Treating each rule condition, which is really an attribute-value pair, as an attribute is similar to the technique known as *conceptual scaling* [17] which has been used to interpret a many-valued context into a (binary) formal context. The crosstable shown was automatically generated from the rules and thus did not require an additional translation step or human effort. Note that any propositional KB can be converted to a decision table [12] and therefore used in the ontology generation approach presented.

Table 1. Formal Context of Contact Lens Rules given in [6]

	1=1[1]	astigmatic = no	Tear_prod = normal	Age = Presbyopic	Prescription = myope	astigmatic = yes	age = young
Rule 0-Lens=None	X						
Rule 1 Lens=Soft	X	X	X				
Rule 2 Lens=Hard	X		X		X	X	
Rule 3 Lens=Hard	X		X			X	X
Rule 4 Lens=None	X	X	X	X	X		

The set of concepts are derived from the formal context in Table 1 by treating each row as an (object) concept and generating additional higher level concepts by finding the intersection of sets of attributes and the set of objects that share the set of attributes. For example, rules 1-4 (last four rows in Table 1) share the attribute: tear_prod=normal. This forms a new concept as shown in concept 2 in Fig. 1. Once all concepts have been found, predecessors and successors are determined using the subsumption relation ≥. This allows the complete lattice to be drawn. Disjunctions of conditions and negation must be removed to allow the rules to be converted into a binary crosstable. Fig. 1 shows the concept lattice for the Contact Lens Prescription domain. To find all attributes (rule conditions) and objects (rule numbers and conclusion codes in our technique) belonging to a concept, traverse all ascending and descending paths, respectively. For example, concept 7 in Fig. 1 includes the rule conditions (attributes) {prescription=myope, tear_production=normal, 1=1} and objects {4-%LENSN (i.e. rule 4, Lens=None) rule, 2-%LENSH (i.e rule 2, Lens=Hard)}.

From this example we can start to explore the relationships between the rules to improve our understanding of the domain. Table 1 has been provided for explanation of the approach, however, the user of this ontology development technique would not be required to define or work with the crosstable. From the user's point of view, they would firstly select the knowledge base or dataset of interest and then select which parts of the knowledge base or dataset that they wished to explore. This could be achieved via specifying one or more key words that are used to automatically select all cases or rules which contain the keywords. As the Cendrowska knowledge base is very small, all rules have been included. By looking at Fig. 1 we see the importance of the tear_production=normal concept and deduce that if we see a case where tear_production is not =normal then the default recommendation of "no lens" will be given. Alternatively, the absence of a condition covering the abnormal state may prompt the user to consider whether the default rule is adequate or whether an alternative or additional recommendation should also be given such as treatment=tear_duct_operation. Moving further down the lattice we can see that astigmatic is an important feature that will affect the prescription. If astigmatic=no

[1] 1=1 ie the default condition that is always true. Rule 0 is the default rule, which will be true if no other rules fire. That is, prescription =no Lens unless …..

then a soft lens is recommended, but only when the age=presbyopic and prescription=myope conditions are not true (concept 4 shows the exception rule stated in rule 4). If astigmatic=yes and the prescription=myope or age=young then a hard lens is recommended. While it is true that there is nothing shown in the concept lattice that can not be extracted from manually analysing the rules it should be apparent that the relationships between the rule conditions and conclusions are more structured and easily determined in the lattice. As in this example, the increased clarity can be useful in identifying knowledge that is potentially missing. The ontology has served as a means of understanding the domain and perhaps for validating/updating the Cendrowska knowledge base which was presumably used to provide expert opinion.

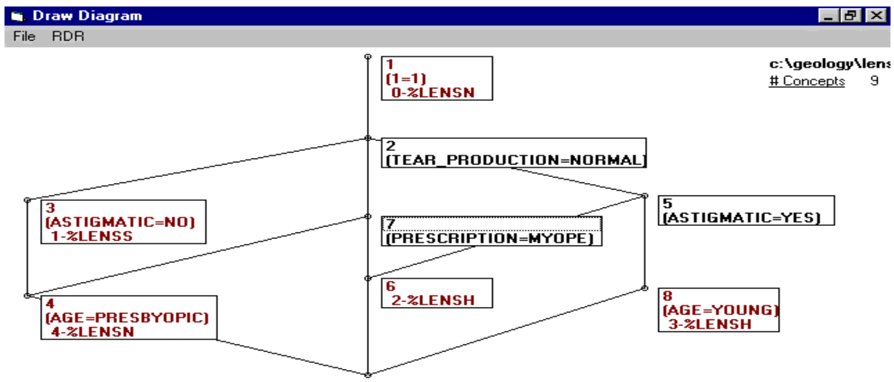

Fig. 1. The Diagram Screen in our tool which shows the Concept Lattice for the Formal Context in Table 1.

The Cendrowska contact lens dataset and rules have been used by a number of researchers to demonstrate the value of various knowledge representations such as PRISM [6], INDUCT [15] and the Visual Language supported by Personal Construct Psychology [16]. We note that this data and knowledge is now out of date since the introduction of Rigid Gas Permeable (RGP) contact lenses have made hard contact lenses almost obsolete. Improvements have also been made to soft lenses in the past decade. Based on a recently expressed viewpoint of an expert optician[2] we demonstrate how the technique the new knowledge can be added to a crosstable for comparison with the old knowledge. The purpose of this comparison may be to determine if any conflicts have arisen and whether the original knowledge base needs updating. We do not include every attribute that could have been used. The rules created (i.e. the rows) and shown in Table 2 are our interpretation of the information given in the article and are not based on the use of a machine or human built set of rules developed from cases. We assume that had the optician's client data been available there would be multiple rules with exceptions to cover the four possible classifications. However, our technique is adequate for the purposes of demonstrating how knowledge from multiple sources of expertise can be displayed and reconciled using an FCA built ontology.

[2] http://www.epinions.com/well-review-5196-AFCVA2d-394701a9-prod2

Table 2. Formal Context of Contact Lens Rules identified from[1]

	Uncomf ortable	Visual acuity=hig	Price=low	Custom Made=yes	Age = Presbyopic	Healthy= Yes	astigmatic = yes	1=1[1]
V2-Rule 0-Lens=None								X
V2-Rule 1 Lens=Soft			X		X	X	X	X
V2-Rule 2 Lens=Hard	X	X			X		X	X
V2-Rule 3 Lens=RGP	X	X		X	X	X	X	X

Tables 1 and 2 can be viewed as two different viewpoints or sources of expertise. As shown in Fig. 1 we can generate an ontology in the form of a concept lattice using FCA. Thus we can view the merging of Tables 1 and 2 as the merging of two ontologies. To achieve this we can simply combine the two formal contexts and regenerate the lattice. Fig. 2 has been developed in a newer tool, known as ConExp[3]. The reading of concepts in ConExp is the same as in our system in Fig. 1 however, the nodes are colour coded where a non-white upper semicircle indicates an attribute attached to the concept, and a black lower semicircle indicates an object attached to the concept. The two viewpoints can be distinguished by the object label: the original viewpoint does not indicate which viewpoint it belongs to, the concepts belonging to the more recent viewpoint have objects labels starting with V2.

From Fig. 2 we see that there is now an inconsistency in that soft lens are appropriate if the patient is astigmatic (Viewpoint 2/Rule 1:V2-R1:SoftLens) but also that soft lens are appropriate if the person is not astigmatic (R1:SoftLens). Either the condition is no longer important for prescribing or choosing which lens is appropriate or the rules shown are incorrect. Perhaps R1 is no longer true, or perhaps V2-R1 needs to be further qualified to state that only Toric soft lenses are appropriate for astigmatic patients. As I am not an optician, I can not answer this question. There are further questions prompted by Fig. 2 that I would like to ask an optician, or to investigate myself through review of the literature, such as whether normal tear production is still a (pre)condition of prescribing any contact lens as appeared to be the situation from Cendrowska's dataset. Clearly the ontology opens up a communication channel for a novice such as myself to explore the domain further with or without a domain expert's assistance and also a means of assisting the domain expert to think about and articulate their knowledge about the domain.

The approach offered here is a human in the loop approach where the goal of the approach is to allow identification of similarities and differences between sources to be highlighted and reconciled via discussion. In a number of projects, we have extended the ontology merging process with a number of reconciliation strategies that assist in identifying if two concepts are in a state of contrast, correspondence, conflict or consensus and a means to identify the degree of consensus between two or more ontologies. See [3, 29, 30] for details. A more automated approach to bottom-up ontology merging can be achieved with the FCA-MERGE technique [36].

[3] http://www.sourceforge.net/projects/conexp

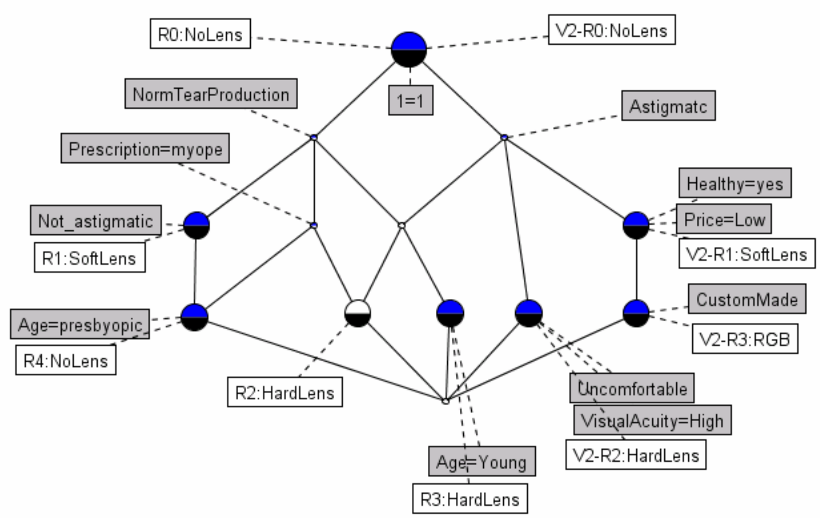

Fig. 2. The Diagram Screen in ConExp which shows the Concept Lattice for the Formal Contexts in Tables 1 and 2.

3 Applications of Adhoc and Personal Ontologies

Common ontologies seek to provide a reusable library of concepts. Adequate time and effort needs to be taken to get the concepts right, define the terms, relationships, axioms and so on. The approach to development is typically top-down. FCA however allows us to work from bottom up, with minimal modeling of the domain beyond the creation of a crosstable containing objects and attributes. As demonstrated in the previous section, what is modeled as an object or an attribute can vary according to the input or questions to be explored. Table 3 provides a summary of a number of projects that have used FCA derived ontologies using input other than conventional cases for a range of different purposes. In each of the projects, the interplay of FCA and ontologies has provided a learning technique, allowed analysis and navigation of the derived ontology and the ontology has enhanced the FCA application [10]. The list of projects is far from exhaustive but gives a taste of the possibilities.

Table 3. Generation of ontologies using FCA from non-standard cases

Project/Domain	Purpose of Ontology	Input	Reference
Treat Anorexia Nervosa Patients	Understand the individual patient	Personal construct and survey data	[37]
Web analysis and visualisation environment (WAVE)	Visualise Web pages	Web pages	[2]
Management of the Lotus Crop	The evolution and management of emerging knowledge Combination of multiple KB	Rules from multiple MCRDR KB	[34]
Igneous Rock Classification	Reconcile multiple sources of knowledge	Laddered grids, structured interviews, protocol analysis and card sorts	[31]
Igneous Rock Classification	Build an initial model to provide initial domain understanding	Card sorts	[13]
The retrieval of web-based documents	Develop personal ontology to make retrieval more customized to the user	User defined categories	[24]
Requirements Engineering	1. Reconciliation of stakeholder viewpoints. 2. More complete use case description	Use case descriptions	[3, 32]
Software Engineering	Validation of models	Software Specifications	[39]
The retrieval of web-based documents	Structure key words, structure relevant documents	Key words, web documents	[8, 9, 25]
Pathology	Discovery of higher level knowledge and patterns	Knowledge bases	[35]
Travel Text Corpus	Merging Ontologies	Web Documents	[38]
Tacit Knowledge Measurement	Compare Responses to Scenarios in a Tacit Knowledge Inventory	Survey Data	[4]
Scientific Knowledge Management	Analyse the value of FCA in knowledge technologies and ontology building	Lists of PC Members, session topics, publications, entity relational data model	[19]

Elsewhere discussion can be found on the nature of the ontology developed using FCA (e.g. [10, 19]) together with a comparison of other techniques for ontology development (e.g. [32]). The purpose of this paper is to consider the role and value of using a domain and/or individual specific ontology as a communication channel, or alternatively, a mediating or temporary representation.

Whether FCA is used to compare rules in a knowledge base, use case descriptions or documents, the approach allows and encourages individuals to express themselves using their own terms and on their own without the interference and restrictions associated with group thinking. This has the benefit of increased engagement with the task and ownership of the knowledge. This becomes even more important when the goal is to build a shared model. By starting with separate sources each group member owns and defends a viewpoint to provide a truly representative and more complete final model. Just as a prototype developed with a 4GL may not give the developer as much freedom and control over the application developed at they might like, the end user can see results sooner and may even be able to use the 4GL to develop the system themselves. As in software engineering, knowledge and ontology engineering may benefit from simpler and user-definable languages, but perhaps with the tradeoff of expressivity. However, creating more expressive ontology languages does not necessarily result in humans being better able to express themselves as the learning curve and structure is usually greater and more complex.

Another plus is the use of the concept lattice for diagrammatic reasoning. For example, our evaluation studies showed that participants were able to identify similarities and differences between viewpoints more quickly and accurately than when presented with the same information in its original textual format [29, 31].

The FCA notion of a concept is compatible, though differences usually exist, with other concept processing approaches. Many of the projects combined FCA with other techniques such as language technology [3, 11, 30, 31], information retrieval [8, 9], Description Logics [29], Conceptual Graphs [41] and Knowledge Based Systems [33]. In the study by Spangenberg and Wolf [37] FCA was combined with the use of Personal Construct Psychology [22] and survey techniques. That study used the repertory grid approach to elicit the responses of anorexia nervosa patients to various people in their lives based on a number of bipolar scales. The goal of that work was to assist the physician to identify the issues faced by the individual patient and did not seek to determine a shared view across patients, which would have been irrelevant in this context, unless of course the patients were related to one another. This early work demonstrated the value of the FCA lattice to provide a personal ontology. To require these patients or the doctor to follow more conventional ontology building processes, typically requiring the assistance of a knowledge engineer, would be out of the question. The physician would probably be unwilling to undergo the special training needed and the presence of a knowledge engineer would interfere with the elicitation process and breach patient-doctor confidentiality.

4. Discussion and Conclusion

We note that there is some conflict between the goal of ontologies and their actual usage. Some have argued that Gruber's definition has led to a view that ontology is :

> " 'a model' where what is being modeled are the concepts or ideas people have in their minds. This reductive error has its roots in the recent tendency to use

the word ‘ontology’ to mean little more than a controlled vocabulary with hierarchical organization”[4].

When one remembers that ontologies are concerned with the nature of being and the world, the focus on what is in people’s heads or the words they use fits more with linguistics, psychology or epistemology rather than metaphysics.

We also note that the goal to create large-scale common ontologies sought to address the KA bottleneck by providing guidance and allowing sharing and reuse. However, it is unclear whether ontology engineering has simply moved the bottleneck higher and earlier in the KA process. Also the desire to share and reuse has led to the need for strategies for merging and reconciliation.

Currently, ontologies are seen to play a pivotal role in the Semantic Web, together with semantic markup languages. However, the effort involved in the two-step authoring and annotation process in a formalism such as OIL and/or RDF “tends to reintroduce the impulse to set up the ‘right’ ontologies in advance. This seems contrary to letting ‘anyone say anything’ [2] or, perhaps, it simply raises the burden of generating Semantic Web content to an inhibitory level” [20]. To address this issue, Kalyanpur et al [20] offer the Semantic Markup Ontology and RDF Editor (SMORE) to support adhoc ontology use, modification, combination and extension. However, what SMORE attempts to achieve is a more seamless environment which merges and simplifies authoring and annotation. The approach allows adhoc use of ontologies, not to be confused with the use of adhoc ontologies as addressed in this paper. However, similar to SMORE, we seek to offer a practical approach.

Bennett and Theodoulidis [1] have investigated the notion of personal ontology and its relationship to organizational ontology and knowledge. They see that a personal ontology is the outcome of personal world experiences leading to personal knowledge that forms a personal ontology. When individuals begin to share their ontologies and agree on meanings, organizational ontologies begin to emerge. In contrast to the flow from experience to knowledge to ontology for the individual, at the organizational level, once an organizational ontology exists, organizational knowledge can emerge resulting in experiences at the organizational level which feed back into personal experiences. If such a cycle does exist, it may be necessary to ensure that approaches for engineering common, upper or reference ontologies support the ongoing development, sharing and integration of personal ontologies.

Despite its various shortcomings, the Waterfall system development life cycle is still the main development method used in many organizations. In practice the method is often modified to include incremental and iterative cycles within and between certain phases. Likewise, common ontologies, such as CYC or WordNet are in widespread use and are often used in conjunction with domain specific and sometimes personal ontologies. The use of FCA to rapidly develop domain and personal ontologies offers many parallels to agile software development in that the technique is incremental, rapid, collaborative and the development cycle is essentially test-first driven producing prototypes (adhoc ontologies) for exploring domain or individual-specific concepts. Using FCA to automatically generate an ontology from whatever source can be mapped to a crosstable with minimal effort, becomes attractive particularly where the ontology or domain itself is volatile and/or temporary.

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[4] http://ontologyworks.com/what_is_ontology.php

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