USING FORMAL ONTOLOGIES FOR THE DEVELOPMENT OF CONSISTENT AND UNAMBIGUOUS FINANCIAL ACCOUNTING STANDARDS

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Abstract: The purpose of accounting is to gather financial data of a business or entity, to interpret this data and to report the results in financial statements to the different users thereof. The interpretation of financial data is regulated by financial accounting standards including a conceptual framework that were developed to facilitate the reporting of financial information of entities. Due to the history of standards development as well as the mechanisms used, inconsistencies in the standards, framework and interpretations are part of the common legacy accountants are confronted with every day. The development of unambiguous and principle based financial accounting standards is therefore a key initiative at present of international accounting standards bodies such as the FASB and the IASB. This paper is concerned with the question of how recently developed computer science technologies could assist in dealing with and eliminating inconsistencies and ambiguities within and between different financial accounting standards. In our research we developed a formal ontology for some of the basic elements, and in this paper we report on our findings as well as make some suggestions for a formal approach to the conceptual framework and financial accounting standards development.

1 INTRODUCTION

"Inconsistencies cannot all be right; but, imputed to man, they may all be true" (Samuel Johnson).

Inconsistencies are part of the common legacy accountants are confronted with every day and something that is part of their daily lives (Adamides, 2008; FASB, 2009). Non-accountants often think that accounting is as clearcut as debit and credit or the age old and proven double entry system (Brief, 1996). With this view, ambiguity cannot be a problem: what can be ambiguous or inconsistent about debit and credit? However, a clear, consistent and unambiguous world is not the reality accountants experience when they compile financial reports. The Financial Accounting Standards Board (FASB) acknowledges this as is evident in this quotation: "The Board believes that financial reporting is both simplified and improved by removing obsolete standards, eliminating inconsistencies, providing certain clarifications to reflect the Board’s intent ...."(FASB, 2009, p.24).

2 BACKGROUND

The information provided in an entity’s financial statements is compiled using an interpretation of its financial data (actual transactions). This interpretation is regulated by Financial Accounting Standards (FAS). These financial accounting standards include an accounting framework and were developed to facilitate the provision or disclosure of financial information of entities so that investors, analysts, creditors as well as the entities themselves can make informed financial decisions (Camfferman and Zeff, 2009; IFRS, 2011).

At present the two international bodies that are the main drivers behind global financial accounting standards (the United States based FASB and the London-based IASB) acknowledge that the task of setting global financial accounting standards that report un-
ambiguously on all possible financial situations for a wide variety of audiences is enormous in scope and extremely difficult, and therefore exhibit ambiguities and inconsistencies (Adamides, 2008; FASB, 2009). There are also a lack of semantic tools and formal techniques that could assist standard setters in eliminating inconsistencies and ambiguities.

Since 2004, a collaborative initiative between the FASB and IASB aims to jointly issue financial accounting standards and a common conceptual framework because of the acknowledged need for international unification and a sound foundation for future financial accounting standards that are principles-based, internally consistent and internationally converged (FASB, 2010; Booth, 2003; FASAC, 2004).

This paper reports on an investigation into the use of ontologies as a mechanism to detect and manage ambiguities and inconsistencies. We argue that the creation of a formal ontology could be a starting point to develop an unambiguous conceptual framework for financial accounting standards. Ontologies and their associated technologies made an appearance within Computer Science during the past ten to fifteen years mainly due to advances in reasoning and modeling technologies (Wolstencroft et al., 2005; Hahn and Schulz, 2007). A formal and widely used definition is that of Gruber who defines an ontology as a formal specification of a conceptualisation (Gruber, 1993). An ontology formally describes a domain model in a way that attaches meaning to the terms (concepts) and relations between these concepts used for describing the domain.

Ontologies allow for the construction of complex and consistent conceptual models, but more significantly, ontologies can assist with the unambiguous formalisation of the terminology of a domain, enabling not only people, but also computers to understand, share and reason using knowledge. Examples where ontologies were applied for standardisation with substantial benefit in the recent past include the Gene Ontology (GO) (GO, 2011) and Snomed CT (IHTSDO, 2011). In both these examples formal ontology technologies were used with great benefit to create an unambiguous and consistent terminology of a domain of discourse, which lead to further benefits such as information integration across sub-disciplines in the domain.

The construction and maintenance of formal ontologies is possible due to the availability of ontology languages such as the class of logics called description logics or DLs, equipped with a well-defined semantics and powerful reasoning tools (Baader et al., 2003). The W3C’s Web Ontology Language (OWL) standard is based on a family of expressive Description Logics (W3C, 2006; McGinness and van Harmelen, 2004). One of the consequences of the standardisation of OWL by die W3C is the development of several tools and reasoners that support the OWL standard such as Protégé 4 and SWOOP (Protege, 2011; SWOOP, 2009), Fact++ and Pellet (Fact++, 2009; Pellet, 2009).1

This paper is concerned with the question of how formal ontology construction using available tools could assist in dealing with and eliminating inconsistencies and ambiguities within and between different financial accounting standards. Definitions are used as foundations in any standardisation effort and should, especially in an environment such as accounting where data should be interpreted correctly by anyone accessing the data, not be inconsistent or ambiguous. The first step in our research was to determine whether formal ontology technologies could be used to formalise the accounting conceptual framework definitions that has to guide the setting of standards.

3 ONTOLOGY CONSTRUCTION

The approach followed was roughly based on an ontology engineering methodology as defined by both Horridge (2009) and Noy (2000). We used Protégé 4 to develop an OWL 2.0 ontology for the basic definitions of the core elements necessary in the conceptual framework (Protege, 2011). Problems encountered, modeling decisions as well as our solutions are discussed in detail in a report available at http://url-to-be-provided. In this paper we depict the formal definitions in DL notation in Table 1.

For the purpose of this paper we consider the definitions of the elements directly related to the measurement of financial position as defined in the Conceptual Framework Document Chapter 4 (IASB, 2011). The elements directly related to the measurement of financial position are assets, liabilities and equity. These are defined as follow:

(a) An asset is a resource controlled by the entity as a result of past events and from which future economic benefits are expected to flow to the entity.

(b) A liability is a present obligation of the entity arising from past events, the settlement of which is expected to result in an outflow from the entity of resources embodying economic benefits.

(c) Equity is the residual interest in the assets of the entity after deducting all its liabilities.

1 A summary of a substantial number of DL reasoners can be found at http://www.cs.man.ac.uk/~sattler/reasoners.html
We investigated each definition and constructed a formal ontology. The first modeling decision resolved was with regards to the modeling of time, specifically the concepts Past, Present and Future as used in the definitions. In standard ontology development, an assertion is a Boolean-valued sentence that is either true or false. An approach to representing time-dependent statements is to associate them with time elements (i.e. instantaneous points or durative intervals). In the discussion of Ma (2007), the theoretical foundations for such an approach are discussed. For this paper it is sufficient to note that three time intervals exist because a statement or report is compiled in the Present, based on Past events and with a perspective on the Future. It may be necessary to refine these time intervals further in future. For now, the concept TimeSlot was modelled to consist completely of the disjoint concepts Past, Present and Future. Other concepts in the ontology necessary to define the elements (such as Past Events) are refined through their participation in relationships with the timeslots. Past, Present and Future are disjoint concepts and TimeSlot is fully described by the union of Past, Present and Future as depicted in Table 1.

3.0.1 Modeling an Asset, Liability and Equity

When we decomposed these definitions, we identified the following concepts: Resource, Entity, Event, Benefit with sub-concept EconomicBenefit, Obligation, Settlement, Interest and ResidualInterest which is a type of Interest. Several refinements on the concepts due to the relationships they participate in, are identifiable:

- **PastEvent** is an Event refined using a Past timeslot through the happenIn object property and **FutureEconomicBenefit** is a EconomicBenefit refined using a Future timeslot through the happenIn object property. Similarly, a **PresentObligation** happens in the Present.

- **ControlledResource** is a type of Resource. However, Control is more than simply a binary relation, meaning that we have to model it as a concept. There are for instance different types of Control and Control is the result of PastEvents. Modelling Control as a concept implies the introduction of object properties that relates **Entity** to **Control** via hasControl and Resource to **Control** via isControlledBy.

- The use of **expected** is problematic as it is not really clear whether it refines **FutureEconomicBenefit** or flow (which is a relation). We made the modeling decision to create an **Expected Future Economic Benefit** or the EFEB concept as a FutureEconomicBenefit that is expectedBy an Entity.

- An Asset is a ControlledResource fromWhichInflow.EFEB.

- An Obligation is a result of at least one PastEvent and an Obligation has a Settlement.

- An Entity has at least one PresentObligation.

- The **outflow of resources embodying economic benefits** refines Settlement. However, this implies the addition of a concept ResourceEmbodyingEconomicBenefit which is a Resource that embodies some EconomicBenefit. However, the whole notion of a resource embodying economic benefit is unclear. Surely this definition should be integrated with the definition of Asset since an outflow from an entity can not be of any resource, only a resource complying with the definition of an asset can flow from the entity.

- The use of **expected** is problematic as it is not really clear whether it refines Settlement or flow (which is a relation). We made the choice consistent with the previous one to create an ExpectedSettlement concept as a Settlement that is expectedBy an Entity.

- A Liability is a PresentObligation and it hasSettlement ExpectedSettlement.

- ResidualInterest has to refined as it is interest in Assets after deducting Liabilities. DL is formally based on set theory and a way to formalise the notion of deduction in a DL ontology is through set difference or formally: \( B \setminus A = \{ x \in B \mid x \notin A \} \). In this case, Equity is Asset and not Liability.

- However, the modeling of Equity remains problematic because, from the previous definitions, an Asset is a refined Resource and a Liability is a refined Obligation. Assets and obligations are derived from different and disjoint concepts and therefore no concept can be created that is a combination of them (e.g. deducting Liability from Asset or AssetInterest). It would be an inconsistent concept implying that no instantiation exists. The definitions as presented formally translates into an inconsistent concept. Equity is Asset and not Liability and the reasoner inferred that this concept is inconsistent.

- To remove this inconsistency, we did further analysis of the definition of Equity. The definition implies a value, or in the terminology of the definition, an interest to be associated with both assets and liabilities because residual interest is the re-
sult. We therefore add
- AssetInterest and LiabilityInterest as types of Interest specifically to be able to show that Asset and Liability hasInterest AssetInterest and LiabilityInterest respectively.
- Using set difference for deduction in this ontology:
  - ResidualInterest is the set difference between Interest and LiabilityInterest.
  - Another decision necessary in order to formally model the set difference, is that all Interest is AssetInterest or LiabilityInterest.
- Equity is Interest and NOT LiabilityInterest.

Table 1: Assertions in the Ontology.

<table>
<thead>
<tr>
<th>Assertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Past ⊆ Timeslot</td>
</tr>
<tr>
<td>Present ⊆ Timeslot</td>
</tr>
<tr>
<td>Future ⊆ Timeslot</td>
</tr>
<tr>
<td>Timeslot = Past ∪ Present ∪ Future</td>
</tr>
<tr>
<td>PastEvent ⊆ Event ∩ happenInPast</td>
</tr>
<tr>
<td>Control ⊆ hasResultOf PastEvent</td>
</tr>
<tr>
<td>Entity ⊆ hasControl Control</td>
</tr>
<tr>
<td>ControlledResource ⊆ Resource ∩ hasControlledByControl</td>
</tr>
<tr>
<td>EconomicBenefit ⊆ Benefit</td>
</tr>
<tr>
<td>FutureEconomicBenefit ⊆ EconomicBenefit</td>
</tr>
<tr>
<td>EconomicBenefit ∩ happenInFuture</td>
</tr>
<tr>
<td>EFEB ⊆ FutureEconomicBenefit ∩ expectedBy Entity</td>
</tr>
<tr>
<td>Asset = ControlledResource ∩ hasControlledByControl</td>
</tr>
<tr>
<td>Obligation ⊆ hasResultOf PastEvent ∩ hasSettlement Settlement</td>
</tr>
<tr>
<td>PresentObligation ⊆ Obligation ∩ happenIn Present</td>
</tr>
<tr>
<td>Entity ⊆ hasObligation PresentObligation</td>
</tr>
<tr>
<td>ResourceEmbodyingEconomicBenefit ⊆ Resource</td>
</tr>
<tr>
<td>Resource ⊆ embodies EconomicBenefit</td>
</tr>
<tr>
<td>Settlement ⊆ fromWhichOutFlow ResourceEmbodyingEconomicBenefit</td>
</tr>
<tr>
<td>ExpectedSettlement ⊆ Settlement ∩ expectedBy Entity</td>
</tr>
<tr>
<td>Liability = PresentObligation</td>
</tr>
<tr>
<td>ResidualInterest ⊆ Interest</td>
</tr>
<tr>
<td>AssetInterest ⊆ Interest</td>
</tr>
<tr>
<td>LiabilityInterest ⊆ Interest</td>
</tr>
<tr>
<td>Interest ⊆ AssetInterest ∪ LiabilityInterest</td>
</tr>
<tr>
<td>Asset ⊆ hasInterest AssetInterest</td>
</tr>
<tr>
<td>Liability ⊆ hasInterest LiabilityInterest</td>
</tr>
<tr>
<td>ResidualInterest ⊆ Interest ∩ ¬ LiabilityInterest</td>
</tr>
<tr>
<td>Equity = ResidualInterest</td>
</tr>
</tbody>
</table>

The Protégé 4 ontology editor allows the use of several reasoners to assist with ontology construction (Fact++, 2009; Sirin et al., 2007) and the inferred concept hierarchy depicts all the consequences of asserted statements such as ResidualInterest concept which is defined as Interest and not LiabilityInterest. The reasoning technologies were used to detect inconsistencies such as that of Equity. Furthermore, Equity = ResidualInterest and therefore ResidualInterest = AssetInterest. This is an example of the advantages of reasoning technologies supporting formal ontology development and it provides evidence of the benefit of these technologies for tasks such as the creation of unambiguous definitions in the accounting framework, especially when the ontology is large and complex.

4 FINDINGS

The construction of a formal ontology for the elements necessary for the measurement of financial position in the conceptual framework resulted in a first version ontology with ALCH DL expressivity formally defining asset, liability and equity unambiguously. The refinement and usefulness of such an ontology require further research. Ontology engineering is also in essence a collaborative exercise and an ontology should reflect consensus about a domain. From this proof of concept it is necessary to create an initiative including all stakeholders for the further development of a formal ontology representing the conceptual framework.

The most significant finding is that the approach allowed us to detect significant assumptions in the definitions of the elements, which is not evident at first glance. Any accountant using these text-based definitions will have to make decisions based on assumptions, and different decisions could lead to contradictory financial interpretations and ultimately, financial reports.

4.1 Findings: Approach and Use of Protégé 4

In the following list the findings with regards to the approach we used as well as the use of Protégé 4 with the bundled reasoners are presented.
- A formal ontology of the element definitions could only be constructed after making several modeling decisions about aspects that were unclear. Anybody intending to use the definitions will be confronted with the same ambiguities and lack of information and clarity. However, it is useful to
4.2 Findings: The Use of Ontology Technologies for the Formalisation of the Conceptual Framework

The following list summarises our findings with regards to the formalisation of the definitions:

- The most significant advantage is that the use of formal ontology technologies allow for clear and consistent definitions because the ontology is constructed with assertions that have specific meaning. The assertions are unambiguous and their meaning is clear. Even if domain experts do not agree completely with an assertion, the meaning thereof is clear and could be altered to reflect consensus.
- The use of ontology technologies allowed us to detect assumptions that could lead to inconsistencies in the current definitions of the basic elements needed for financial reporting.
- The use of this approach allows for the specification of concise definitions of elements, their component concepts and relations. This could be used by standard setters to construct standards and interpretations that adhere to the formal core framework specification.
- The use of precise and formal definitions of elements could assist with detecting inconsistencies between definitions, financial accounting standards and interpretations.
- Concepts and relations were identified within the definitions of the basic elements to be used in the formal ontology without a clarification of the meaning of those concepts and relations. Examples of such assumptions and modeling decisions made include:
  - Resource. The concept resource was identified and used in the ontology, but what exactly is a resource from an accounting perspective? For the concept to be reusable, the meaning within the accounting domain must be clearly indicated.
  - Past, Present and Future Events. The decision was made to identify these notions of time as concepts, but are they really concepts or should they be modeled as relations? Furthermore, are these concepts necessary in the definitions of the basic elements, or can the basic elements be defined without reference to these time indicators?
  - Possible and Expected. These terms are vague and were used in the formal model because they form part of the original definitions. The meaning of these terms is not clear and neither is it clear what the contribution of these terms in the definitions of the basic elements are.
  - Economic Benefit. The concept economic benefit is used in the definitions without any indication to the meaning of the concept.

5 CONCLUSIONS

From the proof of concept ontology construction there is evidence that formal ontologies and the associated technologies can play a substantial role to enhance the quality of the conceptual framework and the associated definitions. Ontology statements are explicit and precise, and consequences of assertions can be exposed using reasoning technologies. Ontologies can represent the required definitions of elements in a much more precise and unambiguous manner than the text format used at present. The formal languages...
used for ontology construction are international standardised languages and this should promote unambiguously, clarity and consistent financial accounting standards and interpretations globally.

Given the results of the investigation into the use of formal ontologies for the development of consistent and unambiguous financial accounting standards, we may perhaps alter Samuel Johnson’s quote to:

“Inconsistencies cannot all be right; and, imputed to the true representation of knowledge, only one consensual truth remains.”

REFERENCES


