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-

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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 Grüber who defines an ontology as *a formal specification of a conceptualisation* (Grüber, 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 **W**eb **O**ntology **L**anguage (OWL) standard is based on a family of expressive Description Logics (W3C, 2006; McGuinness 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 defintions 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 ontolgy 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.

$Past \sqsubseteq Timeslot$
$Present \sqsubseteq Timeslot$
$Future \sqsubseteq Timeslot$
$Timeslot = Past \sqcup Present \sqcup Future$

$PastEvent \sqsubseteq Event \sqcap \exists happenIn.Past$
$Control \sqsubseteq \exists isResultOf.PastEvent$
$Entity \sqsubseteq \exists hasControl.Control$
$ControlledResource \sqsubseteq Resource \sqcap \exists isControlledBy.Control$

$EconomicBenefit \sqsubseteq Benefit$
$FutureEconomicBenefit \sqsubseteq EconomicBenefit \sqcap \exists happenIn.Future$
$EFEB \sqsubseteq FutureEconomicBenefit \sqcap \exists expectedBy.Entity$
$Asset = ControlledResource \sqcap \exists fromWhichInflow.EFEB$

$Obligation \sqsubseteq \exists isResultOf.PastEvent \sqcap \exists hasSettlement.Settlement$
$PresentObligation \sqsubseteq Obligation \sqcap \exists happenIn.Present$
$Entity \sqsubseteq \exists hasObligation.PresentObligation$

$ResourceEmbodyingEconomicBenefit \sqsubseteq Resource \sqcap \exists embodies.EconomicBenefit$
$Settlement \sqsubseteq \exists fromWhichOutflow.ResourceEmbodyingEconomicBenefit$
$ExpectedSettlement \sqsubseteq Settlement \sqcap \exists expectedBy.Entity$
$Liability = PresentObligation \sqcap \exists hasSettlement.ExpectedSettlement$

$ResidualInterest \sqsubseteq Interest$
$AssetInterest \sqsubseteq Interest$
$LiabilityInterest \sqsubseteq Interest$
$Interest \sqsubseteq AssetInterest \sqcup LiabilityInterest$

$Asset \sqsubseteq \exists hasInterest.AssetInterest$
$Liability \sqsubseteq \exists hasInterest.LiabilityInterest$
$ResidualInterest \sqsubseteq Interest \sqcap \neg LiabilityInterest$
$Equity = ResidualInterest$

The Protégé 4 ontology editor allows the usage 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 defintions 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 construct a formal model with explicit meaning that could be refined later rather than to use unclear definitions with ambiguous results.

- Familiarity with the DL languages remains a prerequisite for formal DL-based ontology construction, irrespective of the tools used. An example of this is the modelling necessary for the notion of *deduction*.
- Protégé 4 is easy to use and enabled us to create a formal ontology without too much effort. Ontology editors such as Protégé 4 definitely could assist standard setters to define a *conceptual framework* in a standardised formal language (such as OWL). A drawback of Protégé 4 remains graphical rendering tools. Graphical displays will always remain important for modeling and ontology comprehension. In addition, the lack of tools that could assist with ontology debugging such as explaining an inference result, remains a significant drawback, especially when models are complex.
- There are still at present no firmly established methodologies for ontology engineering. It is generally recognised that this is a research topic that warrants urgent attention (Gómez-Pérez et al., 2004). When constructing a formal ontology for the *conceptual framework* and financial accounting standards, this is even more important and will probably have to be tailored towards the specific requirements of standard setters.
- Protégé 4 is open source software. The source code is freely available and there is an active international developer community. An application can therefore be developed to fulfill the requirements of a specific initiative based on the Protégé 4 environment, for instance by crating special graphical displays of an ontology.

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 defintions:

- 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 has 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 defintions 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 assists 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

Adamides, A. (2008). Fair value project. *Charter*, 79: Accounting and Tax(4):64–65.

Baader, F., Calvanese, D., McGuinness, D., Nardi, D., and Patel-Schneider, P. (2003). *The Description Logic Handbook: Theory, Implementation, and Applications*. Cambridge University Press.

Booth, B. (2003). The conceptual framework as a coherent system for the development of accounting standards. *Abacus*, 39(3),:310.

Brief, R. P. (1996). *Accounting History from the Renaissance to the Present: a Remembrance of Luca Pacioli*. New York: Garland.

Camfferman, K. and Zeff, S. A. (2009). *Financial Reporting and Global Capital Markets: A History of the Inernational Accounting Standards Committee 1973-2000*. Oxford University Press.

Fact++ (2009). Fact++ ontology reasoner. Web.

FASAC (2004). Financial accounting standards advisory council: Joint conceptual framework project.

FASB (2009). Financial accounting series: Exposure draft: Proposed statement of financial accounting standards. file reference no: 1670-100. http://www.fasb.org/draft/ed_technical_corrections.pdf.

FASB (2010). News release 09/28/10: IASB and US FASB Complete First Stage of Conceptual Framework. FASB Website. http://www.fasb.org/.

GO (2011). The gene ontology. http://www.geneontology.org/.

Gómez-Pérez, A., Fernández-López, M., and Chorco, O. (2004). *Ontological Engineering*. Springer.

Grüber, T. (1993). A translation approach to portable ontology specifications. *Knowledge Acquisition*, 5:199–220.

Hahn, U. and Schulz, S. (2007). Ontological foundations for biomedical sciences. *Artificial Intelligence in Medicine*, 39(3):179–182.

Horridge, M. (2009). A practical guide to building owl ontologies using protege 4 and co-ode tools: Edition 1.2. WWW. http://owl.cs.manchester.ac.uk/tutorials/protegeowltutorial/resources/ProtegeOWLTutorialP4_v1_2.pdf.

IASB (2011). *The Conceptial Framework*. IASB. http://eifrs.iasb.org/eifrs/bnstandards/en/framework.pdf.

IFRS (2011). Ifrs. http://www.ifrs.org/Home.htm.

IHTSDO (2011). Snomed ct. http://www.ihtsdo.org/snomed-ct/.

Ma, J. (2007). Ontological considerations of time, meta-predicates and temporal propositions. *Applied Ontology*, 2(Number 1/2007):37–66.

McGuinness, D. L. and van Harmelen, F. (2004). Owl web ontology language overview. W3C Web site. Last accessed 13/9/2006.

Noy, N. F. and McGuinness, D. L. (2000). Ontology development 101: A guide to creating your first ontology. Technical report, Stanford University, Stanford, CA, 94305. http://protege.stanford.edu/publications/ontology_development/ontology101.pdf - Last accessed 16/9/2006.

Pellet (2009). Pellet: The open source owl dl reasoner. Web.

Protege (2011). The protégé Ontology Editor. http://protege.stanford.edu/.

Sirin, E., Parsia, B., Grau, B. C., Kalyanpur, A., and Katz, Y. (2007). Pellet: A practical owl-dl reasoner. *Journal of Web Semantics*.

SWOOP (2009). Swoop - semantic web ontology editor. Web.

W3C (2006). The world wide web consortium (w3c). W3C Web site.

Wolstencroft, K., Brass, A., Horrocks, I., Lord, P., and U. Sattler, e. a. (2005). A little semantic web goes a long way in biology. *Lecture Notes in Computer Science: The Semantic Web ISWC 2005*, 3729:786–800.