Towards the Development of Consistent and Unambiguous Financial Accounting Standards Using Ontology Technologies

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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 an conceptual framework that were developed to facilitate the reporting of financial information of entities so that investors, analysts, creditors as well as the entities themselves can make informed financial decisions. Due to the history as well as some of the mechanisms used to develop the financial accounting standards, conceptual framework and interpretations, inconsistencies and ambiguities are part of the common legacy accountants and auditors are confronted with every day. This is problematic because financial reports have to be clear, concise and unambiguous as the cornerstone of international economies. In order to address the inconsistency problems, the development of unambiguous and principle based financial accounting standards is a key initiative of international financial accounting standards bodies such as the FASB and the IASB at present. This paper is concerned with the question of how recent developments in computer science technologies, specifically within knowledge representation and ontology 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.

Keywords: Accounting ontology, formal ontology, financial accounting standards, conceptual framework, knowledge representation.

1 Introduction

A clear, consistent and unambiguous world is not the reality accountants experience when they compile financial reports. In the accounting world we can still live with inconsistencies if they are known, but we cannot live with ambiguities even though they are known. Inconsistencies are part of the common legacy accountants and auditors are confronted with every day and something that is part of their daily lives (Adamides 2008; FASB 2009).

The Financial Accounting Standards Board (FASB) acknowledges these inconsistencies as is evident in the following quotation: "The Board believes that financial reporting is both simplified and improved by removing obsolete financial accounting standards, eliminating inconsistencies, providing certain clarifications to reflect the Board's intent ...."(FASB, 2009, p.24).

The problematic nature of inconsistencies and ambiguities is emphasised when the purpose of financial reporting is taken into consideration. The process and purpose of financial reporting is to gather financial data of a business or entity during a specific time frame, interpret this data and then to report the results to the different users of the financial statements (Edwards 1989; IFRS 2011). Information provided in financial statements is compiled using an interpretation of accounting data gathered. This interpretation of accounting data is regulated by *Financial Accounting Standards (FAS)*. The purpose of financial accounting standards is essentially to facilitate the disclosure of the financial information of an entity for decision-making by external parties using the financial statements (Camfferman & Zeff 2009; IFRS 2011).

The unenviable task of setting financial accounting standards rests on the shoulders of standard setters. Across all continents and in most countries, financial accounting standards are maintained and revised by standard setting bodies. At present two international bodies are drivers behind global financial accounting standards. The United States based Financial Accounting Standards Board (FASB) and the London-based International Accounting Standards Board (IASB).

Setting the financial accounting standards to report unambiguously on every possible financial situation for a wide variety of users is enormous in scope and thus extremely difficult. In addition, there is a lack of semantic tools and formal techniques to assist the standard setters in identifying inconsistencies and ambiguities within financial accounting standards. Gangolly, Hedley and Wong in 1991 already argued for the use of semantic tools in setting financial accounting standards (Gangolly et al. 1991).

Although the problem of inconsistencies and ambiguities in financial accounting standards is aggravated by the recent globalization of economies, Jacob Kraayenhof, the president of the Seventh International Congress of Accountants already set the challenge in 1951 to study accounting principles with a view of achieving greater international uniformity (Camfferman & Zeff 2009, p.24). Entities nowadays have interests that span countries and even continents, which mean that it is even more important to have clear and unambiguous financial accounting standards globally. Since 2004 there is a collaborative initiative between the FASB and IASB to jointly issue financial accounting standards because of the acknowledged tendency of international unification in business (FASB, 2010).

One of the first joint projects the FASB and IASB agreed upon is the development of a common conceptual framework to assist the standard setters in developing and revising financial accounting standards (Booth, 2003). The aim of the current joint conceptual framework project is to update and refine the concepts in the existing frameworks of the FASB and IASB in order to reflect the changes in markets, business practices and the economic environment that have occurred in the two or more decades since these concepts were first developed.

The stated objective of the *Conceptual Framework Project* is to create a sound foundation for future financial accounting standards that are principles-based, internally consistent and internationally converged (FASAC 2004). In any standardisation effort, definitions and principles of a specific semantic domain, in this case the accounting domain, are used as foundations for use in the standardisation process. Definitions and principles should, especially in the accounting semantic domain, where data should be interpreted correctly not be inconsistent or ambiguous.

This paper is concerned with the question of how recently developed computer science technologies, specifically within knowledge representation and ontology construction, could assist in identifying inconsistencies and ambiguities within the conceptual framework. As the stated objective of the conceptual framework is to serve as a principle-based foundation for the development of financial accounting standards, the use of Computer Science technologies mentioned above, should assist with identifying inconsistencies and ambiguities within the conceptual framework and financial accounting standards.

1.1 Formal ontologies proposed as a semantic tool for standard setters

In order to understand the appropriateness of formal ontologies as a semantic tool to assist standard setters in identifying inconsistencies and ambiguities within financial accounting standards a short description of the history and use of ontologies in Computer Science is provided.

Ontologies made an appearance within Computer Science during the past ten to fifteen years mainly due to advances in reasoning and modelling technologies (Wolstencroft, Brass, I Horrocks, Lord, U. Sattler, et al. 2005; Hahn & Schulz 2007). A formal and widely used definition of the term *ontology* is that of Grüber who defines an ontology as *a formal specification of a conceptualisation* (Gruber 1995). An ontology formally describes a domain model in a way that attaches meaning to the terms and relations used for describing the domain. The importance of this technology is evidenced by the growing use of ontologies in a variety of application areas, as well as being the emerging technology driving the Semantic Web initiative (Berners-Lee et al. 2001).

Ontologies allow for the construction of complex and consistent conceptual models, but more significant, ontologies can assist with the unambiguous formalisation of the terminology of a domain. Ontologies encode *meaning*, 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) (Gene Ontology Consortium, 2000) and Snomed CT (IHTSDO 2011).

The GO project is a collaborative effort to address the need for consistent descriptions of gene products in different databases and the links between databases in order to allow for data integration at a semantic level. The GO is part of a larger classification effort, the Open Biomedical Ontologies (OBO) and recently it was announced that there are now more than 11 million annotations of gene data using GO terminology and facilitating information integration (Gene Ontology Consortium, 2000).

Snomed CT (Systematized Nomenclature of Medicine – Clinical Terms) on the other hand, is a medical ontology also defined as a systematically organized computer processable collection of medical terminology (IHTSDO 2011). Snomed CT allows a consistent way to manage and aggregate clinical data across specialities and sites of care because it describes most areas of clinical information such as diseases, findings, procedures, micro-organisms and pharmaceuticals.

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.

Recent advances in knowledge management technologies within Computer Science have yielded interesting results. Ontologies are formalisations of a conceptual model based on Description Logics, a decidable fragment of first-order logic (Baader & Nutt 2003; Gruninger et al. 2008). What this means, is that these technologies allows a person to formally model a domain and the associated reasoning tools allow a user to extract all the implications of the model, including whether the model is inherently consistent.

A formal ontology typically describes a hierarchy of resource concepts within a domain and associates each concept's crucial properties with it. Therefore ontologies are used to define and manage concepts, attributes and relationships in a precise manner (Bussler et al. 2002).

For this paper, we argue that the creation of a formal ontology could be a starting point to develop an unambiguous conceptual framework for financial accounting standards. By creating formal definitions, the conceptual framework could play a more significant role in the creation of principle-based financial accounting standards and their interpretations. This way we can take up the challenge set by Jacob Kraayenhof already proposed in 1951, learn from history and help, to possibly avoid, future misinterpretations of financial accounting standards due to undetected ambiguities and inconsistencies within and between financial accounting standards and the conceptual framework.

The contributions of this research are summarised as follow:

- The construction of a formal ontology for the definitions of the basic elements of the statement of financial position as defined in the current IASB conceptual framework.
- The identification of ambiguities and inconsistencies in the definitions of the basic elements of the statement of financial position, motivating the use of formal ontologies to create an unambiguous conceptual framework.
- Reporting on the experience and findings, and proposing suggestions for an approach to create an unambiguous conceptual framework.

As the main purpose of the paper is only to establish the feasibility and methodology to construct a formal ontology of the accounting semantic domain using certain definitions as presented in the conceptual framework, socio-political issues and implications will not be addressed at this stage.

The scope of the paper does not allow the authors to apply the methodology established in this study to concrete financial accounting standards. The application of the methodology developed in this paper on concrete financial accounting standards would be considered in future research. This paper serves as a *proof of concept* on the establishment of the development of an ontology formalising definitions from a written text describing certain elements in a semantic domain (the accounting and financial reporting domain).

The paper is structured as follows: Section 2 provides background information on the conceptual framework and financial accounting standards (Section 2.1) as well as ontologies and their role in information systems (Section 2.2). Section 3 describes the construction of a formal ontology for the definition of certain elements of the conceptual framework. Section 4 discusses our findings, as well as perceived advantages and disadvantages and the paper concludes with Section 5.

2 Background

This section provides some background on the conceptual framework and financial accounting standards, including a short history, in Section 2.1. In Section 2.2 we present ontologies and their role in information systems.

2.1 The conceptual framework and financial accounting standards

Accounting as a discipline developed centuries ago primarily because of the need to record and communicate financial transactions between different parties. As transactions became more sophisticated, greater demands were placed on this recording and therefore a set of generalised *rules* was developed. This marked the beginning of the *accounting practice,* as these rules were developed to guide the orderly processing of accounting data and more consistent reporting. As business became more sophisticated during the nineteenth and early twentieth centuries, the associated accounting practice evolved as well, but in a rather haphazard fashion. As result, the accounting *rules* became more voluminous and in general, lacked consistency and coherence (Brief 1996; Edwards 1989; Vorster 2007).

In the second half of the nineteenth century, several factors contributed to the initial development of a body of accounting theory and the standardisation of accounting practices. These factors include the development of railways in the USA and Europe, developments in the legal world specifically with regards to taxation, the notion of the *company* as business entity, and the first establishments of professional accounting and regulatory bodies (Coffman et al. 1993; Vorster 2007).

In the USA, the Accounting Principles Board (APB) was established in 1959 as a committee of the American Institute of Certified Public Accountants (R. K. Storey & S. Storey 1998, p.3). The APB had to formulate principles, to standardise accounting practices and to take the lead in solving accounting issues. During its existence, the APB published thirty-one opinions and four financial accounting standards. Ten years later, the APB was criticised for its apparent inability to achieve its objectives (Spacek 1969). This resulted in the establishment of two study groups, one with the objective to establish accounting principles (the Wheat Committee) (R. K. Storey & S. Storey 1998, p.4), and the other to establish the objectives of financial reports (the Trueblood Committee). Eventually the APB was disbanded and the FASB was established in 1973.

The FASB had the specific objective to formulate a *conceptual framework of accounting* and soon after its inception in 1978, it published its first statement, *Statements of Financial Accounting Concepts No. I*, entitled *SFAC1- Objectives of Financial Reporting by Business Enterprises*. Since then, a number of SFACs have been issued by the FASB, as a whole constituting what is today known as the FASB conceptual framework (Coffman et al. 1993; Edwards 1989; Vorster 2007). The special report published by R. K. Storey & S. Storey (1998) is an extensive report on the development of the FASB conceptual framework also discussing in detail content and meaning of the conceptual framework.

On the European continent, similar developments took place. Because of several public accounting 'scandals' in the UK, the Accounting Standards Committee (ASC) was established in 1970 (Brief, 1996). The ASC published a significant publication dealing with the objectives of financial reports in 1975 called *the corporate report*. During 1990, the ASC was superseded by the Accounting Standards Board (ASB).

During 1989, the then International Accounting Standards Committee (IASC) issued a statement entitled *'Framework for the preparation and presentation of financial statements'*, which was formally adopted in 2001 by its successor body, the International Accounting Standards Board (IASB) (Camfferman & Zeff 2009).

This framework is based on the FASB's conceptual framework and is also not regarded as an *financial accounting standard* and consequently does not override any formal financial accounting standards when there is an inconsistency. Where there is a conflict between the conceptual framework and a specific standard, the standard will always prevail, which is of course problematic as the whole purpose of the conceptual framework is in the first place to guide financial accounting standards development.

2.1.1 The conceptual framework's position in financial accounting standards

The IASB defines the *International Financial Reporting Standards (IFRSs)* as internationally adopted principle-based *financial accounting standards, interpretations and the framework* (Camfferman & Zeff 2009; IFRS 2011). The *framework* or *conceptual framework* thus forms part of the financial accounting standards and provide the context, definitions and principles necessary for the development of financial accounting standards and interpretations. At present the combined 2011 IASB conceptual framework, financial accounting standards and interpretations comprise more than 60 published documents.

The conceptual framework, financial accounting standards, the interpretations of these financial accounting standards (IFRC's) and the accompanying basis for conclusions (BC's) are published in three volumes. Within these three volumes, there were on 1 January 2011 the conceptual framework, 9 IFRS standards, and 29 IAS standards, 27 IFRC interpretations on the financial accounting standards as well as Basis of Conclusions (BC) for all the financial accounting standards and interpretations. The three volumes consist of 3 143 pages. This number of published documents is constantly increasing with the publication of new standards, interpretations and basis of conclusions.

The *Conceptual Framework Document* contains a section discussing its purpose and status, the objective of general purpose financial reporting, qualitative characteristics of useful financial information, and lastly *the framework* primarily discusse the *elements of financial statements, their recognition and measurement* (IFRS 2011).

Concerning the role of the conceptual framework as seen by the IASB and FASB, both bodies define the *financial accounting standards'* purpose as a mechanism to guide accountants in detail to compile financial reports. Both bodies view the purpose of the *conceptual framework* to assist standard setters in developing and revising financial accounting standards. The conceptual framework, therefore, should provide the foundation and context for the development of financial accounting standards.

However, there is also a difference in the stated purpose of the conceptual frameworks between the IASB and FASB. The IASB conceptual framework has a broader purpose than the FASB conceptual framework in that the IASB conceptual framework should assist the IASB in developing or revising financial accounting standards, but its purpose also includes assisting preparers, auditors, and users of financial statements. In contrast, the FASB conceptual framework places less emphasis on purposes other than assisting with financial accounting standards.

For entities preparing financial statements under IFRS, management is expressly required to consider the IASB conceptual framework if there is no standard or interpretation that is specifically applicable or that deals with a similar and related issue. Under US GAAP, the FASB Concepts Statements are ranked no higher than accounting textbooks, handbooks, and articles, and *below* widely recognized and prevalent general or industry practices (FASAC 2004).

At present both the IASB and the FASB state that the conceptual framework(s) does not override financial accounting standards. In this respect it has a lower status than specific financial accounting standards. This is of course problematic if the conceptual framework has to prescribe financial accounting standards and interpretations.

The joint *Conceptual Framework Project* of the FASB and the IASB was initiated in 2004. The purpose is the revision of the respective conceptual frameworks in order to refine, update, complete and joint them into a common conceptual framework. The conceptual framework can then be used for the development of new financial accounting standards as well as for the revision of existing financial accounting standards (FASAC 2004).

A joint project consists of 8 phases as indicated on the IASB Website[1]. At a news release in September 2010, there was an announcement that the first stage of this joint project is completed (FASB, 2010). Phase B of the Conceptual Framework Project (Definitions of elements, recognition and derecognition) is still uncompleted. This provided the motivation for our decision to focus on the definitions of the basic elements of *assets*, *liabilities* and *equity*.

The joint FASB and IASB project also states that an important objective for future standard setters is to develop financial accounting standards that are *principle-based*. The financial accounting standards should not be a loose collection of conventions, but they should be based on fundamental concepts or *principles* as contained in the new conceptual framework.

Once the converged conceptual framework has been completed, some existing FASB and IASB financial reporting standards will inevitably conflict with the concepts as defined in the new conceptual framework. Financial accounting standards will probably not immediately be changed to reflect the new, converged conceptual framework, because at this stage both boards' financial accounting standards assume hierarchical priority over the conceptual framework. The priority is likely still to be given to financial accounting standards. It is expected and necessary, however, that conflicts between the conceptual framework and financial accounting standards disappear as new, converged, principles-based financial accounting standards are developed that are based on the improved, converged concepts.

The challenge to develop a conceptual framework that is sound, comprehensive and internally consistent and globally acceptable is no trivial task. This is aggravated by the fact that the domain of financial reporting is primarily a conceptual domain in contrast with a scientific domain such as the medical domain where standards have been developed successfully. In order to result in coherent financial accounting and reporting, the fundamental concepts in the conceptual framework has to be clear and unambiguous.

In this paper we investigate how ontology technologies, a recent development in computer science, could assist conceptual framework developers with the definition of concise, clear and unambiguous concepts and definitions.

The next section will discuss a background on ontologies and, the mechanism investigated for the formalisation of the definitions of *assets*, *liabilities* and *equity*.

2.2 Ontologies

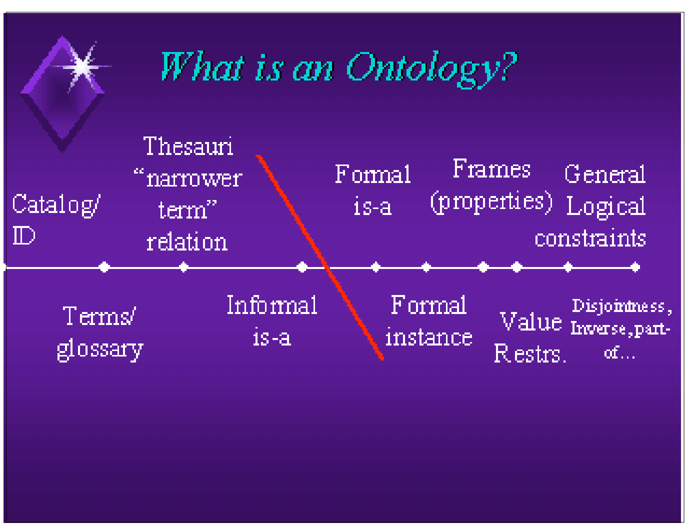

Figure 1: Ontologies can be viewed as a spectrum of detail.

The concept of an ontology was inherited from philosophy and only recently became commonplace in computer systems technology descriptions where an ontology specifies a vocabulary readable by computers (Palmer 2001). The term *ontology* has become widespread within ICT and is used at present to refer to anything from a taxonomy, a domain vocabulary and a conceptual model, to a formal ontology. Lassila & McGuinness (2001) gave a spectrum of ontologies as depicted in Figure 1.
In this diagram it is illustrated how the term ontology is nowadays used to specify anything from a catalogue to a logical formalism.

[1] http://www.ifrs.org/Current+Projects/IASB+Projects/Conceptual+Framework/Conceptual+Framework.htm

A *formal ontology* specifies a *machine-readable vocabulary* in computer systems technology descriptions. Generally such an ontology is defined as a shared, formal, explicit specification of a conceptual model of a particular domain (Broekstra et al., 2001; Decker et al., 2000).

A formal ontology typically describes a hierarchy of *resource concepts* within a domain and associates each concept's crucial properties with it. Ontologies are used to define and manage *concepts*, *attributes* and *relationships* in a precise manner (Bussler et. al., 2002).

The construction and maintenance of formal ontologies greatly depend on the availability of ontology languages equipped with a well-defined semantics and powerful reasoning tools. Fortunately there already exists a class of logics, called description logics or DLs, that provide for both, and is therefore the ideal candidate for ontology languages (Baader et al. 2003).

The necessity for ontology languages and reasoning for effective knowledge representation was already clear fifteen years ago. At that time there was a fundamental mismatch between the expressive power and the efficiency of reasoning that DL systems provided and the expressivity and the large knowledge bases that ontologists needed.

Through the basic research in DLs of the last fifteen years, this gap between the needs of ontologists and the systems that DL researchers provide has finally become narrow enough. Due to these advances in DL research, there is growing interest in the use of ontologies and related semantic technologies in a wide variety of application domains. Arguably the most successful application area in this regard is the biomedical field (Wolstencroft, et al. 2005; Hahn & Schulz 2007).

Some of the biggest breakthroughs in ontological reasoning can be traced back to the pioneering work of Horrocks (2007), who developed algorithms specifically tailored for medical applications. These advances have made it possible to perform standard reasoning tasks on large-scale medical ontologies such as SNOMED CT that has more than 300 000 concepts and more than a million semantic relationships, in less than half an hour. This is a feat that was not possible fifteen years ago (Suntisrivaraporn et al. 2007).

The *Web Ontology Language OWL* is based on a family of expressive Description Logics. OWL was accorded the status of a World Wide Web Consortium (W3C) Recommendation in 2004, and is the official Semantic Web ontology language (McGuinness & van Harmelen 2004). One of the consequences of the standardisation of OWL by the W3C is the development of several tools and reasoners that support the development of formal ontologies based on the OWL standard.

Notable ontology editors are Protégé 4 and SWOOP (Protege 2011; Kalyanpur et al. 2005). Reasoners provide computable and complete reasoning for OWL ontologies, and some are integrated into the ontology editors. Available reasoners are Fact++ and Pellet (Fact++ 2009; Sirin et al. 2007).

Given the recent developments in ontology research, it is clear that the maturity of tools, the advantages already demonstrated in various application domains and the momentum generated from published work will ensure that formal ontologies with their supporting technologies and tools enter mainstream information technology applications.

The use of ontologies for the standardisation of domain vocabularies and the creation of truly intelligent information systems should result in valuable advantages for communities struggling with ambiguities and inconsistencies.

When we use the term *ontology* in this paper, we mean a formal ontology based on one of the OWL standards, which is DL-based.

2.3 Related Work

An investigation of literature indicated that formal ontologies with the associated technologies as focused on in this research have not readily been applied to the development of accounting standards. A similar approach was proposed in the work of Teller (Teller 2008; Masquefa & Teller 2010). Our research has a similar departure point, however, deviates from Teller's notion of syntactic and semantic modelling. Teller's approach to develop an own formalism compromises decidability of

the formalism and we decided to adhere to the underlying DL and OWL representation language as standard in order to reap maximum benefit from the supporting ontology technologies.
Partridge (Partridge 2002a; Partridge 2002b) discussed some ontological choices necessary for the development of a conceptual framework from a philosophical perspective. We agree in principle with this discussion and the necessity to argue the fundamental choices of accounting concepts as a topic of further research flowing from this investigation. However, the focus of this paper is to report on the application of existing ontology technologies as a basic tool to assist with the detection of assumptions and ambiguities when definitions are developed.

3 Ontology construction

In Section 3, the construction of a formal ontology for the definition of some of the elements of the conceptual framework is presented. In Sections 3.1 and in Section 3.2 the approach and the ontology construction for the elements necessary for the measurement of the financial position of an entity is discussed.

3.1 Approach

The approach followed was based on an ontology engineering methodology as defined by both Horridge (2009) and Noy & Mcguinness (2000). The steps followed can be summarised as follow:

- Identification of the *concepts* and concept hierarchy[2].
- Identification of the disjoint concepts.
- Addition of all the relationships[3] between concepts.
- Refinement of concepts based on relationships they participate in.
- Identification of definitions.
- Addition of annotations.
- Refinement of the ontology through various iterations of the above steps.

We used Protégé 4 to develop an OWL 2.0 ontology for the basic definitions of the core elements necessary in the conceptual framework. We used Protégé 4 on Ubuntu 10.04 LTS.

During the execution of the mentioned steps, numerous ambiguities and unclarities were encountered and certain modelling decisions were made in the ontology in order to have an unambiguous, clear and consistent description. It must be emphasized that we refined the model by executing several iterations of the above steps, and not necessarily in the same sequence. During modelling the reasoners bundled with Protégé 4 were used to debug the ontology and ensure consistency.

Problems encountered, modelling decisions as well as our solutions are discussed in detail in the next section.

3.2 Formal ontology of the elements necessary for the measurement of financial position.

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

- *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.*
- *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.*
- *Equity is the residual interest in the assets of the entity after deducting all its liabilities.*

We investigated each definition and following the steps as presented in Section 3.1, we constructed a formal ontology using Protégé 4. The first ontology construction decision to be resolved was the modelling of time, specifically the concepts Past, Present and Future.

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[2] Concepts are called *classes* in Protégé.
[3] Relationships are modelled with *object properties* in Protégé.

3.2.1 Modelling of time

An important aspect that ontology engineers have to consider when constructing any ontology, is the notion of time. In standard ontology development, a statement (or proposition) is a Boolean-valued sentence that is either true or false. However, when considering the definitions of elements in the conceptual framework, we notice the concepts `Past`, `Present` and `Future`. A natural approach to representing such 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 this 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. However, for the definitions of the selected basic elements, it is sufficient to define the three time intervals as `TimeSlots`. The concept `TimeSlot` consists completely of the disjoint concepts `Past`, `Present` and `Future`. Other concepts necessary to define the elements are refined through their participation in relationships with these timeslots.

For modelling *time*, and specifically `Past`, `Present` and `Future`, we identified the following *concepts*:

> `TimeSlot`.
> `Past` is a `TimeSlot`.
> `Present` is a `TimeSlot`.
> `Future` is a `TimeSlot`.
> `Past`, `Present` and `Future` are disjoint concepts.
> Furthermore, `TimeSlot` is fully described by the union of the disjoint concepts `Past`, `Present` and `Future` as depicted in Figure 2.

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

Figure 2: Time

3.2.2 Modelling an asset

Definition of an asset: *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* (IASB 2011, Ch.4).

When we analysed and decomposed this definition, we identified the following *concepts* as building blocks of an asset:

> `Resource`.
> `Entity`.
> `Event`.
> `Benefit` with sub-concept `EconomicBenefit`.
> `Resource`, `Entity`, `Event` and `Benefit` are disjoint.

The following refinements on the above concepts due to the relationships they participate in, are identifiable:

> `PastEvent` is an `Event` refined using a `Past` timeslot through the `happenIn` object property.
> `FutureEconomicBenefit` is an `EconomicBenefit` refined using a `Future` timeslot through the `happenIn` object property.
> `ControlledResource` is a `Resource`. However, `Control` is more than simply a binary relation meaning that we have to model it as a concept to be refined later. There are, for instance, different types of `Control` and `Control` is the result of `PastEvent`. 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 or object property). We made the modelling decision to create an ExpectedFutureEconomicBenefit or the EFEB concept as a sub concept of FutureEconomicBenefit that is also expected by an entity.

Finally, the formal definition of an Asset is a ControlledResource and fromWhichInflow.EFEB.

The formal description for an asset in the ontology in DL notation is presented in Figure 3.

$$
\begin{aligned}
&PastEvent \sqsubseteq Event \sqcap \exists happenIn.Past \\
&Control \sqsubseteq \exists isResultOf.PastEvent \\
&Entity \sqsubseteq \exists hasControl.Control \\
&ControlledResource \sqsubseteq Resource \sqcap \exists isControlledBy.Control \\
\\
&EconomicBenefit \sqsubseteq Benefit \\
&FutureEconomicBenefit \sqsubseteq \\
&EconomicBenefit \sqcap \exists happenIn.Future \\
&EFEB \sqsubseteq FutureEconomicBenefit \sqcap \exists expectedBy.Entity \\
\\
&Asset = ControlledResource \sqcap \exists fromWhichInflow.EFEB
\end{aligned}
$$

Figure 3: Asset

3.2.3 Modelling a liability

Definition of a liability: *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* (IASB 2011, Ch.4).

After decomposing this definition, we identified the following additional concepts for modelling a liability:

Obligation.

Settlement.

Obligation and Settlement are disjoint with one another and with previously defined sibling concepts.

The following refinements on the above concepts due to the relationships they participate in, were identified:

An Obligation a result of at least one PastEvent.

An Obligation has a Settlement.

A PresentObligation happensIn the Present.

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 that is a Resource that embodies some EconomicBenefit. It is possible to model this but the whole concepts of a *resource embodying economic benefit*, is problematic. Surely, this definition should be integrated with the definition of an asset?

The use of *expected* is again problematic as it is not clear whether it refines Settlement or flow (which is a relation or object property). We made the choice consistent with the previous one to create an ExpectedSettlement concept as a Settlement that isExpectedBy some entity

Finally, the formal definition of a Liability is a PresentObligation and it hasSettlement.ExpectedSettlement.

The formal description for a liability in the ontology in DL notation is presented in Figure 4.

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

$$ResourceEmbodyingEconomicBenefit \sqsubseteq$$
$$Resource \sqcap \exists embodies.EconomicBenefit$$
$$Settlement \sqsubseteq$$
$$\exists fromWhichOutflow.ResourceEmbodyingEconomicBenefit$$
$$ExpectedSettlement \sqsubseteq Settlement \sqcap \exists expectedBy.Entity$$

$$Liability \equiv PresentObligation \sqcap \exists hasSettlement.ExpectedSettlement$$

Figure 4: Liability.

3.2.4 Modelling equity

Definition of equity: *Equity is the residual interest in the assets of the entity after deducting all its liabilities* (IASB 2011, Ch.4).

Analysing this definition, we identified the following additional concepts as building blocks of equity:

- `Interest`, a new concept that is disjoint with all previously defined siling concepts.
- `ResidualInterest`, which is a type of `Interest`.

The following refinements on the above concepts were identified:

- `ResidualInterest` has to be refined further as it is interest in assets after deducting liabilities.
  - One way to formalise the notion of *deduction* in a DL ontology is through *set difference* or formally: $B \backslash A = \{x \in B \mid x \notin A\}$[4]. In this case, it is viable to use set difference and therefore `Equity` is `Asset` and not `Liability`.
- However, the modelling of `Equity` remains problematic because, from the previous definitions, an `Asset` is a refined `Resource` and a `Liability` is a refined `Obligation`. An `Asset` and an `Obligation` 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 is an inconsistent concept implying that it can never be instantiated or in other words, no such thing exists.

This research therefore detected that the definitions as presented at this stage could easily formally translate into an *inconsistent concept*. This is depicted in Figure 5 where we asserted that `Equity` is `Asset` and not `Liability` in Protégé 4. The reasoner inferred that the `Equity` and therefore `Asset` concepts are inconsistent as indicated by the red colouring.

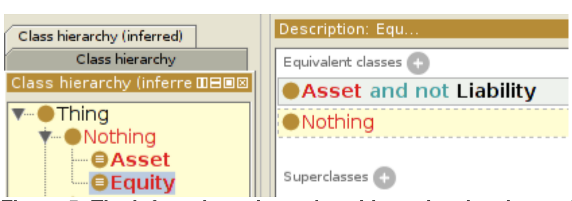

Figure 5: The inferred ontology class hierarchy showing an inconsistent definition of equity.

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 result.

We therefore made a modelling decision to add:

---

[4] DL is formally based on set theory and conceptually; mathematical deduction is modelled with set difference.

AssetInterest and LiabilityInterest as types of Interest specifically to be able to show that Asset and Liability hasInterest some AssetInterest and LiabilityInterest respectively.

Using set difference for deduction in this ontology:

> ResidualInterest is the set difference betwe en Interest and LiabilityInterest.
>
> Another decision necessary here in order to model the set difference properly, is that all Interest is AssetInterest or LiabilityInterest.

Finally, the formal definition of Equity is Interest and not LiabilityInterest. The formal description for Equity in the ontology in DL notation is presented in Figure 6.

$$
\begin{aligned}
&\mathit{ResidualInterest} \sqsubseteq \mathit{Interest} \\
&\mathit{AssetInterest} \sqsubseteq \mathit{Interest} \\
&\mathit{LiabilityInterest} \sqsubseteq \mathit{Interest} \\
&\mathit{Interest} \sqsubseteq \mathit{AssetInterest} \sqcup \mathit{LiabilityInterest} \\
\\
&\mathit{Asset} \sqsubseteq \exists \mathit{hasInterest}.\mathit{AssetInterest} \\
&\mathit{Liability} \sqsubseteq \exists \mathit{hasInterest}.\mathit{LiabilityInterest} \\
\\
&\mathit{ResidualInterest} \sqsubseteq \mathit{Interest} \sqcap \neg \mathit{LiabilityInterest} \\
&\mathit{Equity} \equiv \mathit{ResidualInterest}
\end{aligned}
$$

Figure 6: Equity

3.2.5 Using reasoning

The latest builds of the Protégé 4 ontology editor allows the usage of several reasoners to assist with ontology construction. For the purpose of this ontology, we used the reasoners included in Protégé to debug the ontology and ensure consistency. These reasoning technologies were used to detect inconsistencies such as that of Equity.

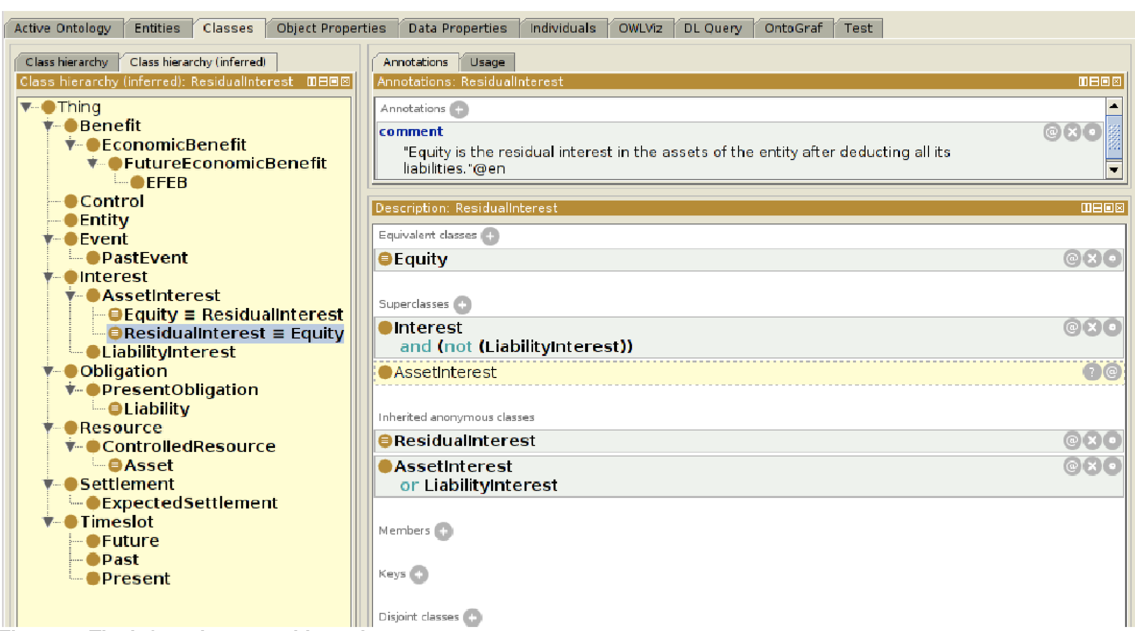

Figure 7: The inferred concept hierarchy.

Figure 9 depicts the inferred class or concept hierarchy that is the result of reasoning on the asserted hierarchy. The inferred concept hierarchy depicts all the consequences of our asserted statements. In

Figure 9 the focus is placed on the ResidualInterest concept, which is defined as Interest and notLiabilityInterest in the right hand window. Furthermore, `Equity = ResidualInterest`.

One result of the reasoning is depicted in yellow with a dotted outline: because `Interest =AssetInterest` or `LiabilityInterest`, it is derived that `ResidualInterest = AssetInterest`. This is an example of the power of reasoning technologies supporting formal ontology development. There is clear evidence of the benefit of these technologies for tasks such as the creation of unambiguous definitions in the conceptual framework, especially when the ontology is large and complex.

4 Findings

The construction of a formal ontology for some of the elements necessary for the measurement of the financial position in the conceptual framework resulted in a first version ontology with *ALCH* DL expressivity. The ontology consists not only of a taxonomy, but of complex concepts because the refinement of concept definitions is done through the specification of relationships they participate in. The ontology is available on the project page at https://sites.google.com/site/ontologyprojects/accounting.

From this work it is clear that an initial ontology could be constructed for the definitions of some of the basic elements in the conceptual framework defining the statement of financial position. This resulted in a first version ontology defining asset, liability and equity clearly and unambiguously. The refinement and usefulness of the ontology is a topic for our further research. In addition, ontology engineering is essentially 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 our approach allowed us to detect significant *assumptions* in the definitions of the elements, which is not evident at first glance. Such assumptions can lead to an inconsistency in the model if they are not clarified and it could have several consequences for anybody trying to use the basic definitions. Any accountant and auditor using these text-based definitions will have to make decisions based on assumptions, and different decisions could lead to contradictory financial interpretations and reports.

The following lists describes our findings with regards to the approach and tools (notably Protégé, and the bundled reasoners) used, as well as our findings with regard to the use of ontology technologies for creating formal definitions for the elements in the conceptual framework defining the financial position.

4.1 Findings: The approach and tools

In the following list the findings about 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 modelling decisions about aspects that were unclear. The decisions were made given available information and interpretations. These interpretations may be based on assumptions that are not correct. However, anybody intending to use the definitions will be confronted with the same ambiguities and lack of information and clarity. It is therefore useful to construct a formal model with explicit meaning that could be refined later rather than using an unclear definition.
- Familiarity with the DL languages remains a prerequisite for formal DL-based ontology construction, irrespective of the tools used.
- 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 modelling and ontology comprehension.
- The reasoners bundled with Protégé 4 are useful and assisted us by depicting consequences of the assertions we made. In our proof of concept ontology these are relatively trivial, but it was evident that the consequences depicting implicit information will be very valuable for conceptual framework construction.

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 (Asuncion Gomez-Perez & Corcho 2002; Asunción Gomez-Perez 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.

Available ontology tools still have limited functionality. The most evident was mentioned in Figure 4: The inferred ontology class hierarchy, as well as the definition of ResidualInterest as displayed in Protégé ready, namely the ability to generate advanced graphical displays of an ontology. 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.

Protégé 4 is open source software. The source code is freely available and there is an active international developer community. The application can therefore be customized to fulfil the requirements of a specific initiative, for instance by creating 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 concerning 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 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 definitions of the basic elements needed for financial reporting. These could be eliminated by refining our assertions.

The use of this approach allows for the specification of concise definitions of elements, their component concepts and relations. Standard setters could use such tools to construct financial accounting 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.

4.2.1 Findings: Possible benefits for standard setters

As formal ontologies are based on *concepts and the relations between the concepts*, the concepts used must be clear and unambiguously defined.

Defining concepts unambiguously strips the concepts from assumptions that form part of the historical use of a concept.

Re-usability of unambiguous concepts becomes possible in the application of those concepts in the wider accounting domain such as derived financial accounting standards and interpretations.

A formal representation language empowers a standard setter to formulate a *clear motivation* on whether to accept or reject specific inconsistencies and ambiguities.

It is possible to *compare and test consistencies* between different definitions and concepts. This was clearly indicated by the inconsistent use of the concept resource in the current definitions of assets and liabilities.

A detail analysis of the basic elements is compulsory to be able to modulate these elements in a formal representation language by way of concepts and relations. The benefit is that the meaning, use and implication of each and every concept and relation must be considered and decided upon.

4.2.2 Findings: Possible problems from an accounting perspective

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 modelling 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 is it really concepts or must it rather be 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: The authors used these terms in the formal model only because they form part of the original definitions, but were not clear on the meaning or contribution of these terms in the definitions of the basic elements.

Economic benefit: The concept economic benefit is used in the definitions without any indication to the meaning of the concept.

Based on the problems encountered, the authors suggest that a standardised formal glossary defining the meaning of concepts and relations must be compiled to ensure the consistent use of these concepts and relations in the definitions of the basic elements.

4.3 Suggestions: Towards an approach for the formalisation of the conceptual framework

Given the results of the proof of concept ontology for the definitions of elements, the following suggestions are proposed for inclusion into an approach:

The role and status of the conceptual framework within the financial accounting standards should be clarified.

For unambiguous financial accounting standards the conceptual framework should possibly prescribe all definitions and principles that guide financial accounting standards and interpretations.

If the conceptual framework provides the context and principles for financial accounting standards development, the content of the conceptual framework should be clearly specified. This content should include clear definitions of elements such as discussed in this paper. All financial accounting standards and interpretations should preferably adhere to the conceptual framework definitions.

From the work described in this paper there is evidence that tools such as ontology technologies could assist with the creation of clear and unambiguous definitions for inclusion in the conceptual framework. Such tools should be identified and included in financial accounting standards development.

A rigorous ontology engineering approach should be adopted. This approach should include the participation of stakeholders in order to establish consensus about the core definitions in the domain.

5 Conclusion

From the proof of concept there is evidence that formal ontologies and the associated technologies can play a substantial role to enhance the quality of the conceptual framework 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 emphasise what has been said in the introduction: in the accounting world we can still live with inconsistencies if they are known, because we can manage them and work around them (like the equity definition), but we cannot live with ambiguities even though they are known because they can result in diverse interpretations with different results based on the same definition.

REFERENCES

Adamides, A., 2008. Fair Value Project. *Charter*, 79: Accounting and tax (4), pp.64-65.

Baader, F. & Nutt, W., 2003. Description Logics Handbook. In p. 47.

Baader, F. et al., 2003. *The Description Logic Handbook: Theory, Implementation, and Applications*, Cambridge University Press.

Berners-Lee, T., Hendler, J. & Lassila, O., 2001. The Semantic Web. *The Scientific American*, 5(1). Available at: http://www.scientificamerican.com/2001/0501issue/0501berbers-lee.html.

Brief, R.P., 1996. *Accounting History from the Renaissance to the Present: a Remembrance of Luca Pacioli* T. A. Lee, A. Bishop, & R. H. Parker, eds., New York: Garland.

Broekstra, Jeen et al., 2001. Enabling Knowledge Representation on the Web by Extending RDF Schema. In *Proceedings of the 10th International World Wide Web Conference (WWW10), Hong Kong*. p. 467. Available at: http://www10.org/cdrom/papers/291/.

Bussler, C., Fensel, Dieter & Maedche, A., 2002. A conceptual architecture for semantic web enabled web services. *ACM SIGMOD, SPECIAL ISSUE: Special section on semantic web and data management*, 31, issue , pp.24-29.

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

Coffman, E.N., Tondkar, R.H. & Previts, G.J., 1993. *Historical Perspectives of Selected Financial Accounting Topics*, Irwin, Boston MA.

Consortium, T.G.O., 2000. Gene ontology: tool for the unification of biology. *Nature Genetics*, 25(1), pp.25-29.

Decker, S et al., 2000. The Semantic Web: The Roles of XML and RDF. *IEEE Internet Computing*, 4, pp.63-74.

Edwards, J.R., 1989. *A History of Financial Accounting*, Routledge: London and New York.

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. Available at: http://www.fasb.org/draft/ed_technical_corrections.pdf.

Fact++, 2009. Fact++ Ontology Reasoner. Available at: http://owl.man.ac.uk/factplusplus/.

Gomez-Perez, Asuncion & Corcho, O., 2002. Ontology Languages for the Semantic Web.

Gomez-Perez, Asunción, Fernández-López, M. & Chorco, O., 2004. *Ontological Engineering*, Springer.

Gruber, T., 1995. Toward principles for the design of ontologies used for knowledge sharing. *Formal Ontology in Conceptual Analysis and Knowledge Representation*, 43(5-6), pp.907-928. Available at: http://linkinghub.elsevier.com/retrieve/doi/10.1006/ijhc.1995.1081.

Gruninger, M. et al., 2008. Ontology Summit 2007 – Ontology, taxonomy, folksonomy: Understanding the distinctions. *Applied Ontology*, 3(Number 3/2008), pp.191-200.

Hahn, U. & Schulz, S., 2007. Ontological foundations for biomedical sciences. *Artificial Intelligence in Medicine*, 39(3), pp.179-182.

Horridge, M., 2009. Protege OWL Tutorial.

IASB, 2011. *The Conceptial Framework*, IASB. Available at: http://eifrs.iasb.org/eifrs/bnstandards/en/framework.pdf.

IFRS, 2011. IFRS Standards. Available at: http://www.ifrs.org/IFRSs/IFRS.htm.

IHTSDO, 2011. SNOMED CT. Available at: http://www.ihtsdo.org/snomed-ct/.

Kalyanpur, A. et al., 2005. Swoop: A Web Ontology Editing Browser. *Journal of Web Semantics*, 4(2).

Lassila, O. & McGuinness, D.L., 2001. *The Role of Frame-Based Representation on the Semantic Web*,

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

Masquefa, B. & Teller, P., 2010. Towards a theoretical framework for the diffusion of accounting and control system. In *Fourth International Conference on Research Challenges in Information Science (RCIS)*. pp. 599-606.

McGuinness, D.L. & van Harmelen, Frank, 2004. OWL Web Ontology Language Overview. Available at: http://www.w3.org/TR/2004/REC-owl-features-20040210/.

Noy, N.F. & McGuinness, D.L., 2000. *Ontology Development 101: A Guide to Creating Your First Ontology*, Stanford, CA, 94305. Available at: http://protege.stanford.edu/publications/ontology_development/ontology101.pdf.

Palmer, S.B., 2001. The Semantic Web: An Introduction. Available at: http://infomesh.net/2001/swintro/.

Partridge, C., 2002a. *Shifting the ontological foundations of accounting's conceptual scheme*,

Partridge, C., 2002b. *Technical Report 23/02: A new foundation for accounting : Steps towards the development of a reference ontologyfor accounting*, Padova, Italy.

Protege, 2011. The Protégé Ontology Editor.

Sirin, E. et al., 2007. Pellet: {A} practical {OWL-DL} reasoner. *Journal of Web Semantics*, 5(2).

Spacek, L., 1969. *A search for fairness in financial reporting to the public: Selected addresses*, A. Andersen (Chicago).

Storey, R.K. & Storey, S., 1998. *The framework of financial accounting concepts and standards,* Norwalk, Conn.: Financial Accounting Standards Board.

Suntisrivaraporn, B. et al., 2007. Replacing {SEP}-{T}riplets in {SNOMED} {CT} using {T}ractable {D}escription {L}ogic {O}perators. In *Proceedings of AIME 2007.*

Teller, P., 2008. A model for accounting standards and its applications. In *Second International Conference on Research Challenges in Information Science. RCIS 2008.* Ieee, pp. 289-300. Available at: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=4632118.

Vorster, Q., 2007. THE CONCEPTUAL FRAMEWORK, ACCOUNTING PRINCIPLES and what we believe is true. *Accountancy SA; Accounting & Tax Periodicals*, p.30.

Wolstencroft, K., Brass, A., Horrocks, I, Lord, P., Sattler, U., et al., 2005. A Little Semantic Web Goes a Long Way in Biology. *DNA Sequence*, pp.786-800.

Wolstencroft, K., Brass, A., Horrocks, I, Lord, P., U. Sattler, et al, et al., 2005. A Little Semantic Web Goes a Long Way in Biology. *Lecture Notes in Computer Science: The Semantic Web – ISWC 2005*, 3729, pp.786-800.