Toward a Perdurantist Ontology of Contracts

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Abstract. Contracts are fundamental toward characterising the very nature of a firm (or enterprise). The firm is considered by some economic theories as a bundle of contracts and contracts in turn are considered also as bundles of rights and obligations (commitments). As such it can be argued that the ontological relationships between the firm and its contracts can be explained through a set of mereological (or whole-part) relationships. Specifically, the relationships between a contract and its parties and between the parties and their rights/commitments are all mereological. This view of what contracts are may appear at first surprising but a perdurantist interpretation of contracts results in such an ontology. The main contribution of this paper is a perdurantist ontology of contracts which introduces the following distinctive features: (1) a differentiation between contract specification and contract execution, (2) contract executions as objects whose spatio-temporal extents intersect those of its parties and (3) a generic model of contractual commitments and fulfilment events impacting the economics of the enterprise. The ontology proposed in this paper is applied to an example scenario to demonstrate its benefits in enterprise modelling.

Keywords: Enterprise Modelling, Contracts, Ontology, Perdurantism.

1 Introduction

Contracts regulate the life of a firm. The agreements that organisations stipulate with other parties (consumers, suppliers, etc.) determine the way in which business processes are executed, the products and services offered, and the economic success or failure of the enterprise. All organisations become party to contracts continuously. Agreeing to a contract can be verbal and implicit (e.g., a baker selling a loaf of bread) or written and explicit (e.g., the supply of oil over 20 years). However implicit or explicit, short- or long-lived the agreed commitments are, contracts are fundamental toward defining the relationships of the enterprise with other economic agents.

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The defining role of contracts is emphasised by several economic theories of the firm albeit with a focus on different specific aspects. Transaction Cost Theory emphasises the costs derived from negotiating and renegotiating contracts from which a firm's transactions with external as well as internal parties (e.g., employees) arise [1]. Agency theory views the firm as a nexus of contracts between resource holders. The focus here is on service contracts in which agents are hired and on the costs associated with such agency agreements. More explicitly Reve [2] and Ayotte and Hansmann [3] view the firm as a bundle of (internal and external) contracts. The reasons for adopting such a view of the firm is especially made clear by Ayotte and Hansmann [3] who underline that the firm cannot be merely considered as a set of owned assets since, especially in recent times, the value of certain companies, like Netflix, is based on their "assemblage of contractual relationships" (p. 5). In fact Netflix does not own the products (e.g., DVDs) they rent.

Similarly contracts are central to Accounting theories such as Commitment Accounting whereby the rights and obligations arising from enforceable agreements should be recorded as soon as the agreement is reached [4]. Ijiri's work [4], among others, strongly influenced the Resources-Events-Agents framework (REA). REA is a conceptual modelling framework specialised in the representation of economic events underlying the life of a business organisation, the interactions that arise among agents taking part in such events and the resources that are exchanged, acquired, converted or produced as a result of such events. REA was originally conceived by McCarthy [5] as a generic conceptual model aimed at improving the way traditional accounting methods represented an organization's transactions. Subsequently REA was reinterpreted to provide it an ontological grounding [6] and extended to introduce new concepts [7] [8] and refine existing ones. In relation to the research presented in this paper the most significant extensions relate to the concepts of commitment and contract [8]. Commitment is now considered a fundamental REA construct while contract is an Enterprise Modelling pattern that can be applied to generate business applications. REA is now a well-recognised Enterprise Modelling approach.

In the field of Enterprise Modelling REA is not unique in leveraging the notion of agreed commitments to model the business and its processes. In REA economic events represent fulfilments of contractual commitments. While the concept of contract (as a whole) was always implicitly present in REA and then defined with Hruby [8], a further modelling approach called Approach Based on Contract (ABC) [9] explicitly adopts contracts as the starting point to model business processes. Overall ABC, similarly to REA, views contracts as a means to specify service-provider relationships involving, for example, an exchange, the possible production of goods and/or the provision of services.

This paper presents research aimed at developing an Ontology of Contracts as an example of the challenges encountered when modelling socially constructed objects. While our ontology utilises theories and approaches, as the ones above, as sources to inform, drive and clarify the notion of a contract, the model that we propose, unlike previous work, adopts a philosophical theory of existence known as perdurantism (or 4D).

The paper is organised as follows. Section 2 defines ontology and presents the reasons for adopting perdurantism. Section 3 provides an overview of the foundational 4D ontology adopted to drive the discovery of the contract domain ontology. Section 4

presents the proposed perdurantist Contract Ontology and Sections 5 and 6 will discuss the limitations of the ontology proposed and future work.

2 Ontology

The research in this paper is inspired by philosophical ontology. In Philosophy, ontology is defined by Lowe as "the set of things whose existence is acknowledged by a particular theory or system of thought" [10]. While this definition is not widely adopted among the Information Systems (IS) and Computer Science communities, it does remind ontology engineers of an important principle. This principle is that of ontic (or ontological) commitment. Lowe's definition indicates that any ontological model must refer to things that exist in reality and, as a consequence, that there must be evidence of such things existing, evidence that could derive, for example, from an analysis of information systems data or scientific data.

Conversely, Gruber [11] defines ontology as a (formal) "specification of a conceptualisation". This widely referenced definition also has its merits. First, it emphasises the fact that any model created for the purposes of information systems development or knowledge representation must be expressed in a formal language in order for it to be processed by computers. Second, it implicitly brings into focus how conceptualisations naturally develop in the minds of software and knowledge engineers as part of the initial phases of IS development. The major differences with Lowe's definition also lie in the two points just made.

In fact a formal specification relies on the logical consistency of formal semantics thus assuring that the statements made in the model are not contradictory. Logical consistency is essential for executable models but at the same time it is also necessary that an ontological model be a model of reality. Therefore alongside formal semantics, an ontological model must possess a high degree of real world semantics achieved by accurately mapping things in the real world to things (symbols) in the model. Logical consistency without an accurate representation of reality is likely to produce ineffective and costly to maintain enterprise systems. Consequently if one only formally models a 'conceptualisation' rather than reality, then there is a risk that the models produced become representations not of the real world but of "concepts conceived as human creations" as Smith [12] aptly states.

The development of accurate ontological models is difficult and an enterprise modeller would instinctively begin from the representation of his or her own conceptualisations of the organisational domain. Particularly challenging is the modelling of socially (or intentionally) constructed objects, i.e. things that exist because human society has created them [13]. Examples include governmental institutions, money, marriage and a long list of social constructs including, of course, contracts. Enterprise modelling relies heavily on socially constructed objects. These objects are indeed human creations and therefore manifestations of human conceptualisations. One may argue that ontologies of domains like law, economics and the firm mostly model conceptualisations since there does not appear to be any real tangible counterpart in the world (e.g., one cannot touch the agreement underlying a contract). Instead, as this paper will demonstrate in the case of contracts, socially constructed objects are real and produce real world objects (mainly in the

from of states and events) that can be accurately modelled. Philosophical ontology can help to produce accurate enterprise models.

In Philosophy, ontology, as a discipline, is the study of existence and of the kinds of things that exist. There are two predominant theories: endurantism and perdurantism [14]. The main difference lies in each theory's conception of time and how objects change in time. In endurantism a three-dimensional object is wholly present at any given instant and persists by 'sweeping' through a region of space-time (in the words of Sider). While wholly present at all moments of its existence, an object preserves its identity via a set of essential attributes (for example, a person's DNA). In perdurantism an object has a four-dimensional extension (or extent) in the universe (i.e., the region of space-time that it occupies) and it is not therefore totally present at any given instant, but instead only partially present. Identity is defined by the object's four-dimensional extension. In its lifetime an object goes through states (or stages). For example, a person goes through the stages of childhood and adulthood. In perdurantism change is explained via successive dissimilar temporal parts. Therefore, while an endurantist object persists in three-dimensional space and entirely shifts from one point in time to the next, in perdurantism an object exists in four-dimensional space-time and is partially present at any time or portion of its spatiotemporal extension.

The analysis and interpretation of contracts carried out in this paper is based on perdurantism. There are some fundamental reasons for adopting such a theory over endurantism especially for the purposes of modelling the enterprise. As stated above, enterprise ontologies require the representation of many socially constructed objects. These objects live and evolve with the enterprise through a series of complex events that define the interactions occurring among parts of the organisation and between the organisation and external parties. These events often produce objects and/or states, some of which overlapping, and together (events and states) define the processes that occur during an organisation's existence (with contracts playing a significant role in defining such processes). All this requires an ontological theory that is capable of more naturally representing events, states (more generally temporal parts) and overlapping objects. As explained above, objects in perdurantism extend through time and are therefore intrinsically capable of having spatiotemporal extensions that contain or overlap with the extensions of other objects. Such temporal containment or overlap becomes very difficult or impossible to model with an endurantist ontology.

In order to develop a domain model, such as the Contract Ontology of Section 4, it is necessary to adopt a foundational ontology that not only clearly answers the question of what it means for a thing to exist but also defines the kinds of existence that things can have (i.e., a categorical theory). This research adopts the Business Object Reference Ontology (BORO), as its foundational ontology.

3 A Perdurantist Foundational Ontology

BORO, developed by Partridge [15], is a perdurantist upper level ontology strongly based on extensionality. BORO inspired the upper level ontology of the International Defence Enterprise Architecture Specification for exchange Group [16] and adopted by the U.S. Department of Defense Architecture Framework (DoDAF). BORO has been applied in various industrial sectors including finance, oil and gas, and defence.

The aim of this section is to present the BORO foundational ontology and provide the reader with the fundamental knowledge to understand the Contract Ontology described in the following section. It is beyond the scope of this paper to provide an exhaustive explanation and definitions of the whole foundational ontology. The discussion will be limited to the higher level and scoped to those foundational classes and relationships that will be necessary to model contracts. For an in depth presentation of BORO the reader is invited to refer to Partridge [15] in its original form or IDEAS [16] for a slightly modified, yet still detailed, version.

Figure 1 presents a graphical representation of the foundational ontology. The notation is that of the Unified Modelling Language (UML). For limitations of space and in order to provide the reader with an uncluttered picture of the ontology, the diagram only presents a partial view of the entire foundational ontology; a more complete representation is provided by IDEAS [16].

At its highest level the BORO foundational ontology represents:

- *Objects*: Anything that exists. (In IDEAS the term *Thing* is used in place of *Objects*.)
- *Individuals*: An individual is a physical body with a spatiotemporal extent (i.e., particulars).
- *Types*: A type is a set or class of objects (i.e., universals). The extension of a type is given by all the objects of that type. Objects of a certain type are said to be instances of that type. Types can have individual instances (*IndivudalTypes*), type instances (*Powertypes*) or tuple instances (*TupleTypes*). Only *TupleTypes* are explicitly represented in Figure 1.
- *Tuples*: A tuple is a relationship between two or more objects.
- *Tuple Types*: A type whose instances are tuples.
- *TemporalParts*: A temporal part is an individual whose spatiotemporal extent is part of another individual.
- *Events*: An event is an individual temporal part that does not persist through time (i.e., an event has zero 'thickness' along the time dimension). Events represent temporal boundaries that either create (*CreationEvents*) or dissolve (*DissolutionEvents*) individuals (e.g., a person) or individual temporal parts that persist through time (i.e., states).
- *States*: A state is a temporal part of an individual that persists through time. States (and individuals in general) are bounded by events. A state can have further temporal parts (i.e., states and events).
- *causedBy*: This tuple type represents the relationship between an event and the individual(s) which causes the event.
- *happensTo*: This tuple type relates an event with one or more individuals affected by the event. *happensTo* has two subtypes:
  - *creates*: Relates a creation event with the individual(s) whose creation is triggered by the event.
  - *dissolves*: Relates a dissolution event with the individual(s) whose dissolution is triggered by the event.
- *happensAt*: This tuple type relates an event with a *TimeInstant* and it indicates the time at which an event takes place.
- *temporalPartOf*: This tuple type relates an individual with its temporal parts (states and/or events).

To visually clarify how BORO as a perdurantist ontology models the real world including change, let us consider a simple example of a person named *John* who enrols on an undergraduate programme becoming a student (Figure 2). As the figure shows *John* (as a 4D individual) extends through space-time. A portion of *John*'s extension has a temporal part named '*John's UG Student State*' which is created by an event named '*John's Enrolment*' and finishes (or is dissolved) by another event named '*John's Graduation*'. The two events and the state illustrated in the figure are all temporal parts of John. Although not represented in the figure, '*John's UG Student State*' can be further decomposed into substates with their respective boundary events. These states may be '*John's 1st year state*', '*John's 2nd year state*', etc.

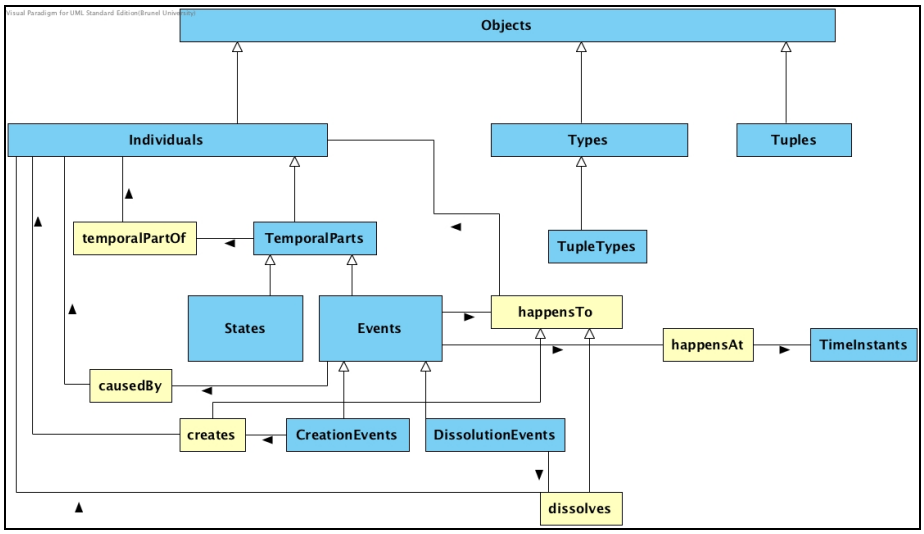

Fig. 1. BORO foundational ontology (partial view). (*Types* are represented in blue or darker colour and *TupleTypes* in yellow or lighter colour).

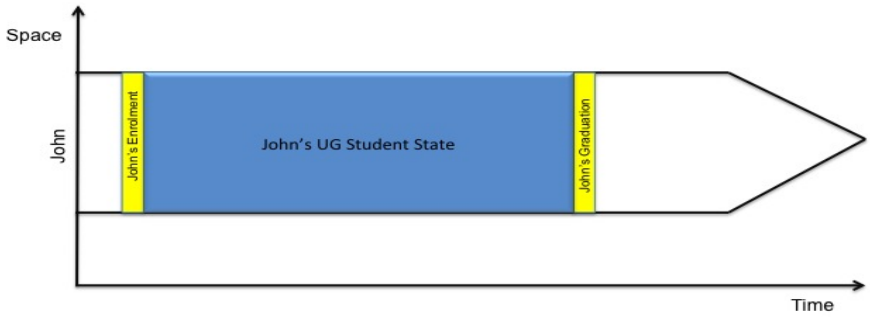

Fig. 2. Example space-time map

4 A Perdurantist Ontology of Contracts

Contracts have been defined and regulated over the centuries by national legislations. While there are some differences in the subtleties of their definitions and the types of contracts regulated, it is possible for the purposes of this research to extract some common elements that all contracts possess. Thereafter, in order to develop the ontology of contracts, it is necessary to semantically interpret these common elements and contracts as a whole from the perspective of the foundational ontology adopted.

Generally speaking a contract can be defined as follows: "an agreement with specific terms between two or more persons or entities in which there is a promise to do something in return for a valuable benefit known as consideration. […] The existence of a contract requires finding the following factual elements: a) an offer; b) an acceptance of that offer which results in a meeting of the minds; c) a promise to perform; d) a valuable consideration (which can be a promise or payment in some form); e) a time or event when performance must be made (meet commitments); f) terms and conditions for performance, including fulfilling promises …" (Definition from http://dictionary.law.com/ also cited by Kabilan [17]).

Dissecting the definition it appears that the necessary elements of a contract are:

1. Agreement among persons: At least two persons or entities must consent to the specific terms of the contract. An entity (or juridical person) is accorded 'legal personality' and therefore considered by law a person. Hence, we will refer only to persons. When agreeing to a contract a person becomes party to the contract. The agreement is formed once both (or all) parties give their consent (e.g., verbally or by signature). Elements (a) and (b) in the definition together form the agreement. Once the offer is accepted then the contract is stipulated.
2. Promise: The parties commit themselves to fulfilling obligations (or commitments) according to the terms agreed. These commitments can be of different types (generally either to perform or to not perform). Normally there is a relationship of reciprocity between the set of commitments to which both parties agree. A similar type of relationship (duality) exists between the fulfilments of the commitments.
3. Consideration: In general an exchange of resources (in the economic sense) that is of value to the parties.

From the above brief analysis it is possible to begin a perdurantist interpretation of contracts by discovering the spatiotemporal extensions of a contract, its parts and the persons party to it. The question to ask is: what is the spatiotemporal extension of a contract? In attempting to answer this question it becomes apparent that the term contract bundles two different and related meanings. First, contract refers to the actual written or verbal specification that documents the agreement and specifies all the terms and conditions (in general *ContractClauses*) that the parties must respect. Second, contract refers to the execution of the events that occur after the stipulation in fulfilment of the contractual obligations. As such two distinct types are identifiable:

ContractSpecifications and *ContractExecutions*. The former is manifest in the case of written contracts whereby a document models, among other things, the commitments and the future fulfilment events. A contract execution realises a contract specification. The extension of a contract specification is straightforward in the case of a written document and it represents the life of the document itself starting from its stipulation.

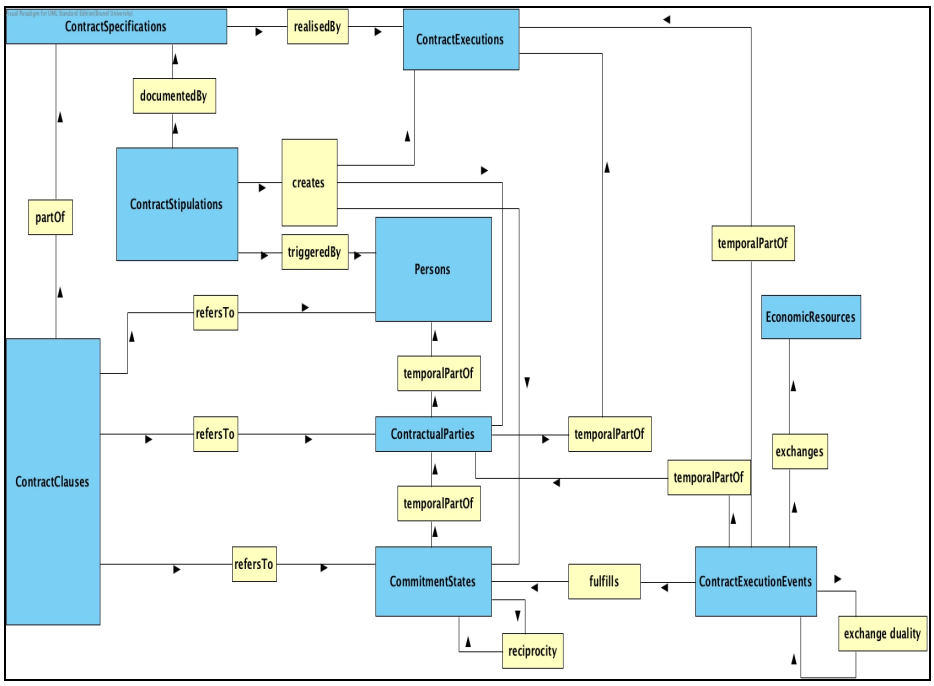

Fig. 3. Partial Perdurantist Ontology of Contracts

ContractStipulations are significant creation events. It is with the contract stipulation that the execution begins and the committed *Persons* enter in a state of being *ContractualParties*. At the same time the agreed obligations place the parties in various *CommitmentStates* each of which will terminate (or dissolve) once each individual commitment is fulfilled. Commitments are fulfilled via *ContractExecutionEvents*. It is at this point, once we start analysing the type of relationships between the instances of the types defined above, that the perdurantist model of contracts shows its fundamental differences with other contract representations in the literature. Figure 3 depicts the Perdurantist Contract Ontology.

Figure 4 illustrates such relationships with a space-time map by representing a simple contract in which a Car Dealer (named DMS) agrees to sell Mary a car and Mary agrees to buy the car by paying a certain amount of money in two instalments. In relation to the contract execution the following significant events occur:

(E_1) Stipulation of the contract to sell/buy the car at time t_1. This event creates DMS's and Mary's respective states (P_1 and P_2) of being party to the contract. It also produces three commitment states: DMS's commitment to deliver the car (C_1) and Mary's two commitments to pay the instalments (C_2 and C_3). It can be noted from Figure 2 that P_1 is temporally part of DMS and C_1 is temporally part of P_1. Similarly C_2 and C_3 are temporal parts of P_2 which is a temporal part of Mary.

(E_2) DMS's delivery of the car at t_2 ending DMS's commitment C_1.

(E_3) Mary's first payment at t_3 ending Mary's commitment C_2.

(E_4) Mary's second payment at t_4 ending Mary's commitment C_3. E_4 also dissolves or terminates the contract execution as the final remaining commitment of the contract is fulfilled.

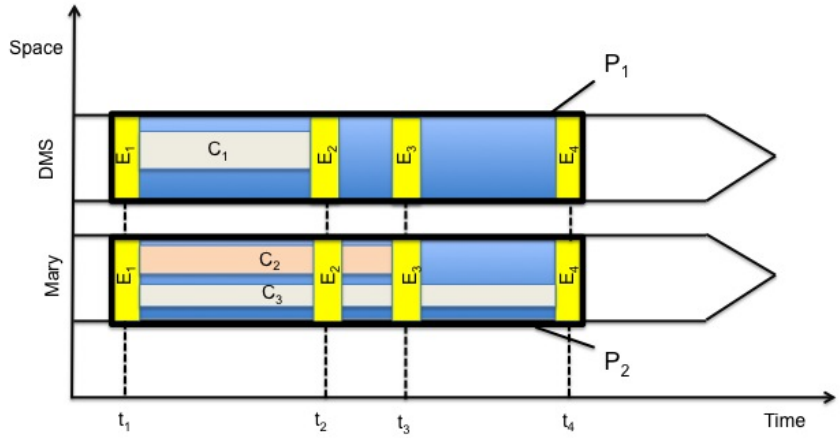

Fig. 4. Space-time map of the execution of a sales contract.

Figure 4 visually shows these temporal part relationships. For example, DMS physically contains its contractual party state, its commitment state and all related events. At this point the answer to the initial question of what is a contract execution appears clear. The execution of the contract (CEx) is the mereological sum of all *ContractualParties* involved. In the example, CEx = $P_1 + P_2$.

5 Discussion

The example in Section 4 serves the purpose of explaining and visually showing how a perdurantist ontology models a socially constructed individual such as a contract or, to be precise, the execution of a contract. Based on this representation being party to a contract is a temporal part of the person agreeing to that contract. In terms of the foundational ontology depicted in Figure 1, *ContractualParties* is a subclass of *States*. An individual contractual party would then also have temporal parts represented by specific *CommitmentStates* and specific *ContractExecutionEvents* fulfilling (or terminating) the commitments. The two contractual parties are together temporal parts

of the overall contract execution. Hence, the spatiotemporal extent of a contract execution intersects with the spatiotemporal extents of the persons involved and overlapping with these persons' contractual party states.

The events described above have been simplified in order to keep the example clear. In fact event E_1 may more realistically be decomposed into two further events: the first representing DMS's decision to agree to the contract stipulation and the second representing Mary's decision to agree herself. These two decisions can happen at different times and together would compose the 'complex' stipulation event E_1. Similar considerations can be made for the other events. For example, the buyer can make a payment at a time different to when the seller receives the payment.

Figure 4 also implicitly shows the relationship of *reciprocity* between the set of DMS's commitments (C_1), on the one hand, and the set of Mary's commitments (C_2 and C_3) on the other. Similarly there also exists a relationship of *exchange duality* between both parties' execution events fulfilling their respective commitments, specifically E_2 carried out by DMS versus E_3 and E_4 carried out by Mary. Moreover, the *EconomicResources* exchanged, and not represented in Figure 4, are the car sold and delivered to Mary against the cash that DMS receives as payments. These elements (duality, reciprocity and economic resources) are borrowed from REA and here remodelled.

The ontology in Figure 3 is a partial representation of contracts. A more complete Contract Ontology would require a model that is capable of representing and explaining the set of different alternative scenarios that can unfold once a contract is stipulated, ranging from the case in which all parties comply with the commitments promised to an eventual breach of contract. There are both technical and theoretical considerations to be made. From a technical perspective, it must be considered that some possible scenarios or state-of-affairs (for example, a breach of contract) may not necessarily be described by the contract specification alone, but also by laws and norms that legally integrate contracts of a specific type (e.g., sales contracts) in a mandatory manner. From a theoretical perspective, perdurantism and extensionality must be integrated by a theory capable of explaining alternate possible scenarios. In Philosophy a theory that explains the notion of possibility is that of Possible Worlds (for example, see Kripke [18] and Lewis [19]).

While it is beyond the scope of this paper to provide a detailed representation of contracts based on Possible Worlds or related theories, it would be useful to mention that an integration of perdurantism and Possible Worlds must elegantly answer the question of how states-of affairs of different possible worlds can be mapped to one another and traced back to the same original contract of our actual world. To be consistent with the principle of strong extensionality of the BORO foundational ontology, it would be however appropriate to develop a solution that somehow is rooted itself in extensionality.

6 Conclusion

The Perdurantist Contract Ontology presented in Section 4 represents research that requires further refinement, expansion and evaluation. It represents an example of how a perdurantist ontology is capable of modelling socially constructed objects. Due

to limitations of space we have omitted a thorough comparison with similar work aimed at modelling contracts and services (for example, see [17], [20], [21], [22], [23]). Suffice to note here that the main difference lies in the modelling of commitments and their fulfilment events as temporal parts of the parties involved in the contract. We realise that such a representation may radically depart from the common conception of contract whether it be by the technical information systems community or by the layperson. While we expect that the more explicit and precise real world semantics of such an ontology would positively affect the design and implementation of software systems in terms of their level of adaptability to change, at this stage of the research it must be noted that further empirical work is necessary in order to ascertain benefits and limitations of such a representation. In terms of future work we intend to progress along the following directions:

- First, refine the representation of *ContractSpecifications* and its parts, specifically those parts of contracts, which model the timeline that the parties must abide by, generating a plan of commitments which can be used during the course of the contract's execution to determine whether the parties are respecting their obligations or alternatively if different courses of action must take place. This would give rise to various new states (possibly of the parties or even also of the contract specification) related to the successful completion or breach of the contract.
- Second, model a typology of contract types (e.g., sale, rental, etc.) and respective commitment types (for example, payments, provision of goods/services, periodic commitments, on-demand commitments, etc.).
- Third, formalise the ontology in an ontology language such as the Web Ontology Language (OWL), populating the model with instance data and testing for consistency and correctness.
- Fourth, since laws and regulations impose constraints on contracts (in all their manifestations, e.g. specifications, stipulations and executions) it becomes necessary to investigate the ontological nature of such regulatory frameworks and their relationship with contracts. Such an analysis is required since the validity of contracts must be explicitly or implicitly consistent with the fulfillment of regulatory constraints.

References

1. Williamson, O.E.: Transaction Cost Economics: How it Works; Where it is Headed. De Economist 146(1), 23–58 (1998)
2. Reve, T.: The firm as a nexus of internal and external contracts. In: Foss, N.J. (ed.) The Theory of the Firm: Critical Perspectives on Business and Management, pp. 310–334. Routledge, London (2000)
3. Ayotte, K., Hansmann, H.: Economic and Legal Entities as Transferable Bundles of Contracts. Working paper (2010), http://www.law.northwestern.edu/colloquium/law_economics/documents/Ayotte_Hansmann.pdf (last accessed December 01, 2011)

4. Ijiri, Y.: Theory of Accounting Measurement. Studies in Accounting Research #10. American Accounting Association, Sarasota, Florida (1975)
5. McCarthy, W.E.: The REA Accounting Model: A Generalized Framework for Accounting Systems in a Shared Data Environment. The Accounting Review 57(3), 554–578 (1982)
6. Geerts, G.L., McCarthy, W.E.: An ontological analysis of the economic primitives of the extended-REA enterprise information architecture. International Journal of Accounting Information Systems 3, 1–16 (2002)
7. Geerts, G.L., McCarthy, W.E.: Policy-Level Specifications in REA Enterprise Information Systems. Journal of Information Systems 20(2), 37–63 (2006)
8. Hruby, P., Kiehn, J., Scheller, C.: Model-Driven Design Using Business Patterns. Springer (2006)
9. Lévine, P., Pomerol, J.C.: From Business Modeling Based on the Semantics of Contracts to Knowledge Modeling and Management. In: Proceedings of the 34th Hawaii International Conference on System Sciences. IEEE (2001)
10. Lowe, E.J.: Ontology. In: Honderich, T. (ed.) The Oxford Companion to Philosophy, p. 634. Oxford University Press, New York (1995)
11. Gruber, T.R.: A Translation Approach to Portable Ontology Specifications. Knowledge Acquisition 5(2), 199–220 (1993)
12. Smith, B.: Beyond Concepts: Ontology as Reality Representation. In: Varzi, A., Vieu, L. (eds.) International Conference on Formal Ontology and Information Systems (2004)
13. Searle, J.R.: The Construction of Social Reality. Free Press (1997)
14. Sider, T.: Four-Dimensionalism: An Ontology of Persistence and Time. Oxford University Press, USA (2002)
15. Partridge, C.: Business Objects: Re-Engineering for Re-Use. Butterworth-Heinemann (1996)
16. IDEAS Group: The IDEAS Model, http://www.ideasgroup.org/foundation/
17. Kabilan, V.: Using Multi-tier Contract Ontology to Model Contract Workflow Models. Ph.D. Thesis, Stockholm University, Sweden (2003), http://kth.diva-portal.org/smash/get/diva2:7604/FULLTEXT01
18. Kripke, S.: Naming and Necessity. Harvard University Press, Cambridge (1980)
19. Lewis, D.: On the Plurality of Worlds. Blackwell (1986)
20. Daskalopulu, A., Sergot, M.: The Representation of Legal Contracts. AI and Society 11(1/2), 6–17 (1997)
21. Chopra, A.K., Oren, N., Modgil, S., Desai, N., Miles, S., Luck, M., Singh, M.P.: Analyzing Contract Robustness through a Model of Commitments. In: Weyns, D., Gleizes, M.-P. (eds.) AOSE 2010. LNCS, vol. 6788, pp. 17–36. Springer, Heidelberg (2011)
22. Ferrario, R., Janiesch, C., Guarino, N., Oberle, D., Probst, F.: Towards an Ontological Foundation of Services Science. The General Service Model. In: The Proceedings of Wirtschaftsinformatik, Zurich, Switzerland (2011)
23. Ferrario, R., Guarino, N., Fernandez Barrera, M.E.: Towards an Ontological Foundations for Services Science: the Legal Perspective. In: Sartor, G., Casanovas, P., Biasiotti, M., Fernandez Barrera, M. (eds.) Approaches to Legal Ontologies. Law, Governance and Technology Series, vol. 1, pp. 235–258. Springer (2011)