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LKIF Core: Principled Ontology Development for the Legal Domain

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Abstract. In this paper we describe a legal core ontology that is part of the *Legal Knowledge Interchange Format*: a knowledge representation formalism that enables the translation of legal knowledge bases written in different representation formats and formalisms. A legal (core) ontology can play an important role in the translation of existing legal knowledge bases to other representation formats, in particular as the basis for articulate knowledge serving. This requires that the ontology has a firm grounding in commonsense and is developed in a principled manner. We describe the theory and methodology underlying the LKIF core ontology, compare it with other ontologies, introduce the concepts it defines, and discuss its use in the formalisation of an EU directive.

Keywords. ontology, legal ontology, ontological engineering, legal concept, LKIF, knowledge representation, framework, methodology, common sense

Introduction

This article describes a legal core ontology that is part of the *Legal Knowledge Interchange Format*, developed in the Estrella project.[1] LKIF specifies a knowledge interchange *architecture* that serves two main purposes. Firstly, it enables the *translation* between legal knowledge bases written in different representation formats and formalisms. The second purpose of LKIF is to be a *knowledge representation formalism* in its own right, i.e. to form the basis for standard reasoning services provided by legal knowledge systems.

Languages used by commercial knowledge-based systems vendors are typically rather idiosyncratic rule formalisms with varying expressiveness [34]. The LKIF language is therefore expressive enough to cover the full range of formalisms used in practice, and has proven to be able to translate back and forth between a number of vendor specific languages [13]. This approach is similar to that of the Knowledge Interchange Format (KIF) of [31] and its successor CommonLogic [46] which have the expressiveness of full first order predicate logic.

[1] Estrella is a 6th European Framework project (IST-2004-027665). See http://www.estrellaproject.org

However, LKIF differs from KIF in that it is not a uniform formalism, but rather combines two different knowledge representation formalisms: OWL 2 DL, and LKIF Rules [60, 3, 6]. Moreover, the language offers the ability to represent legal argumentation schemes [33, 32].[2] This versatile, hybrid character of LKIF enables the mapping of many formalisms used in the practice of building legal knowledge systems.

Although indeed many such systems are specified using rule formalisms, it becomes increasingly popular to capture legal knowledge in *ontologies*, as this book shows. Over the years, ontologies have been cast in a large variety of formalisms and languages ranging from industry standards such as UML and TopicMaps to OWL DL, the W3C's standard for representing ontologies on the Semantic Web. OWL differs significantly from UML and TopicMaps because is an explicit knowledge representation formalism that has the attractive properties of being sound, complete and decidable. Moreover, efficient inference engines – tableaux based theorem provers – have been specifically developed and optimised for this language. As we will show below, this is exactly what is needed to use ontologies as knowledge bases. However, these attractive properties come with a price: the language has limited expressiveness.[3] The Estrella project has developed translators that allow translating back and forth between UML and OWL [13].

Ontologies capture that knowledge which is considered to be the undisputed backbone of what is known about a particular domain. It is an axiomatic starting point and necessary foundation for describing a domain's wide range of less indisputable or more specific knowledge. For instance, although most if not all of our knowledge of the world around us is based on assumptions and beliefs, an ontology captures that (terminological, conceptual) knowledge on which such strong agreement is reached that it is undisputed and universally held to be true (for some purpose). This agreement is often described as an *ontological commitment* [22]; it defines *that which we hold to exist*. In fact, the ontology must capture that knowledge shared by humans knowledgeable in the domain: it is a *shared* commitment. Furthermore, it is shared by the fact that the definitions of terms in an ontology form the common ground for the knowledge captured by more specific domain knowledge bases.

A Core Ontology

Given the central role of ontologies, one would expect currently existing knowledge systems to contain ontologies as a basic resource for reasoning. Unfortunately, this is rarely the case – although a notable exception can be found in the field of qualitative reasoning [26]. Often, ontologies are rather used as domain vocabularies for the management of large collections of documents. Arguably, the legal domain is a typical example where such shared vocabularies can significantly improve accessibility of legal information. Information management problems dealing with law and legal documents are not only of importance to legal professionals, but to citizens as well.

This article describes the LKIF Core ontology, an ontology that *can* be used as central knowledge component for legal knowledge systems. For instance, the HARNESS ar-

[2] The vocabulary used in the specification of LKIF Rules and argument schemes is also specified in OWL 2 DL as part of the ontology presented here (see e.g. [47]). A reasoner for unfolding argumentation schemes is implemented as part of the Carneades argument mapping system, `http://carneades.berlios.de/`.

[3] This poses some problems in translating UML or TopicMaps into OWL DL. The main bottleneck is in the fact that in UML and TopicMaps (and for that matter also RDF) allow meta classes and reification (e.g. association classes).

chitecture allows legal reasoning based on this ontology, e.g. the application of norms to cases represented in OWL DL for the purposes of legal assessment [16, 76].[4] In this respect, the LKIF ontology is similar to the domain ontology developed in the CLIME project [78, 80].[5] However, it differs in that it is a *core ontology*, i.e. it contains the terms common to some field of activity or discipline, but which not specific to some domain.

In [12, 44] we identified four main ways for a legal core ontology to support information exchange in the context of LKIF. First of all, the ontology can serve as a resource for special, legal *inference*. Secondly, the definitions of terms in the ontology can facilitate *knowledge acquisition*, a terminological framework can facilitate the *exchange* of knowledge across multiple knowledge bases, and lastly it can be a basis for semantic *annotation* of legal information sources.

Resource for Special Legal Inference Typical and abstract legal concepts are often strongly interrelated and thereby provide the basis for computing equivalencies, or paraphrases, and implications. For instance, by representing an obligation as the opposite of a prohibition, a (legal) knowledge system can make inferences that capture the notion that they are each others' inverse. A prohibition leaves all options open – except the one that is forbidden – while an obligation is unavoidable when all its requirements, or conditions, are satisfied. Although this implicit knowledge is relevant when reasoning with norms and cases, it does not express the control knowledge of reasoning (as in problem solving methods), but merely elicits the implications of declarative definitions. Specialised legal inference can be based on definitions of concepts in an ontology: an inference engine can generate the implied consequences of explicit concept definitions. LKIF Core defines deontic qualifiers (prohibition, obligation and permission) in such a way that they can be used in normative reasoning (see Figure 7). HARNESS uses these definitions to assess legal cases, i.e. to infer violation of, or compliance with norms.[6]
A classical example of specialised inference using the definitions in an ontology and a (general) inference engine is temporal reasoning based on [1]'s ontology of time (Section 4.1). To enable special inference, terms should be highly interrelated and form a coherent *cluster* with little or no external dependencies ([41], and Section 2). An example of such a cluster in the legal domain is that of the terms that denote deontic qualifications. Clusters of this type are usually found at very high levels of abstraction.

Knowledge Acquisition Support The classical use of both top and core ontologies in knowledge representation is as a means to support knowledge acquisition. If well designed and explained, they provide an initial structure to which domain terms can be attached as subclasses. Inheritance of properties and other implicit knowledge can then be used to check not only consistency, but also the extra-logical quality of the ontology: whether what is derived (classes, properties) makes sense. The use of a core or top structure that has well tested and evaluated implications, makes it easier to check whether domain refinements are not only consistent, but also arrive at inferences that correspond to what the knowledge engineer or user holds to be valid. The knowledge acquisition support of ontologies is not restricted to just

[4] HARNESS: Hybrid Architecture for Reasoning with Norms Exploiting Semantic web Standards.
[5] CLIME, Cooperative Legal Information Management and Explanation, Esprit Project EP25414
[6] These inferences are produced via the use of the Pellet DL reasoner (http://pellet.owldl.com/).

ontological or even terminological knowledge. For instance, the CLIME ontology was successfully used for the incremental specification of normative knowledge [81].

Preventing Loss in Translation A legal ontology can play an important role in the translation of existing legal knowledge bases to other representation formats. In particular when these knowledge bases are converted into LKIF as the basis for articulate knowledge serving. Similar to a translation between different natural languages, a formal, 'syntactic' translation may clash with the semantics implied by the original knowledge representation. An ontology, as representation of the semantics of terms, allows us to keep track of the use of terms across multiple knowledge bases.

Resource for Semantic Annotation The semantic annotation of legal sources, such as regulations and jurisprudence is an important contribution to the accessibility and maintainability of these sources. First of all, an ontology can be a source for information retrieval. Secondly, the status of an officially sanctioned legal text is primarily determined by its relation to other legal texts [8]. This status can be made explicit by expressing it using ontologically defined relations. In fact, these relations do not just hold between the texts themselves, but between the formal representations of their content as well [48].

The following sections describe the theoretical and methodological framework against which the LKIF core ontology has been developed. Section 1 discusses the perspective used in its construction in relation to five other ontologies. The methodology used to construct the LKIF ontology is discussed in Section 2. Section 3 extends this methodology by introducing a distinction between ontologies and *frameworks*, followed by a discussion of the modules and most important concepts of LKIF Core in Section 4. Section 5 gives an example of how the ontology can be used in the formalisation of a regulation.

1. Points of View: Other Ontologies

As we discussed, one of the main roles of ontologies is to ease knowledge acquisition by providing readily usable concept definitions. The same bootstrap can be applied to ontology development itself; existing ontologies can be a viable resource for ontology construction in the form of predefined concepts and relations. These definitions convey ontological commitments that capture important ontological choices [54]. When these choices are in concert with our requirements, adopting and extending an existing ontology relieves us from the burden of micromanaging these choices ourselves.

The topmost layers of a top or core ontology characteristically distinguish fundamental, but highly abstract categories of knowledge, that for centuries have been subject to philosophical study and debate [71]. Many distinctions prominent in this debate have found their way to contemporary ontologies. It therefore seems advisable to assess the currently available top-ontologies as source for re-usable definitions (see also Section 2). In a similar vein, an ontology may provide abundant inspiration for dealing with recurrent problems in knowledge representation in the form of *design patterns* (viz. [30, 43]). In this section, we outline two main requirements for the LKIF Core ontology, and show that even at this highly abstract level, the point of view taken in the development of an ontology has a large impact on *how*, and *which* categories are defined.

Besides the general requirements for knowledge representation ontologies, the ontology is to contain a core set of definitions for describing specific legal terms. Valente [75] conceived of law as an instrument used by the legal and political system to identify and control situations and events in social interaction. By far the bulk of social situations, be it in our family life, at work, related to transport, property, crime, etc. is not described in specialised technical terms: their meaning is part of common sense. For instance, the conflicts and problems brought to court – legal cases – are initially described using common sense terms, and are gradually translated into legal technical terminology in the process of coming to a decision. For this legal qualification to be possible, the gap between the vocabulary of a case and legal terminology needs to be bridged [79]. The possibility of legal qualification in general – by legal professionals – is a strong indication that the vocabularies of legal knowledge and common sense are not disjoint. Legal terminology can be reduced to the actual societal events and states governed by law. In other words, the basic categories of the LKIF ontology should reflect Valente's view that legal world knowledge is an abstraction of common sense [75].

A third requirement for LKIF is given by the ideal of the Semantic Web to achieve understanding both between web services and between human users. In fact, a commonsense perspective is also applicable to any serious endeavour towards a Semantic Web. As the the web is about the most diverse information source we know today, a common sense oriented ontology would certainly be an important first step to more uniform web-based knowledge representation. Conversely, the distribution of legal information across various strongly interconnected sources is a demanding use case for semantic web technology [42]. An important requirement is therefore that the LKIF core ontology should be represented using the DL profile of OWL.

Given a commonsense perspective, we expected that (at least parts of) existing ontologies would be re-usable, ranging from a source of inspiration to straightforward import of definitions. This would hold, in particular, for top ontologies that include legal terms, as for instance listed in [17]. Unfortunately, it turned out that the amount of re-use and inspiration was rather limited. Not only do existing ontologies diverge on approach, coverage and knowledge representation language used; those ontologies that do claim a common sense or similar perspective differ in their conception as to what such a perspective *means*.

We consulted several ontologies and evaluated them for their potential contribution to LKIF Core. The main requirement is their suitability to enable the primary roles of the LKIF ontology outlined in the previous section. We pay specific attention to their definition of commonsense and legal terms, and possibilities for safe reuse: reuse should not alter the semantics of the reused ontology [18].

1.1. Suggested Upper Merged Ontology

The SUMO ontology of [63] brings together insights from engineering, philosophy, and information science. It provides definitions for general purpose terms, is intended as a unifying framework for more specific domain level ontologies. As a starting point for a legal core ontology SUMO has several drawbacks. First of all, it does not readily provide definitions of terms relevant to the legal field – e.g. its coverage of mental and social entities is limited. Because of the way in which SUMO is constructed, it has a bias towards more abstract and theoretical insights coming from engineering and philosophy. Although it is non-revisionist, as in e.g. the distinction between objects and processes, it does not have a real commonsense basis. Furthermore, SUMO is a *foundational ontology* and uses meta modelling, such as in the definitions of classes, binary relations and sets. As SUMO is represented in the expressive language KIF, and more recently CommonLogic, this practice is not fundamentally problematic. However, it means that safe reuse of SUMO definitions in the construction of an OWL DL ontology is not possible.

1.2. Descriptive Ontology for Linguistic and Cognitive Engineering

DOLCE is part of the WonderWeb library of foundational ontologies, cf. [54, 27]. It was meant as a reference point for the other ontologies in the library, to make explicit the differing rationale and alternatives underlying the ontological choices of each ontology. Rather than a coherent set of ontological commitments, it captures a range of alternatives. This way, the library would form a network of different but systematically related ontology modules. The relation between an ontology, available in the library, and the DOLCE ontology expresses its ontological commitment to particular ontological options. DOLCE was therefore never presented as the foundational ontology it is currently regarded as, but it has been successfully used as such in a large number of projects.

DOLCE is very much an ontology in the philosophical tradition, and differs from the knowledge representation perspective in two significant ways. Firstly, its perspective is philosophical with respect to its *content*, i.e. it is aimed to directly represent reality. And secondly, it is subject to the epistemological promiscuity of philosophical ontology because it is rather an extension of the knowledge representation formalism at the *ontological level* [39], than a model expressed using that formalism. The meta-level character of DOLCE means that the ontology is not a representation of knowledge, but of the terms used to describe knowledge – in the same way that the constructs of OWL are. Like SUMO, DOLCE was originally specified in first order logic and the highly expressive KIF language. Its OWL DL representation (DOLCE-Lite) is more restrictive, e.g. it does not consider temporal indexing and relation composition.

The DOLCE ontology is *descriptive*, and is based on the stance that "the *surface structure* of natural language and human cognition"[7] is ontologically relevant. It is argued that this perspective results in an ontology that captures cognitive artefacts more or less depending on human perception, cultural imprints and social conventions, and *not* deep philosophical insights of Ontology. DOLCE thus claims an approach that fits more with a commonsense perspective than the science perspective of SUMO. However, the suggestion that this surface structure has any bearing on common sense is not based on evidence. Rather, the methodological commitment to the *surface* structure of language and cognition almost inevitably resulted in an intricate framework of theoretical notions needed to encompass the idiosyncrasies of human language use. Alternatively, rather than constructing an ontology by studying reality through the kinds of categories implicit in natural language, a pragmatic approach based more directly on the conceptualisation of reality we use and live by in our daily routine is more appropriate [10, 45, and Section 1.5].

[7]Emphasis by the authors, [54]

1.3. Core Legal Ontology

Over the years, DOLCE has been extended in several ways. DOLCE+ is the extension of DOLCE with a theory on descriptions and situations (also called D&S, [28]). CLO, the Core Legal Ontology [29] extends DOLCE+ even further and defines legal concepts and relations based on its formal properties. CLO was designed to support both the definition of domain ontologies, a juridical Wordnet, and the design of legal decision support systems. To a large extent these goals correspond with the requirements of the LKIF ontology.

CLO conceives the legal world as a *description* of social reality, an ideal view of the behaviour of a social group. It builds on the D&S distinction between *descriptions*, and *situations*. Examples of legal descriptions, or *conceptualisations*, are the *contents* of laws, norms, and crime types. These descriptions constrain legal situations, i.e. legal *facts* of *cases*, such as legal, relevant non-legal and juridical states of affairs. Every legal description *classifies* a state of affairs. More precisely, a legal description is the reification of a theory that formalises the content of a norm, or a bundle of norms. A legal case is the reification of a state of affairs that is a logical model of that theory. A description is satisfied by a situation when at least some entity in the situation is classified by at least some concept in the description. Classification in CLO is thus not DL classification, and it is unclear as to what extent the two interpretations are compatible.

Viewing the legal system as description, or rather *pre*scription, of reality is not new, cf. [75, others]. However, the CLO distinction between descriptions and situations is rather one dimensional in that it does not commit to an ontological view of the *kinds* of descriptions involved. In line with the DOLCE ontology, it confounds the distinction between representation and the *represented* with representation and *reality*. Although it introduces new levels of abstraction by reification, it does not provide ontological categories that can be used to describe the knowledge at these levels. In a language that itself can be conceived as providing the means to construct descriptions of reality (situations), such as OWL DL, it is unclear what the epistemological status of the classes 'description' and 'situation' *themselves* is. For instance, what is the difference between an individual description being classified-in-the-OWL-sense as some description class, and a situation class being classified-in-the-CLO-sense by that same description?

As CLO relies on a subset of DOLCE for the definition of *elements* of situations, it is subject to the same criticism with respect to its commonsense perspective. Moreover, the lack of ontological commitment at the level of descriptions undermines its suitability for knowledge acquisition support in a legal setting as well. Although for sure a norm can be described as some description of a situation, it is not the norm-as-description that uniquely characterises what a norm *is*. This holds especially for less obvious 'descriptions' (in CLO terms), as e.g. damage or right of way.

1.4. CYC

CYC is a huge unified ontology of commonsense concepts [53, 52]. Although the project has started as early as 1984, its general set-up corresponds to that of later large scale ontology efforts. The main motivation for the Cyc Project was that all software programs would benefit from the availability of commonsense knowledge. This idea is not new, and was acknowledged in the early years of AI: "A program has common sense if it automatically deduces for itself a sufficiently wide class of immediate consequences of anything it is told and what it already knows" [56, p.2].

The idea is that, when enough commonsense knowledge is represented, and a certain threshold is reached, a quantum-leap ("The Singularity")[8] would enable CYC to expand its knowledge through guided learning (as a human child would). This theory is in line with Minsky's ideas about how computers can become intelligent beings: add enormous amounts of commonsense knowledge [58, 59]. This basic knowledge about the workings of the world would finally allow you to send the kid to school. With currently over 300K concepts, the knowledge base seems well under way in reaching this threshold, however we still have to see the first results.[9]

The upper part of the CYC ontology is claimed to express a commonsense view and indeed it is more concrete than either SUMO or DOLCE. On the other hand, from a methodological point of view, the CYC approach is not very satisfactory either. Technically, CYC qualifies rather as a terminological knowledge base than as an ontology proper.[10] Instead of a meticulous study of the actual workings of the world, as in SUMO, or the surface structure of language and cognition, as in DOLCE, it seems the approach followed is to have a bunch of knowledge engineers simply put everything they know into the CYCL formalism.[11] This procedure results in a large portion of the knowledge base being decidedly non-ontological, but rather context dependent *frameworks* (see Section 3).

Furthermore, CYC suffers from two more technical impediments for reuse. Firstly, like SUMO and DOLCE, it is specified in the very expressive CYCL representation language, which is based on first-order predicate calculus. Recently a port of the publicly available OpenCYC effort has been made available in OWL Full, but again, this does not cover the full semantics of the ontology.[12] CycL admits meta modelling, which indeed is used liberally throughout the ontology – even more so than in DOLCE and SUMO. Secondly, the sheer size of the knowledge base – as with most unified ontologies – introduces significant reasoning overhead for even the simplest tasks. As such, CYC seems more suitable for direct inclusion in a knowledge based system than as a conceptual coat rack for ontology development on the Semantic Web.

1.5. Ontology Reuse

Thus far, the ontologies we reviewed do not appear to meet the requirements for the top structure of a legal core ontology. Although in the past few years the ontologies underwent changes and extensions, these results are in line with the outcome of an earlier review [10]. Firstly, the ontologies are specified at multiple (meta) levels of abstraction, using very expressive languages, which limits possibilities for safe reuse.

Furthermore, in all three ontologies those concepts that are of relevance to law are either scarce and under specified, or overly theoretical. In particular, our requirement

[8] Indeed, CYC is a much-hyped project, and has received a lot of criticism because of it.

[9] The online game FACTory for teaching CYC is online at `http://game.cyc.com`.

[10] A random concept search just returned 'Laurel Goodwin', the acclaimed American actress who played the memorable role of Yeoman J.M. Colt in the 1966 pilot of Star Trek. See `http://sw.cyc.com/2006/07/27/cyc/LaurelGoodwin`.

[11] See `http://www.cyc.com/cycdoc/ref/cycl-syntax.html`

[12] See `http://www.opencyc.org` for an online browser and `http://www.cyc.com/2004/06/04/cyc` for the OWL Full version

that a legal core ontology should be built on a commonsense conception of reality is not met. Where a commonsense perspective is claimed, it is not motivated, explained or substantiated. The common sense of CYC is in fact *common knowledge*, or rather "human consensus reality knowledge" [53, p. 33], i.e. that knowledge of things most humans will concede to exist in reality. In contrast, the DOLCE and SUMO ontologies do not commit to the ontological relevance of human consensus, but rather aim to provide an ontological grounding for *all* knowledge. They do this in two distinct ways. SUMO is based on scientific knowledge of objective reality, and for DOLCE the way in which we apply and consciously report our knowledge is ontologically relevant.

Both approaches are generic enough to be the basis for an ontology that describes our common sense, in the sense of common knowledge. However, in our view, common sense refers not to some common body of knowledge of reality, but rather to the commonality of the scope and detail of that knowledge as it manifests itself in individual persons: it is a *level of description*, much akin to the *basic level* of [49] (see Section 2). Characteristic of this level is not just the *kind* of things we commonly know, but more importantly, the way in which this knowledge is *structured*. But for the last requirement, a philosophical approach would be perfectly adequate. However, a commonsense ontology should not be specified in highly specific, theoretical jargon, but should rather have a commonsense structure of its own.

1.5.1. LRI Core

The review in [10] motivated a decision to develop a legal core ontology to support the development of ontologies for criminal law in various European countries, as part of the e-Court project.[13] This ontology, *LRI Core*, was developed with a set of design goals similar to that of LKIF Core, cf. [11, 10]. What sets LRI Core apart from other ontology efforts is that its definitions were aimed to be verifiable through empirical research on how humans relate concepts in actual understanding of the world; and not about revisionist views of how we should view the world as it actually *is* (as e.g. in correct theories of the physical world) or as it makes up a parsimonious view on reality (as e.g. in philosophical views on the main categories of description).[14] This kind of empirical evidence can range from cluster analysis of semantic distance between terms, to neuro-psychological evidence.

Central to this effort is the view that common sense is rooted in a conceptualisation that is at its heart the result of our evolution. This conceptualisation is developed in order to deal with a dynamic and potentially dangerous environment. Our capacity to move, perceive and interact with reality has led to increasingly complex cognitive representations. These representations range from hard-wired abstraction in our perception system, such as the ability to perceive straight lines and angles at a mere 2 neurones away from the retina, via the inborn syntheses of perceptual input into basic properties, to – eventually – the representations accessible to conscious thought.

This range of increasingly abstract and complex representations of reality defines an axis that indexes organisms in successive stages of evolutionary development, e.g.

[13]Electronic Court: Judicial IT-based Management. e-Court was a European 5th Framework project, IST 2000-28199.

[14]For instance the classical distinction between abstract and concrete concepts in philosophy does not fit well with human understanding of the dynamics of the world in terms of physical causation, intention and life. The commonsense explanation of an event may involve all three categories.

from viruses and bacteria to multi-cell organisms, insects, mammals, primates and finally homo sapiens. In other words, the competencies of our genetic ancestors give insight in what the roots of our common sense are. These roots may well be hidden too deep to be accessible to conscious thought and introspection. Nonetheless, on the basis of insights in cognitive science we can make several basic distinctions that go well beyond a mere hunch. As most are of relevance to the LKIF Core ontology as well, they are briefly outlined below.

A Cognitive Science Perspective Given that the physical environment is relatively stable – the notable exceptions being day-night cycles, changing weather conditions and the occasional geological perturbation – the perceptual apparatus of most organisms is tuned to register the slightest change occurring against this stable canvas. Of particular relevance is the ability to be aware of changes induced by other organisms. Firstly, the presence of another organism may present an opportunity for *reproduction* and sustaining *metabolism* (i.e. by eating). And secondly, their presence may signify a direct threat to an organisms' existence. The result is a prominent distinction in cognition between '*background*' and '*foreground*'. In general our awareness is directed to the *dis*continuity of change rather than spatial arrangements of objects or historical continuity. The ability to perceive stability is enabled by episodic memory, though it requires some conception of the physical constraints underlying this stability. An example is the general rule that physical objects keep their position unless subjected to a change in the exertion of force. Changes occur against the canvas of temporal and spatial positions, and the speed of a change is indicative of whether it becomes foreground or remains in the background.

In LRI Core, the view that knowledge serves to interpret occurrences in the world was reflected by a contrast between concepts on the one hand, and individuals and their occurrence (instance) on the other. Furthermore, the cognitively primary distinction between static and dynamic elements in the (physical) world is reflected by differentiating objects and processes. Objects have extensions in space where processes have extensions in time, but are contained by objects. Processes reflect a causal explanation of change. The notions of space and time do not just play a role as the extension of objects and processes but can indicate positions as spatio-temporal referents. The spatio-temporal position of of objects is not inherent: a change in position does not constitute a change *in* an object.

Very recent – at least in evolutionary terms – mammals developed the ability to attribute intentions to other animals. Because of the intentional interpretation of behaviour, change is no longer private to physical causation but to the *actions* of other *agents* as well. Actions are always intentional "under some description" [20]: performing an action comes down to the initiation of processes that bring about some intended change or state. Paradoxically enough, taking into account the mental state of other animals precedes the ability to consciously reflect on our *own* mind. And although this was long thought to be a skill exclusive to humans, it has been shown that our next of kin – chimpanzees, bonobo's – have self awareness as well.

Because mental representation of other mental representations is a fairly recent accomplishment, the models we construct reuse many parts of the conceptualisation originally developed to deal with physical reality. We think and speak of mental *processes* [15] and mental *objects* in the same terms we use to talk about the physical world. In other

[15] Also: mental actions, e.g. in (trying) to control one's thoughts.

words, these terms are metaphors of similar physical notions. Some, i.e. [50], even argue that the same mechanism is used to construct the highly abstract notions of mathematics.

Social awareness and self awareness are the most important prerequisites for complex social behaviour. First of all, they enhance the predictability of our environment by allowing us to take the possible intentions of other agents into consideration for planning and control. Secondly, it allows us to share plans with other agents. Repeated execution of such co-operative plans can render them institutionalised by a community. Plans make extensive use of *roles* to specify expected or default behaviour. The ability to play a certain role expresses a (recognised) competence, sometimes acknowledged as a social 'position'. In LRI Core, roles played a central part in the construction of social structures.

The LRI Core ontology distinguished four 'worlds':

1. A *physical world*, divided by processes and objects, each containing matter and energy.
2. A *mental world*, containing mental objects and mental processes. The mental world is connected to the physical world through actions, which translate an intention into some physical change.
3. A *social world*, built from mental objects such as roles
4. An *abstract world*, which contains only formal, mathematical objects.

Because of its grounding in cognitive science and its explicit common sense perspective, the characteristics of the LRI Core ontology are relatively similar to those intended for the LKIF ontology – especially in comparison to the other ontologies we discussed so far. And it is indeed true that it can in many ways be seen as the direct precursor of the LKIF ontology.[16]

Nonetheless, the LRI Core ontology falls short in several important respects. Though it is specified in OWL DL, most concepts in the ontology are under specified. They are defined by subsumption relations, and are only sparsely characterised using more complex class restriction. Furthermore, the distinction between the different worlds in LRI Core is fairly absolute, and no theory is provided as to how they are connected and interact. Thirdly, apart from a relatively well-developed characterisation of roles, LRI Core is relatively underdeveloped with respect to the mental world. For instance, it emphasises physical objects, processes, energy and substance while remaining rather sketchy with respect to their mental counterparts. In part the limitations of LRI Core can be ascribed to an unprincipled top down methodology.

Concluding, although the perspective and main distinctions of LRI Core were used as inspiration in the construction of the LKIF ontology, it is not simply a specialisation of LRI Core. Not only is it built from the ground up, the methodology by which it is constructed forces a broader, more concrete, and more rigorous definition of concepts and relations. First, the scope of the ontology was determined by selecting a core set of basic concepts. These concepts were organised in modules, and formed the basisz for a middle-out construction of the ontology.

[16] This is not really surprising as there exists an overlap between the developers of LRI Core and LKIF Core.

2. Methodology

The construction of LKIF Core is guided by a combination of methodologies for ontology engineering. Already in the mid-nineties, the need for a well-founded ontology development methodology was recognised, most notably by [36, 37, 74, 73] and later [25]. These methodologies follow in the footsteps of earlier experiences in knowledge acquisition, such as the CommonKADS approach [68] and others, but also considerations from *naive physics* and *cognitive science*, such as [41] and [49], respectively.

Hayes, in [41], describes an approach to the development of a large-scale knowledge base of naive physics. Instead of rather metaphysical top-down construction, his approach starts with the identification of relatively independent *clusters* of closely related concepts. These clusters can be integrated at a later stage, or used in varying combinations allowing for greater flexibility than monolithic ontologies. Furthermore, by constraining (initial) development to clusters, the various – often competing – requirements for the ontology are easier to manage.

Where the domain of Hayes' proposal concerns the relatively well-structured domain of physics, the combination of common sense and law does not readily provide an obvious starting point for the identification of clusters. In other words, for LKIF Core, we cannot carve-up clusters from a pre-established middle ground of commonsense and legal terms. And furthermore, the field does not provide a relatively stable top level from which top-down development could originate.

In [74], who are the first to use the term 'middle-out' in the context of ontology development, it is stressed that the most 'basic' terms in each cluster should be defined before moving on to more abstract and more specific terms within a cluster. The notion of this basic level is taken from Lakoff [49], who describes a theory of categorisation in human cognition. Most relevant within the context of ontology engineering [74, 49, p. 12 and 13] are *basic-level categorisation*, *basic-level primacy* and *functional embodiment*. Categories are organised so that the categories that are cognitively basic are 'in the middle' of a taxonomy, generalisation proceeds 'upwards' from this basic level and specialisation proceeds 'downwards'. Furthermore, these categories are functionally and epistemologically primary with respect to (amongst others) knowledge organisation, ease of cognitive processing and ease of linguistic expression. Basic level concepts are used automatically, unconsciously, and without noticeable effort as part of normal functioning. They have a different, and more important psychological status than those that are only thought about consciously. This approach thus fits well with the theoretical considerations of the previous section.

For the purpose of the LKIF ontology, we have made slight adjustments to the methodology of [41, 73]. We established design criteria for the development of the LKIF ontology based on [35, 73]. These criteria were implemented throughout the following phases: identify *purpose and scope*, ontology *capture* and *coding*, *integration* with existing ontologies and *evaluation*.

2.1. Ontology Capture

The LKIF Core ontology should contain 'basic concepts of law'. However, it depends on the (potential) users what kind of vocabulary is aimed at, and which concepts are *basic*. We identified three main groups of users: *citizens*, *legal professionals* and *legal scholars*.

Table 1. Ten highest scoring terms for *importance*, *abstractness*, and *legal relevance*

Importance	**Abstractness**	**Legal Relevance**
Law	Deontic operator	Civil law
Right	Law	Law
Jurisdiction	Norm	Legal consequence
Permission	Obligative Right	Legislation
Prohibition	Permissive Right	Obligation
Rule	Power	Right
Sanction	Right	Authority
Violation	Rule	Deontic operator
Power	Time	Duty
Duty	Anancastic Rule	Jurisdiction
Legal Position	Existential Initiation	Legal Fact
Norm	Existential Termination	Legal Person
Obligation	Potestative Right	Legal Position
Permissive Right	Productive Char.	Legal Procedure
Argument	Absolute Obl. Right	Liability

Although legal professionals use the legal vocabulary in a far more precise and careful way than laymen, for most of these terms there exists a sufficient common understanding to treat them more or less as similar, cf. [51]. Nonetheless, a number of basic terms have a specific legal-technical meaning, such as 'liability' and 'legal fact'. Technical terms were included because they capture the 'essential', abstract meaning of terms in law. Furthermore, these terms can be used to structure the relations between more generally understood legal terms.

The Estrella consortium includes representatives of these three kinds of experts. Each partner was asked to supply their 'top-20' of legal concepts. Combined with terms we collected from literature (jurisprudence and legal text-books) we obtained a list of about 250 terms. As such a number is unmanageable as a basic set for modelling, we asked partners to assess each term from this list on five scales: level of *abstraction*, *relevance* for the legal domain, the degree to which a term is *legal* rather than *common-sense*, the degree to which a term is a *common legal term* (as opposed to a term that is specific for some sub-domain of law), and the degree to which the expert thinks this term should be *included* in the ontology. The relative position of a term with respect to these scales indicates its appropriateness for inclusion in the basic clusters. For instance, the higher a score for importance, legal relevance, and common legal term, the more appropriate a term is for inclusion in the ontology. On the other hand, a high or low score for abstractness and 'common-sense vs. legal' indicates that a term is not basic. For those scales, we were looking rather for terms that have an average score.

The resulting scores were used to select an initial set of 50 terms plus those re-used from other ontologies (see section 1), and formed the basis for the identification of clusters and the development of the LKIF Core ontology. To illustrate, table 1 shows the ten highest scoring terms for three of the scales.

3. Frameworks and Ontologies

Many of the terms we gathered are not necessarily suited for inclusion in the core ontology. Even if scores on the five scales indicate that a term is of the utmost importance, this does not immediately mean that a term, and the relations it has, is of *ontological* relevance. We adhere to a rather restrictive view on what an ontology should contain: terminological knowledge, i.e. intensional definitions of concepts, represented as classes with which we interpret the world. Definitions that do not meet this rule should not be part of an ontology, and in earlier papers we have consistently advocated a distinction between ontologies and so-called *frameworks* [12, 44].

The distinction between ontology and actual situations is often said to coincide with the contrast between terminological knowledge (T-Box) and assertional knowledge (A-Box). However, this distinction is not concise enough for our present purposes. As a rule, terminological knowledge is generic knowledge while assertional knowledge describes the (actual) state of some world: situations and events. Such states can be generalised to patterns typical to particular kinds of situations. To be sure, if some pattern re-occurs and has a justifiable structure, it might evidently pay to store its structure as generic description. For instance, it may capture a predictable course of events. The combination of the situations and events related to eating in a restaurant is a typical example, and served in the Seventies to illustrate the notion of knowledge represented by scripts [67] or 'frames' [57]. For representations of this kind of generic knowledge, which is indeed rooted in terminological knowledge, we use the term *framework*. As we will see, representations of frameworks are structurally different from ontologies.

Whereas frameworks capture the systematic co-occurrence or the structural *relations* something has with other things, ontologies capture what things *are* in and of themselves. Where ontologies consist of definitions of terms that have 'natural' subsumption ('is-a') relations, frameworks describe such things as how activities are causally or intentionally related, or how objects are spatially and functionally configured.

Arguably, at a formal level the two are indistinguishable: every class in OWL is defined in relation to other classes, it cannot be otherwise. This distinction therefore is conceptual: it does not map easily onto representation formalisms. The conceptual distinction is analogous to the difference between intrinsic and accidental relations. We distinguish between those relations that make what a concept *is* and relations that place a concept in a particular frame of reference, or *context*. When a context is recurring and sufficiently stereotypical, it might well pay to represent its characteristic features. These features are not real 'properties', as they do not 'define' a concept, but merely enable its recognition.

Take for example a *hammer*, its composition of head and shaft is not by accident: it is this particular combination that allows the hammer to be used 'as a hammer'. However, the mereological relation between the hammer as object, and its composites is not part of its ontological definition. Many different kinds of hammers exist, e.g. sledgehammers, mallets, conveniently shaped stones etc., each of which differs ever so slightly in the nature of its composites and the relations between them. But they are all hammers. It is therefore only the function of the hammer as an instrument that defines what a hammer *is*, its mereological properties are merely circumstantial evidence. Searle [70] stressed that the hammer-as-such cannot be substituted with the hammer-as-object; whether some object is a hammer is a social fact and depends on an attribution of the hammer function given a context of use. This attribution pinpoints exactly the conceptual difference between ontologies and frameworks. Where frameworks may incorporate the context in which this attribution holds by default and thus (over) generalise the typical physical features of a hammer-as-object to the hammer-as-such, ontologies should maintain an explicit distinction between the two.

From a methodological point of view, this allows us to introduce a rule of thumb: a combination of concepts and relations, as in e.g. a class restriction, is only to be considered part of an ontology when this particular combination is either systematic and independent of context, or when it makes the context explicit. A possible second consideration is inspired by the limitations imposed on admissible structures by the knowledge representation formalism. Of course this is a rather practical consideration, but nonetheless useful when considering the widespread use of OWL. If the primary task of ontology is to describe what things are, then a representation formalism specifically tailored to classification can be a fair benchmark for determining whether the kind of knowledge you want to express should be considered part of ontology or not. Given the limited expressiveness of OWL DL, especially because of its tree-model property [61], many frameworks are more easily represented using a rule formalism as they often require the use of variables. In fact, as we show in [43], OWL can be used to represent non-tree like structures commonly found in frameworks but only in a very round-about and non-intuitive manner. Furthermore, *epistemic frameworks* may define epistemic roles which can only be applied by reasoning architectures that go beyond the services provided by OWL DL reasoners (e.g. when they require meta-level reasoning). The limitations of OWL thus indicate a correlation between the conceptual distinction and representation formalisms. However, the two perspectives should not be confounded. Frameworks belong to the T-Box of any knowledge representation system, independent of whether it is based on a DL formalism or not.

We distinguish three types of frameworks:

3.1. Situational frameworks

Situational frameworks are most characteristic for the notion of framework in general, because of the strong emphasis on context and teleology they share with frames and scripts [57, 67]. They are the stereotypical structures we use as plans for achieving our goals given some recurrent context, such as making coffee. These plans are not necessarily private to a single agent, and may involve transactions in which more than one actor participates. For instance, the definition of Eating-in-a-restaurant[17] is a structure consisting mainly of dependencies between the actions of clients and service personnel.

Another notable characteristic of situational frameworks is that they are not subclasses of the goal directed actions they describe. For instance, Eating-in-a-restaurant is not a *natural* sub-class of Eating but rather refers to a typical model of this action in the situational context of a restaurant. Furthermore, it usually does not make sense to define subclass relations between situational frameworks themselves. Although we can easily envisage a proliferation of all possible contexts of eating – Eating-at-home, Eating-with-family, etc. — but does eating in a French restaurant fundamentally differ from eating in a restaurant in general? [4, 10].

[17] In the following all concepts will start with a capital letter, properties and relations will not

From a legal perspective, situational frameworks can be imposed on actual situations through articles of procedural ('formal') law. Although the *stereotypical* plans given in by custom, and the *prescribed* plans of law differ in their justification – rationality vs. authority – their representation is largely analogous. Similarly, legal norms combine generic situation descriptions with some specific state or action, where the description is qualified by a deontic term. For instance, the norm that "vehicles should keep to the right of the road" states that the situation in which a vehicle keeps to the right is obliged.

In short, situational frameworks are a fundamental part of the way in which we makes sense of the world, and play a prominent role in both general and legal problem solving.

3.2. Mereological frameworks

Most entities, and objects and processes in particular, can be decomposed into several parts: they are *composites*. As we have seen in the hammer example, it can be tempting to incorporate a mereological view in the definition of a concept. A typical example is the definition of Car as having at least three, and usually four wheels, and at least one motor. However, a full *structural* description of a concept's parts and connections goes beyond what it *essentially* is. Cars are designed with a specific *function* in mind, and although there are certainly some constraints on its physical properties relevant to its definition, these are limited to those constraints actually necessary for fulfilling that function. Concept descriptions that do iterate over all or most parts of the concept are *mereological frameworks*, and can appear under a large diversity of names: structural models, configurations, designs, etc. Mereological frameworks play a major role in qualitative reasoning systems (see e.g. [21, 40]).

Arguably, the line between the mereological framework and ontological definition of a term is sometimes very thin. For instance, if we want to describe a bicycle as distinct from a tricycle, it is necessary to use the cardinality of the wheels as defining properties as these are *central* to the nature of the bicycle. On the other hand, the number of branches a tree might have hardly provides any information as to what a tree *is*.

3.3. Epistemological frameworks

Inference in knowledge based reasoning seldom occurs in isolation. It is part of a larger structure of interdependencies between various steps in the reasoning process. Such *epistemological frameworks* focus on the epistemological status of knowledge, e.g. the *use* of knowledge in reasoning as hypothesis or conclusion. Typical examples are the problem solving methods (PSM) found in libraries of problem solving components [15, 62, 68]. What sets the epistemological framework apart from mereological frameworks is its characteristic specification of dependencies between distinct steps in a reasoning methodology. For instance, a problem solving method is not just a break-down of some problem, but it also specifies control over inferences by assessing success and failure in arriving at (sub)goals in problem solving. They invariably have at least two components: some method for selecting or generating potential solutions (hypotheses), and a method for testing whether the solutions hold. Whether a solution holds depends on whether it satisfies all requirements, or whether it corresponds with, *explains*, empirical data.

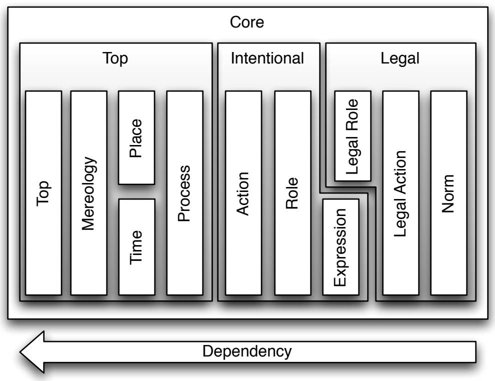

Figure 1. Dependencies between LKIF Core modules.

Not all epistemological frameworks are as specific as problem solving methods. For example, the Functional Ontology of Law of [75] is an epistemological framework describing the roles played by different types of knowledge in law as a system that controls society [14].

4. Ontology Modules

The preceding sections introduce the requirements for LKIF Core and specify a principled approach to (legal) ontology development. This approach is based on insights from cognitive science and uses a well established methodology. With these considerations in mind, the LKIF ontology was initially designed as a collection of eight ontology modules: *expression*, *norm*, *process*, *action*, *role*, *place*, *time* and *mereology*, cf. [9]. This collection was later extended with a top ontology, two more ontology modules (*legal_action*, *legal_role*), and two frameworks (*time_modification* and *rules*), see Figure 1, [44, 12]. Each of these modules contains a relatively independent cluster of concepts, represented using OWL DL in a middle-out fashion: for each cluster the most central concepts were represented first.[18]

We can distinguish three layers in the ontology: the *top* level (Section 4.1), the *intentional* level (Section 4.2) and the *legal* level (Section 4.3). These layers correspond to the different 'stances' one can adopt towards a domain of discourse, and are inspired by the work of Dennett [23] and Searle [70]. Dennet identified three stances we can adopt for explaining phenomena in the world: the *physical* stance, used for explaining behaviour in terms of of the laws of physics, the *design* stance, which assumes a system will behave according to its design, and the *intentional* stance, which can be adopted to explain the behaviour of rational agents, with beliefs, desires and intentions. The first two correspond roughly to the top level of LKIF Core , where the intentional stance is captured by the intentional level. The LKIF ontology thus adds a *legal* layer, containing concepts that are only sensible from a legal perspective. Accordingly, we represent social and legal

[18]The ontologies were developed using TopBraid Composer (`http://www.topbraidcomposer.com`) and Protégé 4.0a (`http://protege.stanford.edu`).

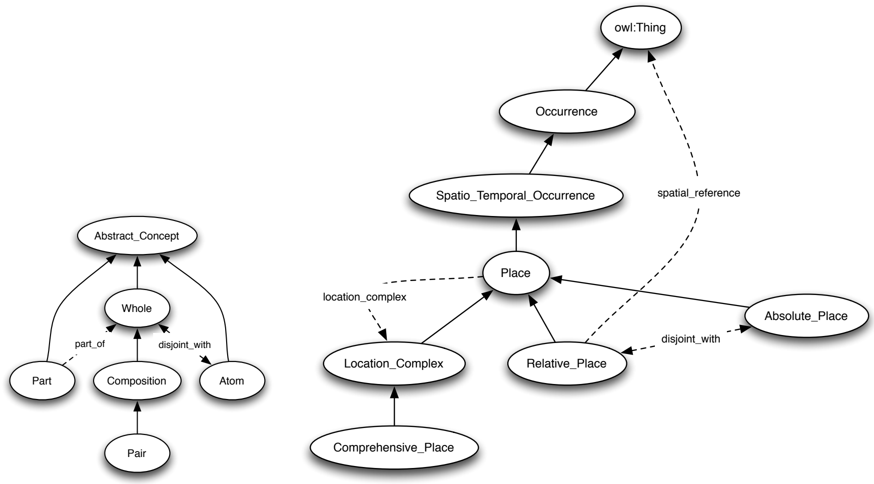

Figure 2. Place and Mereology related concepts.

concepts as social constructs separate from the physical entities having such imposition, e.g. persons are said to play roles, objects fulfil functions [70].

The layers in LKIF Core should not be confused with stratified meta levels; each new layer introduces a straightforward extension of existing definitions. At each level, concepts are expressed in terms of concepts defined at a higher level of abstraction, adding new organising structures (such as properties) where necessary. This methodology ensures a modular set-up that improves reusability and allows extensions to commit to the ontology at any of the levels.

4.1. First Things First: The top-level

The description of any legally relevant fact, event or situation requires a basic conceptualisation of the context in which these occur: the backdrop, or canvas, that is the physical world. Fundamental notions such as location, time, part-hood and change are indispensable in a description of even the simplest legal account. The top level clusters of the ontology provide (primitive) definitions of these notions, which are consequently used to define more intentional and legal concepts in other modules. The most general categories of the LKIF ontology are based on the distinction between 'worlds' of LRI Core. We distinguish between mental, physical and abstract entities, and occurrences. Mental entities reside in the human mind, and only have a temporal extension. Physical entities exist independent of human experience, and have a spatial extension as well. Although these categories are superimposed on the concepts in the top level clusters, they were not directive in in their design.

Mereological relations allow us to define parts and wholes; they can be used to express a systems-oriented view on concepts. Examples are functional decompositions, and containment characteristic for many frameworks (Figure 2). Mereology lies at the basis of definitions for *places* and moments and intervals in *time*. The ontology for places is based on the work of [24] and adopts the Newtonian distinction between *relative* and *absolute* places. A relative place is defined by reference to some thing; absolute places

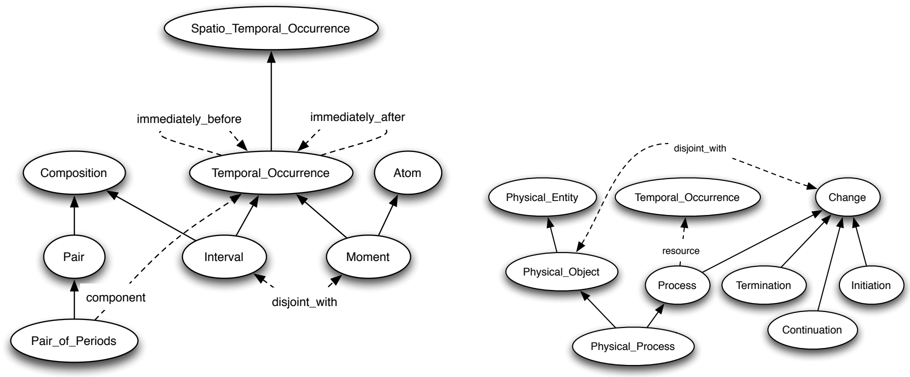

Figure 3. Concepts related to time and change.

are part of absolute space and have fixed spatial relations with other absolute places. A Location_Complex is a set of places that share a common reference location, e.g. the locations of all furniture in a room. See figure 2 for an overview of concepts defined in the place module. Of the properties defined in this module, meet is the most basic as it is used to define many other properties such as abut, cover, coincide etc. See [12, 24] for a more in depth discussion of these and other relations. Currently this module does not define classes and properties that express direction and orientation.

Similar relations can be used to capture notions of time and duration. We adopt the theory of time of [1, 2], and distinguish between the basic concepts of Interval and Moment. Intervals have an extent (duration) and can contain other intervals and moments. Moments are points in time, they are atomic and do not have a duration or contain other temporal occurrences (see figure 3). Relations between these temporal occurrences can be used to express a timeline. [1] introduced the meet relation to define two immediately adjacent temporal occurrences. To discern between the temporal meets relation and its spatial counterpart [24], we dub it immediately_before. Where the spatial relation is unrestricted with respect to direction, the temporal meet relation is directed and asymmetric. It is used to define other temporal relations such as before, after, during. Locations and temporal entities are used to define the extension of mental and physical entities, e.g. the time when you had a thought, the location where you parked your car. They are *occurrences* and do not have extensions themselves, they *are* extensions.

With these classes and properties in hand we introduce concepts of (involuntary) change. The process ontology relies on descriptions of time and place for the representation of duration and location of changes. A Change is defined as a difference between the situation before and after the change. It can be a functionally coherent aggregate of one or more other changes. More specifically, we distinguish between Initiation, Continuation and Termination changes.

Changes that occur according to a certain recipe or procedure, i.e. changes that follow from causal necessity are Processes. They thus introduce causal propagation and are said to *explain* the occurrence of change. Processes in LKIF Core are similar to the fluents of event calculus [77]. However, the ontology does not commit to a particular theory of causation and we consider the perspective generic enough to enable the definition of various disparate conceptions of causal relata. Contrary to changes, processes

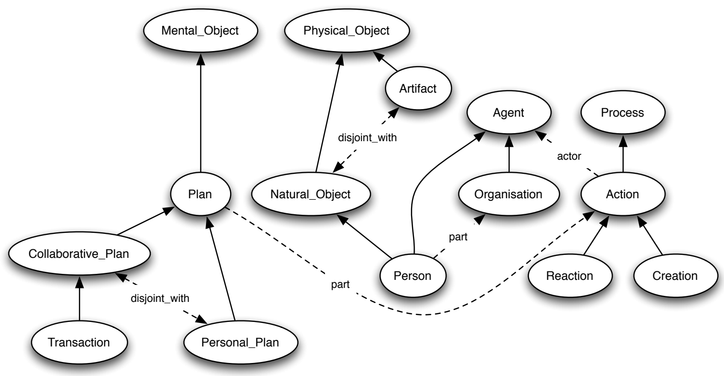

Figure 4. Actions, agents and organisations.

are both spatially and temporally restricted. They extend through time – they have duration – and are located at some temporal and spatial position. We furthermore distinguish Physical_Processes which operate on Physical_Objects.

4.2. *The Intentional Level*

Legal reasoning is based on a common sense understanding that allows the prediction and explanation of intelligent behaviour. After all, it is only the behaviour of rational agents that is governed by law. The modules at the intentional level include concepts and relations necessary for describing this behaviour: Actions undertaken by Agents in a particular Role. Furthermore, it introduces concepts for describing the mental state of these agents, e.g. their Intention or Belief, but also communication between agents by means of Expressions.

The class of agents is defined as the set of things which can be the actor of an action: they may perform the action and are potentially liable for any effects caused by the action (see figure 4). Actions are processes, they are the changes brought about by some agent in realising his intentions. Agents are the medium of an action's intended outcome: actions are always intentional. The intention held by the agent usually bears with it some expectation that the intended outcome will be brought about: the agent believes in this expectation. The actions an agent is expected or allowed to perform are constrained by the *competence* of the agent, sometimes expressed as *roles* assigned to the agent. Because actions are processes, they can play a role in of causal propagation, allowing us to reason backwards from effect to agent. Actions can be creative in that they initiate the coming into existence of some thing, or the converse terminate its existence. Also, actions are often a direct *re*action to some other action (see figure 4).

We distinguish between persons, individual agents such as "Joost Breuker" and "Pope Benedict XVI", and Organisations, aggregates of other organisations or persons which acts 'as one', such as the "Dutch Government" and the "Sceptics Society". Artefacts are physical objects designed for a specific purpose, i.e. to perform some Function as instrument in a specific set of actions such as "Hammer" and "Atlatl"[19]. Persons are

[19] An atlatl is a tool that uses leverage to achieve greater velocity in spear-throwing, see http://en.wikipedia.org/wiki/Atlatl

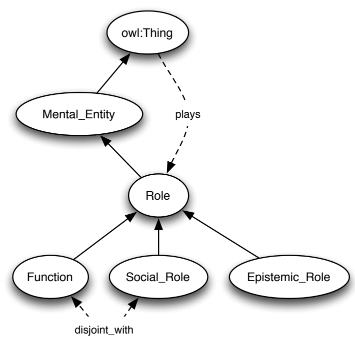

Figure 5. Roles.

physical objects as well, but are not designed (though some might hold the contrary) and are subsumed under the class of Natural_Objects. Note that natural objects can function as tools or weapons as well, but are not *designed* for that specific purpose.

The notion of roles played an important part in recent discussions on ontology [72, 55, 38]. Roles specify standard or required properties and behaviour of the entities playing the role (see figure 5). However, they not only allow us to categorise objects according to their prototypical use and behaviour, they also provide the means for categorising the behaviour of other agents. They are a necessary part of making sense of the social world and allow for describing social organisation, prescribe behaviour of an agent within a particular context, and recognise deviations from 'correct' or normal behaviour. Indeed, roles and actions are closely related concepts: a role defines some set of actions that can be performed by an agent, but is conversely defined by those actions. The role module captures the roles and functions that can be played and held by agents and artefacts respectively, and focuses on *social* roles, rather than traditional thematic or relational roles.

A consequence of the prescriptive nature of roles is that agents connect expectations of behaviour to other agents: intentions and expectations can be used as a model for intelligent decision making and planning.[20] It is important to note that there is an *internalist* and an *externalist* way to use intentions and expectations. The external observer can only ascribe intentions and expectations to an agent based on his observed actions. The external observer will make assumptions about what is *normal*, or apply a *normative* standard for explaining the actions of the agent.

The expression module covers a number of representational primitives necessary for dealing with Propositional_Attitudes (viz. [19]). Many concepts and processes in legal reasoning and argumentation can only be explained in terms of propositional attitudes: a relational mental state connecting a person to a Proposition. However, in many applications of LKIF the attitude of the involved agents towards a proposition will not be relevant at all. For instance, fraud detection applications will only care to distinguish between potentially contradictory observations or expectations relating to the same propositional

[20] Regardless of whether it is a psychologically plausible account of decision making. Daniel Dennett's notion of the *Intentional Stance* is interesting in this context (cf. [23]). Agents may do no more than occasionally apply the stance they adopt in assessing the actions of others to themselves.

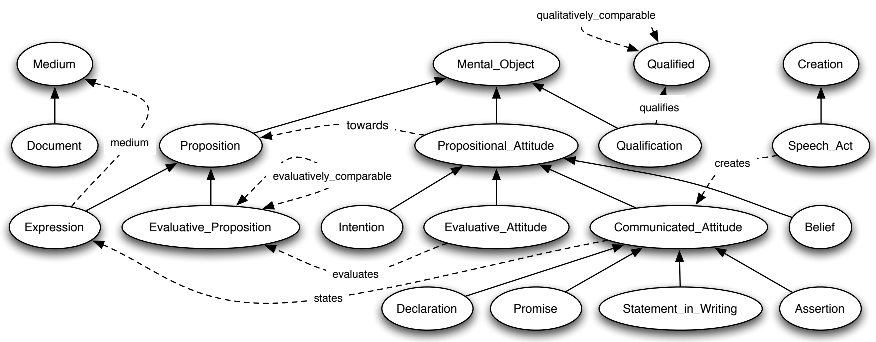

Figure 6. Propositions, Attitudes and Expressions.

content. Examples of propositional attitudes are Belief, Intention, and Desire. Each is a component of a mental model, held by an Agent.

Communicated attitudes are held towards expressions: propositions which are externalised through some medium. Statement, Declaration, and Assertion are expressions communicated by one agent to one or more other agents. This classification is loosely based on Searle (cf. [69]). A prototypical example of a medium in a legal setting is e.g. the Document as a bearer of legally binding (normative) statements.

When propositions are used in reasoning they have an epistemic role, e.g. as Assumption, Cause, Expectation, Observation, Reason, Fact etc. The role a proposition plays within reasoning is dependent not only on the kind of reasoning, but also the level of trust as to the validity of the proposition, and the position in which it occurs (e.g. hypothesis vs. conclusion). In this aspect, the expression module is intentionally left underdefined. A rigourous definition of propositional attitudes relates them to a theory of reasoning and an argumentation theory. This argumentation theory is to be supplied by an argumentation ontology or framework. The theory of reasoning depends on the type of reasoning task (assessment, design, planning, diagnosis, etc.) LKIF is used in, and should be filled in (if necessary) by the user of LKIF .

Evaluative_Attitudes express an evaluation of a proposition with respect to one or more other propositions, they express e.g. an evaluation, a value statement, value judgement, evaluative concept, etc. I.e. only the type of qualification which is an attitude towards the thing being evaluated, and not for instance the redness of a rose, as in [27] and others. Of special interest is the Qualification, which is used to define norms based on [7]. Analogous to the evaluative attitude, a qualification expresses a judgement. However, the subject of this judgement need not be a proposition, but can be any complex description (e.g. a situation).

4.3. The Legal Level

Legally relevant statements are created through public acts by both natural and legal persons. The legal status of the statement is dependent on both the kind of agent creating the statement, i.e. Natural_Person vs. a Legislative_Body, and the rights and powers attributed to the agent through mandates, assignments and delegations. At the legal level, the LKIF ontology introduces a comprehensive set of legal agents and actions, rights and

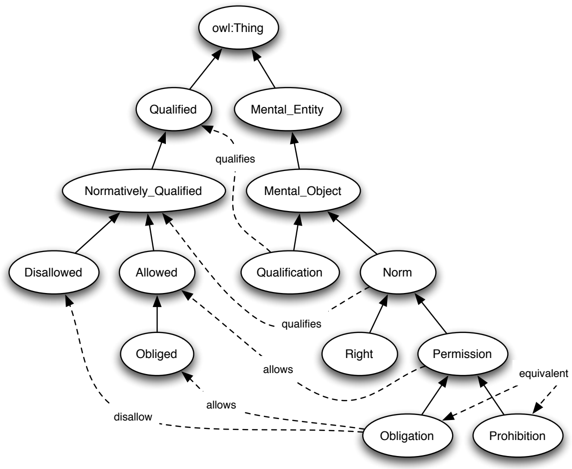

Figure 7. Qualifications and Norms

powers (a modified version of [66, 65]), typical legal roles, and concept definitions which allow us to express normative statements as defined in [7, 5, 6].

The Norm is a statement combining two performative meanings: it is *deontic*, in the sense that it is a qualification of the (moral or legal) acceptability of some thing, and it is *directive* in the sense that it commits the speaker to bringing about that the addressee brings about the more acceptable thing (cf. [64]), presumably through a sanction. These meanings do not have to occur together. It is perfectly possible to attach a moral qualification to something without directing anyone, and it is equally possible to issue a directive based on another reason than a moral or legal qualification (e.g. a warning).

A norm applies to (or qualifies) a certain situation (the Qualified situation), allows a certain situation – the Obliged situation or Allowed situation – and disallows a certain situation – the Prohibited or Disallowed situation, see Figure 7. The obliged and prohibited situation are both subsumed by the situation to which the norm applies.[21] Besides this, they by definition form a complete partition of the case to which the norm applies, i.e. all situation to which the norm applies are either a mandated case or a prohibited situation. This is true of the obligation and the prohibition: they are simply two different ways to put the same thing into words. The permission is different in that it allows something, but it does not prohibit anything. The logical complement of the mandated situation is here an opposite qualified situation, about which we know only that it cannot be obliged.

Where in other approaches, cf. CLO, a situation is the reification of some state of affairs, the normatively qualified situations in LKIF Core are instantiated by states of affairs: they are defined as class descriptions that represent a set of possible states of affairs. This means that a standard reasoner can infer whether some actual situation is subsumed under a generic situation, and thus whether norms exist that allows or disallows that situation. Similarly, a classifier will create an inferred hierarchy of situations, which enables a relatively straightforward resolution of *lex specialis* exceptions between norms [7].

[21] Normatively qualified situations are analogous to the generic situations, or generic cases of [75].

The next section gives a brief example of how this mechanism can be applied to build representations of actual normative systems.

5. The Ontology in Practice

The LKIF ontology not only provides a theoretical understanding of the legal domain, but its primary use in practice is as a tool to facilitate knowledge acquisition, exchange and representation: i.e. to formalise pieces of existing legislation. The first, comprehensive evaluation of LKIF Core was done in the formalisation of EU Directive 2006/126 on driving licences,[22] a relatively straightforward regulation in which at least two types of normative statement are recognisable – definitional and deontic. An example of a *definitional statement* from the directive is:

> **Art. 4(2)** *Category AM*
> Two-wheel vehicles or three-wheel vehicles with a maximum design speed of not more than 45 km/h.

The mereology module of the ontology along with a qualified cardinality restriction (available in OWL 2) allows us to express that AM vehicles have two or three wheels:

$$\mathsf{AM} \sqsubseteq \mathsf{composed\_of}\ \textbf{exactly}\ 2\ \mathsf{Wheel} \sqcup \mathsf{composed\_of}\ \textbf{exactly}\ 3\ \mathsf{Wheel}$$

Modelling 'design speed not more than 45 km/h' is more challenging as it requires us to represent the domain of speeds and distances. Of course, one could introduce the datatype property designSpeed and require its value be expressed in km/h. Although the set of built-in datatypes of OWL 2 does not include km/h, we can define a custom datatype for speeds. However, the representation of speed using a concrete domain does not do justice to its conceptual complexity, as it involves several other notions: unit of measurement, number, designed speed, and a 'no-more' relation. Furthermore, a custom datatype can only impose a syntactic check on a value. As a speed-value is syntactically no different than the values covered by built-in datatypes such as xsd:integer and xsd:float, introducing a custom datatype does not extend expressive power.

In fact, for the current purposes, the concept can be represented by imposing a *linear ordering* relation less-than on the different (instances of the) subclasses of a class DesignSpeed. For any $n \leq m$, we have that:

$$\mathsf{DesignSpeed\text{-}km\text{-}h\text{-}}n(a)\ \mathsf{less\text{-}than}\ \mathsf{DesignSpeed\text{-}km\text{-}h\text{-}}m(b)$$

with a, b instances. This allows us to define the class of those DesignSpeeds with a value not exceeding that of the class of speeds with the exact value '45', i.e. less-than **only** DesignSpeed-km-h-45. The representation of definitional statements using the LKIF ontology is thus somewhat limited because of the broad range of domain concepts possibly involved in a definition. Of course, a complete coverage of all domains can not be expected of a core ontology. Nonetheless, the representation of article 4(2) suggests the need for an extension of the LKIF ontology with a module that defines quantities, units of measurement, numbers, fractions, mathematical operations, etc. This is crucial not only for the EU Directive 2006/126, in which most definitional statements contain quantita-

[22] The text is available on-line at http://eur-lex.europa.eu/.

tive features of vehicles (e.g. power, cylinder capacity), but quantities and calculations play a central role in most, if not all legislative texts. We are currently evaluating possible inclusion of readily available unit ontologies.[23]

On the other hand, *deontic statements* express norms in terms of the concepts introduced by definitional statements. For instance,

> **Art. 4(2)**
> The minimum age for category *AM* is fixed at 16 years.

This article expresses an obligation whose logical form can be rendered by an implication:

> If x is driving a AM vehicle, then x **must** be at least 16 years old.

Here, the antecedent is the *context* to which the obligation applies; the consequent (minus the deontic operator **must**) is the *content* of the obligation itself, i.e. that which the obligations prescribes it ought to be the case. Consistent with this analysis, the LKIF ontology defines obligations as classes (see Section 4.3).

The article allows situations that match the description DriverAM $\sqcap$ DriverOlderThan16 and forbids DriverAM $\sqcap$ $\neg$DriverOlderThan16. Given the presence of straightforward definitions of DriverOlderThan16 and DriverAM,[24] we can define the obligation that drives of AM vehicles must be at least 16 years or older as follows:

$$\mathsf{MinAgeAM} \sqsubseteq \mathsf{allows}\ \textbf{only}\ (\mathsf{DriverAM} \sqcap \mathsf{DriverOlderThan16})$$

$$\mathsf{MinAgeAM} \sqsubseteq \mathsf{allows}\ \textbf{some}\ (\mathsf{DriverAM} \sqcap \mathsf{DriverOlderThan16})$$

$$\mathsf{MinAgeAM} \sqsubseteq \mathsf{disallows}\ \textbf{only}\ (\mathsf{DriverAM} \sqcap \neg\mathsf{DriverOlderThan16})$$

$$\mathsf{MinAgeAM} \sqsubseteq \mathsf{disallows}\ \textbf{some}\ (\mathsf{DriverAM} \sqcap \neg\mathsf{DriverOlderThan16})$$

Other deontic operators, such as permission or prohibition, can be accounted in an alike manner (see [6]). Notwithstanding the parsimony of this type of definition, using the LKIF ontology to model normative statements proves to be rather straightforward. Of course, a specialised modelling environment for legislative drafters would need to provide a shorthand for the standard patterns used in OWL definitions of norms. The norm module is currently used in the development of a legal assessment plugin to Protege 4.

Use of the ontology in practice not only called for more detailed domain modelling, as was to be expected, but it also required us to explore the limits of OWL 2's expressiveness, in particular in the representation of the complex structure of transactions and situations [43]. Furthermore, as versioning and applicability play a central role in legal reasoning, we evaluated the the ontology in the representation of intricate versioning of definitions and norms in the Nomic game in [48].

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[23] E.g. the ontology by Michel Dumontier, or a translation of the PHYSSYS ontology in OWL DL. See `http://www.dumontierlab.com/`, `http://www.ksl.stanford.edu/software/ontolingua/`, respectively.

[24] The class DriverOlderThan16 can be defined by using a more-than ordering relation, roughly along the same lines as the class less-than **only**DesSpeed-km-h-45.

6. Discussion

We presented a principled approach to ontology development in the legal domain, and described how it was applied in the development of the LKIF Core ontology. The initial requirements for this ontology, as part of LKIF, are that it should be a resource for special, legal inference, and that it provides support for knowledge acquisition. The legal domain poses additional requirements on the ontology in that it presupposes a common sense grounding. We discussed several other ontologies, argued where they fall short in providing this grounding, and presented an approach based on insights from cognitive science and knowledge engineering, rather than philosophy. This approach was further discussed as the basis for a comprehensive methodology for ontology development, including a principled distinction between frameworks and ontologies. The LKIF Core ontology was developed using this methodology, and is composed of fourteen modules, two of which represent frameworks. We briefly introduced the main concepts in these modules and gave an example of how the ontology can be used in modelling an EU directive.

As LKIF Core was developed by a heterogeneous group of people, we specified a number of conventions to uphold during the representation of terms identified in the previous phases [12]. One of these is that classes should be represented using necessary & sufficient conditions as much as possible (i.e. by means of owl:equivalentClass statements). Using such 'complete' class definitions ensures the ability to infer the type of individuals, which is not possible by means of partial class definitions (using only necessary conditions).

In retrospect, this convention turned out to pose severe problems for existing OWL 1 and OWL 2 DL reasoners as their performance is significantly affected by the generic concept inclusion axioms (GCI): axioms where the left-hand side of a rdfs:subClassOf statement is a complex class definition. These axioms are abundant when defining classes as equivalent to e.g. owl:someValuesFrom restrictions and in combination with lots of inverse property definitions, this creates a large completion graph for DL reasoners.[25] As result of these findings, the LKIF ontology has underwent a significant revision since its initial release. However, reasoner performance remains an issue with large, complex ontologies such as LKIF Core. Accurate representations for the purpose of legal reasoning push the limits of OWL even further, and we expect some optimisation to be necessary before a legal assessment system based on this technology can be used in practice.

Using LKIF Core to represent regulations, as e.g. in the traffic example, furthermore points to the traditional knowledge representation threshold: for any formal representation of any domain, one needs to build formal representations of adjoining domains. As has been said, this can be largely overcome by including other generic or domain ontologies in a representation based on the LKIF ontology; provided that the quality of these ontologies is sufficient. Depending on availability we might consider providing a library of 'compatible' ontologies to users of LKIF Core. This will be of especial use when the ontology vocabulary is adopted for expressing the LKIF vendor models that are currently being developed within the Estrella project. Recent experience suggests that the ontology should be extended with not only a module for expressing measurements, but also frame-

[25] Thanks to Taowei David Wang for pointing this out, see http://lists.owldl.com/pipermail/pellet-users/2007-February/001263.html

works that allow us to adequately capture transactions and other more complex action structures.

With respect to coverage of the legal domain, the purpose of the study outlined in Section 2.1 is more ambitious than only the selection of the most basic terms for describing law, but time and effort constraints make it that we could only consider a small pool of referents. To achieve best results, the list of terms could be subjected to a more rigourous empirical study, e.g. by consulting groups of legal professionals (taking courses in legal drafting) and law students. This empirical study is planned in the sideline of Estrella. By applying statistical cluster analysis, we might be able to identify the properties of the scales used (e.g. are they independent?) and determine whether the statistical clusters have some resemblance to the clusters we have identified based on more theoretical considerations.

The LKIF ontology is available online as separate but interdependent OWL DL files, and can be obtained from the Estrella website at `http://www.estrellaproject.org/lkif-core`. This website also provides links to online documentation and relevant literature.

References

[1] J. Allen. Towards a general theory of action and time. *Artificial Intelligence*, 23:123–154, 1984.

[2] James F. Allen and George Ferguson. Actions and events in interval temporal logic. Technical Report TR521, Rochester University, Department of Computer Science, NY, 1994.

[3] S. Bechhofer, F. van Harmelen, J. Hendler, I. Horrocks, D. L. McGuinness, P. F. Patel-Schneider, and L. A. Stein. OWL web ontology language reference. W3C recommendation, World Wide Web Consortium (W3C), February 2004. M. Dean, G. Schreiber (eds.).

[4] Olivier Bodenreider, Barry Smith, and Anita Burgun. The ontology-epistemology divide: A case study in medical terminology. In Achille C. Varzi and Laure Vieu, editors, *Formal Ontology in Information Systems, Proceedings of the Third International Conference (FOIS 2004)*, Frontiers in Artificial Intelligence and Applications, pages 185–195, Torino, November 2004. IOS Press.

[5] Alexander Boer. Note on production rules and the legal knowledge interchange format. Technical report, Leibniz Center for Law, Faculty of Law, University of Amsterdam, 2006.

[6] Alexander Boer, Thomas F. Gordon, Kasper van den Berg, Marcello Di Bello, András Förhécz, and Réka Vas. Specification of the legal knowledge interchange format. Deliverable 1.1, Estrella, 2007.

[7] Alexander Boer, Tom van Engers, and Radboud Winkels. Mixing legal and non-legal norms. In M-F. Moens and P. Spyns, editors, *Jurix 2005: The Eighteenth Annual Conference.*, Legal Knowledge and Information Systems, pages 25–36, Amsterdam, 2005. IOS Press.

[8] Alexander Boer, Radboud Winkels, Tom van Engers, and Emile de Maat. A content management system based on an event-based model of version management information in legislation. In T. Gordon, editor, *Legal Knowledge and Information*

Systems. Jurix 2004: The Seventeenth Annual Conference., Frontiers in Artificial Intelligence and Applications, pages 19–28, Amsterdam, 2004. IOS Press.

[9] Joost Breuker, Alexander Boer, Rinke Hoekstra, and Kasper van den Berg. Developing content for LKIF: Ontologies and frameworks for legal reasoning. In Tom M. van Engers, editor, *Legal Knowledge and Information Systems. JURIX 2006: The Nineteenth Annual Conference*, volume 152 of *Frontiers in Artificial Intelligence and Applications*, 2006.

[10] Joost Breuker and Rinke Hoekstra. Core concepts of law: taking common-sense seriously. In A.C. Varzi and L. Vieu, editors, *Proceedings of Formal Ontologies in Information Systems (FOIS-2004)*, pages 210–221. IOS-Press, 2004.

[11] Joost Breuker and Rinke Hoekstra. Epistemology and ontology in core ontologies: FOLaw and LRI-Core, two core ontologies for law. In Aldo Gangemi and Stefano Borgo, editors, *Proceedings of the EKAW Workshop on Core Ontologies in Ontology Engineering*. CEUR, 2004.

[12] Joost Breuker, Rinke Hoekstra, Alexander Boer, Kasper van den Berg, Rossella Rubino, Giovanni Sartor, Monica Palmirani, Adam Wyner, and Trevor Bench-Capon. OWL ontology of basic legal concepts (LKIF-Core). Deliverable 1.4, Estrella, 2007.

[13] Joost Breuker, Patries Kordelaar, and et al. Comparing models. Deliverable 2.5, estrella project, University of Amsterdam, 2008.

[14] Joost Breuker, Andre Valente, and Radboud Winkels. Use and reuse of legal ontologies in knowledge engineering and information management. In V.R. Benjamins, P. Casanovas, J. Breuker, and A.Gangemi, editors, *Law and the Semantic Web*, pages 36 – 64. Springer, 2004.

[15] Joost Breuker and Walter Van De Velde, editors. *CommonKADS Library for Expertise Modeling: reusable problem solving components*. IOS-Press/Ohmsha, Amsterdam/Tokyo, 1994.

[16] Joost Breuker, Saskia van der Ven, Abdallah El Ali, Marc Bron, Rinke Hoekstra, Szymon Klarman, Urosh Milosovics, Lars Wortel, and Andŕas Förhécz. Developing HARNESS. Estrella deliverable 4.6, University of Amsterdam, http://relay.leibnizcenter.org/, 2008.

[17] Pompeu Casanovas, Nuria Casellas, Joan-Josep Vallbe, Maria Poblet, Richard Benjamins, Mercedes Blazquez, Raul Pena, and Jesus Contreras. Semantic web: a legal case study. In Jahn Davies, Rudi Studer, and Paul Warren, editors, *Semantic Web Technologies*. Wiley, 2006.

[18] Bernardo Cuenca Grau, Ian Horrocks, Yevgeny Kazakov, and Ulrike Sattler. Ontology reuse: Better safe than sorry. In Diego Calvanese, Enrico Franconi, Volker Haarslev, Domenico Lembo, Boris Motik, Anni-Yasmin Turhan, and Sergio Tessaris, editors, *Description Logics*, volume 250 of *CEUR Workshop Proceedings*. CEUR-WS.org, 2007.

[19] Mats Dahllöf. On the semantics of propositional attitude reports, 1995.

[20] Donald Davidson. *Essays on Actions and Events*. Oxford University Press, Oxford, 2001.

[21] R. Davis. Diagnostic reasoning based on structure and behavior. *Artificial Intelligence*, 24:347–410, 1984.

[22] Randall Davis, Howard E Shrobe, and Peter Szlovits. What is knowledge representation? *AI Magazine*, 14(1):17–33, 1993.

[23] Daniel C. Dennett. *The Intentional Stance*. MIT-Press, 1987.

[24] M. Donnelly. Relative places. *Applied Ontology*, 1(1):55–75, 2005.

[25] Mariano Fernández, Asunción Gómez-Pérez, and Natalia Juristo. METHONTOLOGY: From ontological art towards ontological engineering. In *AAAI-97 Spring Symposium on Ontological Engineering*, pages 33–40, 1997.

[26] K. D. Forbus. Qualitative process theory. *Artificial Intelligence*, 24:85–168, 1984.

[27] A. Gangemi, N. Guarino, C. Masolo, A. Oltramari, and L. Schneider. Sweetening ontologies with DOLCE. In A. Gomez-Perez and V.R. Benjamins, editors, *Proceedings of the EKAW-2002*, pages 166–181. Springer, 2002.

[28] A. Gangemi and P. Mika. Understanding the semantic web through descriptions and situations. In *Proceedings of CoopIS/DOA/ODBASE*, pages 689–706, 2003.

[29] A. Gangemi, M.T. Sagri, and D. Tiscornia. A constructive framework for legal ontologies. In V.R. Benjamins, P. Casanovas, J. Breuker, and A. Gangemi, editors, *Law and the Semantic Web*, pages 97–124. Springer Verlag, 2005.

[30] Aldo Gangemi. Ontology design patterns for semantic web content. In Yolanda Gil et al., editor, *International Semantic Web Conference*, volume 3729 of *Lecture Notes in Computer Science*, pages 262–276. Springer, 2005.

[31] Michael R. Genesereth and Richard E. Fikes. Knowledge Interchange Format, Version 3.0 Reference Manual. Technical Report Logic-92-1, Computer Science Department, Stanford University, Stanford, CA, USA, 1992.

[32] T.F. Gordon. Constructing arguments with a computational model of an argumentation scheme for legal rules. In Radboud Winkels, editor, *Proceedings of the Eleventh International Conference on Artificial Intelligence and Law*, pages 117–121. IAAIL, ACM, 2007.

[33] T.F. Gordon, H. Prakken, and D. Walton. The carneades model of argument and burden of proof. *Artificial Intelligence*, 171(10-11):875–896, 2007.

[34] Thomas F. Gordon, Kasper van den Berg, Patries Kordelaar, Jasmine Lee, Samir Sekkat, and Adam Wyner. Formal specifications of the knowledge formats of participating LKBS vendors. Deliverable 1.2, Estrella, 2007.

[35] T. R. Gruber. A translation approach to portable ontology specifications. *Knowledge Acquisition*, 5(2):199–220, 1993.

[36] T. R. Gruber. Toward principles for the design of ontologies used for knowledge sharing. In N. Guarino and R. Poli, editors, *Formal Ontology in Conceptual Analysis and Knowledge Representation*, Deventer, The Netherlands, 1994. Kluwer Academic Publishers.

[37] Michael Grüninger and Mark S. Fox. Methodology for the design and evaluation of ontologies. In *IJCAI'95, Workshop on Basic Ontological Issues in Knowledge Sharing*, 1995.

[38] N. Guarino and C. Welty. Evaluating ontological decisions with OntoClean. *Communications of the ACM*, 45(2):61–65, 2002.

[39] Nicola Guarino. The ontological level. In R. Casati, B. Smith, and G. White, editors, *Philosophy and the Cognitive Sciences, Proceedings of the 16th International Wittgenstein Symposium*, pages 443–456, Vienna, 1994. Hölder-Pichler-Tempsky.

[40] W. C. Hamscher, L. Console, and J. de Kleer, editors. *Readings in Model-Based Diagnosis*. Morgan Kaufmann, San Mateo, CA, 1992.

[41] P. J. Hayes. The second naive physics manifesto. In J. R. Hobbs and R. C. Moore, editors, *Formal Theories of the Commonsense World*, volume 1 of *Ablex series in Artificial Intelligence*, pages 1–36. Ablex, Norwood, NJ, June 1985.

[42] Rinke Hoekstra. Use of OWL in the legal domain (statement of interest). In Kendall Clark and Peter F. Patel-Schneider, editors, *Proceedings of OWL: Experiences and Directions (OWLED 2008 DC)*, Washington, DC (metro), April 2008.

[43] Rinke Hoekstra and Joost Breuker. Polishing diamonds in OWL 2. In Aldo Gangemi and Jérôme Euzenat, editors, *Proceedings of the 16th International Conference on Knowledge Engineering and Knowledge Management (EKAW 2008)*, LNAI/LNCS. Springer Verlag, October 2008. To be published.

[44] Rinke Hoekstra, Joost Breuker, Marcello Di Bello, and Alexander Boer. The LKIF Core ontology of basic legal concepts. In Pompeu Casanovas, Maria Angela Biasiotti, Enrico Francesconi, and Maria Teresa Sagri, editors, *Proceedings of the Workshop on Legal Ontologies and Artificial Intelligence Techniques (LOAIT 2007)*, June 2007.

[45] Rinke Hoekstra, Joost Breuker, Marcello Di Bello, and Alexander Boer. LKIF Core: Principled ontology development for the legal domain. In Joost Breuker, Pompeu Casanovas, Michel Klein, and Enrico Francesconi, editors, *Law, Ontologies and the Semantic Web*, Frontiers of Artificial Intelligence and Applications. IOS Press, Amsterdam, 2008. To be Published.

[46] ISO/IEC. Common Logic (CL) - a framework for a family of logic-based languages. Technical Report 24707:2007, ISO/IEC, 2007.

[47] Szymon Klarman and Rinke Hoekstra. Summary of the specification of the Legal Knowledge Interchange Format deliverable 1.1. Technical report, University of Amsterdam, 2008.

[48] Szymon Klarman, Rinke Hoekstra, and Marc Bron. Versions and applicability of concept definitions in legal ontologies. In Kendall Clark and Peter F. Patel-Schneider, editors, *Proceedings of OWL: Experiences and Directions (OWLED 2008 DC)*, Washington, DC (metro), April 2008.

[49] George Lakoff. *Women, Fire and Dangerous Things*. University of Chicago Press, 1987.

[50] George Lakoff and Rafael Núñez. *Where Mathematics Comes From*. Basic Books, 2000.

[51] Guiraude Lame. Using nlp techniques to identify legal ontology components: Concepts and relations. *Artificial Intelligence and Law, This Issue?*, 2004.

[52] Douglas B. Lenat. CYC: A large-scale investment in knowledge infrastructure. *Communications of the ACM*, 38(11):33–38, 1995.

[53] Douglas B. Lenat, R. V. Guha, Karen Pittman, Dexter Pratt, and Mary Shepherd. Cyc: toward programs with common sense. *Commun. ACM*, 33(8):30–49, 1990.

[54] C. Masolo, S. Borgo, A. Gangemi, N. Guarino, and A. Oltramari. WonderWeb ontology library. Deliverable D18, version 1, ISTC-CNR (Italy), 2003.

[55] C. Masolo, L. Vieu, E. Bottazzi, C. Catenacci, R. Ferrario, Aldo Gangemi, and Nicola Guarino. Social roles and their descriptions. In *Proceedings of Knowledge Representation Workshop*, 2004.

[56] John McCarthy. Programs with common sense. In *Proceedings of the Teddington Conference on the Mechanization of Thought Processes*, pages 75–91, London, 1959. Her Majesty's Stationary Office.

[57] Marvin Minsky. A framework for representing knowledge. In P.H. Winston, editor, *The Psychology of Computer Vision*. McGraw-Hill, New York, 1975.

[58] Marvin Minsky. Why people think computers can't. *AI Magazine*, 3(4), Fall 1982.

[59] Marvin Minsky. *The Society of Mind*. Simon & Schuster Inc., 1984.

[60] Boris Motik, Peter F. Patel-Schneider, and Ian Horrocks. OWL 2 web ontology language: Syntax. Pre-working draft, W3C, 2008. (to be published, may be superseded).

[61] Boris Motik, Ulrike Sattler, and Rudi Studer. Query answering for OWL-DL with rules. *Journal of Web Semantics: Science, Services and Agents on the World Wide Web*, 3(1):41 – 60, July 2005.

[62] Enrico Motta. *Reusable Components for Knowledge Modelling*. FAIA-Series. IOS Pres, Amsterdam NL, 1999.

[63] I. Niles and A. Pease. Towards a standard upper ontology. In Chris Welty and Barry Smith, editors, *Proceedings of the 2nd International Conference on Formal Ontology in Information Systems (FOIS-2001)*, Ogunquit, Maine, October 17-19 2001.

[64] Jan Nuyts, Pieter Byloo, and Janneke Diepeveen. On deontic modality, directivity, and mood, 2005.

[65] Rosella Rubino, Antonino Rotolo, and Giovanni Sartor. An owl ontology of fundamental legal concepts. In Tom M. van Engers, editor, *Legal Knowledge and Information Systems. JURIX 2006: The Nineteenth Annual Conference*, volume 152 of *Frontiers of Artificial Intelligence and Applications*. IOS Press, 2006.

[66] Giovanni Sartor. Fundamental legal concepts: A formal and teleological characterisation. Technical report, European University Institute, Florence / Cirsfid, University of Bologna, 2006.

[67] R. Schank and R. Abelson. *Scripts, Plans Goals and Understanding*. Lawrence Erlbaum, New Jersey, 1977.

[68] G. Schreiber, H. Akkermans, A. Anjewierden, R. de Hoog, N. Shadbolt, W. Van den Velde, and B. Wielinga. *Knowledge Engineering and Managament: The CommonKADS Methodology*. MIT Press, 2000.

[69] John Searle and Daniel Vanderveken. *Foundations of illocutionary logic*. Cambridge University Press, Cambridge, England, 1985.

[70] John R. Searle. *The Construction of Social Reality*. The Free Press, New Yor, NY, 1995.

[71] John F. Sowa. *Knowledge Representation: Logical Philosophical, and Computational Foundations*. Brooks Cole Publishing Co, Pacific Grove, CA, 2000.

[72] Friedrich Steimann. On the representation of roles in object-oriented and conceptual modelling. *Data and Knowledge Engineering*, 35(1):83–106, October 2000.

[73] Mike Uschold. Building ontologies: Towards a unified methodology. In *16th Annual Conf. of the British Computer Society Specialist Group on Expert Systems*, Cambridge, UK, 1996.

[74] Mike Uschold and Martin King. Towards a methodology for building ontologies. In *Workshop on Basic Ontological Issues in Knowledge Sharing, IJCAI-95*, Montreal, Canada, 1995.

[75] A. Valente. *Legal Knowledge Engineering: A Modelling Approach*. PhD thesis, University of Amsterdam, Amsterdam, 1995.

[76] Saskia van de Ven, Rinke Hoekstra, Joost Breuker, Lars Wortel, and Abdallah El-Ali. Judging Amy: Automated legal assessment using OWL 2. In *Proceedings of OWL: Experiences and Directions (OWLED 2008 EU)*, October 2008.

[77] Michiel van Lambalgen and Fritz Hamm. *The Proper Treatment of Events*, volume 4 of *Explorations in Semantics*. Blackwell Publishing, 2005.

[78] R. Winkels, A. Boer, J. Breuker, and D. Bosscher. Assessment based legal information serving and cooperative dialogue in clime. In *Proceedings of Jurix-98*, pages 131–146, Nijmegen, Netherlands, 1998. GNI.

[79] Raboud Winkels and Henk de Bruijn. Case frames: Bridging the gap between a case and the law. In I. Carr and A. Narayanan, editors, *Proceedings of the First European Conference on Computers, Law and AI*, pages 205–213, Exeter, 1996. EUCLID.

[80] Radboud Winkels, Alexander Boer, and Rinke Hoekstra. CLIME: lessons learned in legal information serving. In Frank Van Harmelen, editor, *Proceedings of the European Conference on Artificial Intelligence-2002, Lyon (F)*, Amsterdam, 2002. IOS-Press.

[81] R.G.F. Winkels, D. Bosscher, A. Boer, and J.A. Breuker. Generating exception structures for legal information serving. In Th.F. Gordon, editor, *Proceedings of the Seventh International Conference on Artificial Intelligence and Law (ICAIL-99)*, pages 182–195. ACM, New York, 1999.