Automation of Legal Reasoning and Decision Based on Ontologies

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Abstract. The main goal of our research is to build a legal reasoning system that performs decision support functions in the criminal domain. The system is based on a rule-based reasoning model which is composed of a legal domain ontology, rule base and reasoning engine. The legal domain ontology is needed for modelling the legal norms of the criminal domain. For this purpose, a middle-out approach is proposed to modularize the ontology in order to reduce the complexity and the difficulties of ontology building process. The rule base contains set of logic legal rules formalized based on the ontology.

Keywords: Legal Ontology, Rule-Based Reasoning, Modular Ontology, Ontology Reuse, Ontology Integration, Criminal Domain.

1 Research Question

Our research analyses the problem of building reusable legal domain ontologies for legal reasoning and decision support systems. Legal decision support systems, known as legal knowledge based systems (LKBS) [1], are capable of legal reasoning [2], since they are based on a model that describe the norms operating in the legal system [3]. There are three main models for legal reasoning: rule-based, case-based and hybrid. For the current research, the scope is limited to rule-based legal reasoning. Generally, rule-based reasoning models are composed of two main parts: rule-based domain knowledge and reasoning engine [4]. We motivate to develop a simple, but expressive, domain knowledge in order to produce useful reasoning. Legal domain ontologies are needed for developing such domain knowledge. They are used mainly for modelling the legal norms of the given legal domain.

Generally, Building ontologies from scratch is not an easy task. It is considered as a resource-intensive, time consuming and costly task. This is due to the difficulty and the complexity of capturing knowledge from legal sources which are mainly unstructured textual documents such as legislations and codes. In this regard, to reduce the complexity of building legal domain ontologies, a modular middle-out approach is proposed. This approach tends to simplify the ontology building process based on reusing existent foundational ontologies in a top-down strategy and on ontology learning process in a bottom-up strategy. Both strategies will be integrated to obtain the resulting ontology. In order to complete the domain knowledge of the rule-based legal

reasoning model, a set of logic rules will be constructed based on the obtained legal domain ontology. In this context, an integration process will take place to combine the ontology and the rules.

The domain application of this research is the Lebanese criminal system and the Lebanese criminal code is considered as the main textual resource since it contains the legal norms of the Lebanese criminal domain.

2 Challenges

In this research, there are two main challenges concerning the building of the criminal decision support system mainly for the reasoning model components: building a reusable legal domain ontology for modelling the legal norms of the criminal domain and formalizing the logic rules of the legal reasoning model of the decision support system based on the resulting ontology.

It is commonly known that ontologies aim to capture consensual knowledge of a given domain in a generic and formal way, to be reused and shared across applications and by groups of people [5]. Meanwhile, it is considerable in the literature that the number of ontologies has increased and they are becoming larger and more complex to manage and reuse [6]. For this purpose, the challenge that we face is to build reusable ontology for modelling the norms of the criminal domain using modularization techniques as an ontology engineering principle. Ontology modularization and the problem of formally characterizing a modular representation for ontologies are great challenges in the ontological engineering domain.

Furthermore, based on the legal domain ontology, there is a need to formalize legal norms of the criminal domain. In this context, the challenges to be faced are how to integrate the obtained ontology with logic rules. The integration of ontologies and rules remains a challenging task in the knowledge engineering domain for building rule-based reasoning models.

3 State of the Art

Our research is composed in two main parts: the building process of the criminal domain ontology and the construction of the legal reasoning model of the rule-based decision support system.

Concerning the ontology building process, in the literature, two main categories of approaches exist: top-down and bottom-up [7]. The bottom-up approaches start from the most specific concepts and build a structure by generalization [8] where the building process of the ontology usually starts with linguistic study on existing data structures forms (documents, reports, etc.) in order to extract relevant concepts of the domain and relations among them with the semi-automatic support in document analysis.

Top-down approaches start from the most generic concept and build a structure by specialization [8]. In this approach, the building process of the ontology starts by an

analysis and study of relevant information sources about the given domain and then modeling the top level concepts which will be refined in next steps.

Meanwhile, for the construction of the legal rule-based reasoning model, two main approaches are found in the literature for integrating ontologies and rules: homogeneous and hybrid [9].

The homogeneous approaches define the integration between ontologies and rules over a tight semantic integration where ontologies and rules are embedded in a common logical language. The most typical homogeneous paradigms are: Combination of OWL ontologies with SWRL rules expressed in First Order Logic (FOL) and Description Logic programs (DLP) [10]. However, the hybrid approaches define the integration between ontologies and rules over a strict semantic separation where the ontology elements and the rules predicates are separated. In this strategy, rules are expressed in Logic Programming LP formalism. The most typical hybrid approaches are Answer Set programming (ASP) [11], *dl-programs* [12] and DL+log [13].

4 Proposed Approaches

In our research we have proposed two main approaches: a modular middle-out approach for building the criminal domain ontology and a homogenous approach for integrating the resulting ontology with the logic rules in order to form the legal reasoning model of the legal decision support system.

4.1 Modular Middle-Out Approach for Building Criminal Domain Ontology

A modular middle-out approach has been proposed for building a criminal modular domain ontology [14]. The proposed approach tends to combine two complementary strategies: top-down and bottom-up. In the ontology building process the modularization techniques are used to split the ontology into four independent modules (upper, core, domain and domain-specific), which are themselves ontologies, that can be reusable.

At the highest level, the upper module represents the most general concepts and relations that cover all the domains. The core module provides a definition of structural knowledge in the legal domain. The domain module, in turn, describes the conceptualization of the criminal domain. Finally, at the lowest level, the domain-specific module describes the most-specific knowledge of the Lebanese criminal domain.

Concerning the strategies: *top-down* consists of the definition of the highest part of the conceptual structure of the criminal domain which is modeled as ontology modules (upper and core). In this strategy, reusing existent ontologies, that capture similar or complementary knowledge (foundational and core-legal ontologies such as UFO [15], LKIF-Core [16]-[17]) can help in building well-founded ontology.

Meanwhile, the *bottom-up* strategy consists of extracting the legal concepts and relations among them from textual resources (the Lebanese criminal code) by using Ontology Learning and NLP techniques and then modeling this knowledge as a domain and domain-specific modules.

Furthermore, the two strategies are combined together to form the complete architecture of the criminal domain ontology that is modularized into four modules: upper, core, domain and domain-specific.

4.2 Homogenous Approach for Ontology and Rules Integration

In order to build the legal reasoning model of the legal decision support system, there is a need to integrate the resulting criminal domain ontology with set of logic rules. For this purpose, a homogenous approach is proposed to define a tight semantic integration where the ontology and the rules are embedded in a common logical language. In this approach, the ontology is treated as external sources of information accessed by rules. Ontology concepts and properties may be defined through the rules. The most typical homogeneous paradigm is the combination of OWL ontology with SWRL rules expressed in First Order Logic (FOL).

5 Results

In this section, we will discuss briefly the results obtained for the proposed approaches concerning the criminal modular domain ontology and the rule-base of the legal reasoning model.

5.1 Criminal Modular Domain Ontology

After applying the proposed middle-out approach, a criminal modular domain ontology, named CriMOnto. The proposed approach is defined by developing the modules independently and then combining them together to compose the whole CriMOnto (see Fig.1) [14]. From this perspective, the different modules are in different subjects since they are in different conceptual levels. Therefore, an integration process is performed to combine them [18].

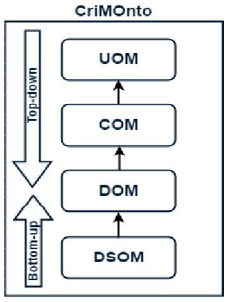

Fig.1. Middle-out approach for building CriMOnto.

Upper Ontology Module

The UOM consists of abstract concepts and relations which are effectively independent of any specific domain. For a well founded building of this module, the unified

foundational ontology UFO [19], proposed by Guizzardi and Wagner [20], is partially reused to facilitate and speeding up the ontology development process by preventing to reinvent the wheel concerning basic categories [21]. Therefore, UFO permits the building of an ontology reusing some generic concepts such as *category*, *kind*, *subkind*, *relator*, *role*, *role mixin* and Event, where the ontologist does not need to rebuild these concepts.

In order to make possible the activity of conceptual modeling via UFO, a conceptual modeling language, named OntoUML [22], is used. OntoUML uses the ontological constraints of UFO as modeling primitives and is specified above the UML 2.0 meta-model [23].

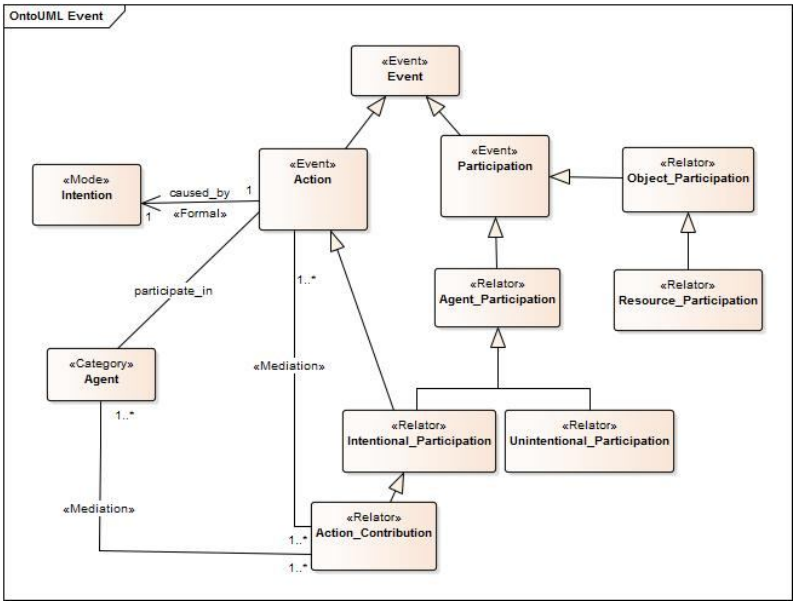

Fig.2. Fragment of the upper module in OntoUML.

Core Ontology Module

The COM consists of concepts and relations that are common across the domains of law and can provide the basis for specialization into domain and domain-specific concepts. The same perspective is applied, as for upper module, for reusing partially the legal core ontology, LKIF-Core, to build this module (see Fig.3).

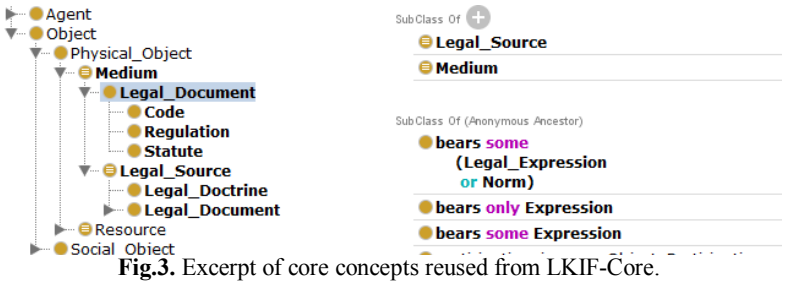

Fig.3. Excerpt of core concepts reused from LKIF-Core.

Domain Ontology Module

The DOM is composed of categories that are related mainly to the criminal domain in general such as *Criminal_Act*, *Penalty*, *Misdemeanor*, *Violation*, etc. In order to build this module, two main strategies are applied: (1) specialize the concepts and relations of the core module (Fig 4 (a)); (2) extract the knowledge from textual resources using ontology learning and NLP techniques [24] (Fig 4 (b)).

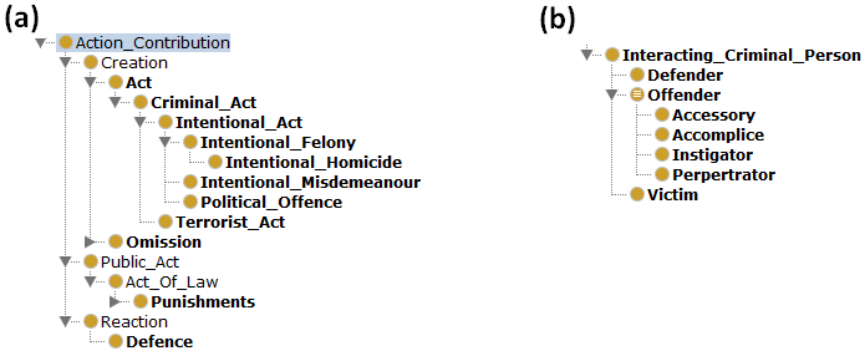

Fig.4. Excerpt of the domain concepts in Protégé.

Domain-Specific Ontology Module

The DSOM consists of concepts and relations of a specific subject domain such as the Lebanese criminal system. The bottom-up strategy helped to generate semi-automatically the domain-specific ontology. Unfortunately, the generated results were inexpressive and thus insufficient for practical use. For this reason, a reengineering process, inspired from the work of [25], is applied to correct, prune and enrich the extracted ontology and make it more expressive by transforming it to heavyweight or axiom-based ontology.

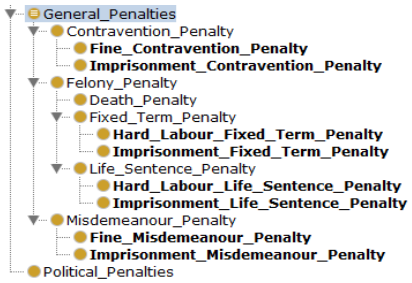

Fig.5. Excerpt of the domain-specific ontology module represented in Protégé.

Integration Process of Ontology Modules

The integration phase is the final step after building the independent ontology modules to form the resulting ontology CriMOnto. The source ontologies (upper, core, domain and domain-specific modules) are aggregated, combined, and assembled together. In this context, a simple vertical mapping strategy is applied between the concepts of the different modules. In our experiments, since ontology modules are located on vertical conceptual levels from general (upper module) to specific (domain-specific module), the mappings will be based mainly on a parent-child hierarchical relationship [26]. At the end, all the modules are imported into the final ontology using the *OWL:imports* formalisms (see Fig.6).

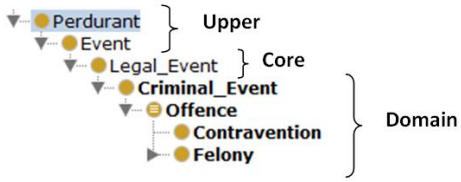

Fig.6. Hierarchical mapping in Protégé.

5.2 Rule-Base of the Legal Reasoning Model

The Rule base of the legal reasoning model of the decision support system stores the knowledge in form of rules. In the legal domain, a legal norm is represented by an *obligation rule* that denotes that the conclusion of the rule will be treated as an obligation[52] in the following form:

IF *condition* (operative facts) THEN *conclusion* (legal effect).

For representing the norms of the Lebanese criminal code, a modelling process is needed, as well as a rule language. The modeling process is based on a homogeneous integration of the obtained criminal domain ontology and SWRL selected as a rule language. In SWRL, rules are of the form of an implication between an antecedent (body) conjunction and a consequent (head) conjunction in the following form [9]:

$$a_1 \wedge a_2 \wedge \ldots \wedge a_n \rightarrow b_1 \wedge b_2 \wedge \ldots \wedge b_m;$$

In Table 1, some examples of SWRL rules, expressed using CriMOnto elements.

Table 1.Excerpt of the Lebanese criminal code rules expressed in SWRL.

Legal Norms	Rules expressed in SWRL
Article 547: "Anyone who intentionally kills another person shall be punishable by hard labour for a term of between 15 and 20 years".	Intentional_Homicide(killing), committed_towards(killing, ?y), committed_by(killing, ?x) -> is_punished_by(?x, hard_labour), imposed_for_maximum(hard_labour, max_d_2), imposed_for_minimum(hard_labour, min_d_2), term_value(max_d_2, 20), term_value(min_d_2, 15), term_type(max_d_2, "years"), term_type(min_d_2, "years")
Article 213: "An accomplice to an offence shall be liable to the penalty prescribed by law for the offence".	Accomplice(?x), commit(?x, ?y), is_punishable_by(?y, ?z) -> is_liable_to_punished_by(?x, ?z)

6 Discussion

In our research, a modular middle-out approach is applied to build a criminal modular domain ontology (CriMOnto). The modularization direction is tracked, with the support of ontology reuse and integration, in order to reduce and simply the complexity of ontology building process. This approach is considered as useful track for the ontologists who seek to build domain ontologies based partially on existent valid ontologies. Furthermore, a legal reasoning model of a legal decision support system is designed based on CriMOnto which is used to model the legal rules of the criminal domain. For this purpose, a homogeneous approach is applied for the integration of the ontology and the rules to form the rule base of the reasoning model.

In further works, a prototype for the rule-based decision support system will be constructed in order to validate the achieved results.

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