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Procedia Computer Science 112 (2017) 632–642

Procedia Computer Science

www.elsevier.com/locate/procedia

21th International Conference on Knowledge Based and Intelligent Information and Engineering Systems, KES2017, 6-8 September 2017, Marseille, France

Towards a Legal Rule-Based System Grounded on the Integration of Criminal Domain Ontology and Rules

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Abstract

This research aims to define an integrated strategy for modelling legal norms in the criminal domain for supporting the legal reasoning. For this purpose, OWL-DL criminal domain ontology is captured from legal texts, using a middle-out approach, and legal rules are then formalized based on the ontology. The goal is to construct a legal rule-based decision support system for the Lebanese criminal domain, grounded on the integration of the criminal domain ontology and set of logic rules which are defined using the expressive ability of SWRL rule language.

Peer-review under responsibility of KES International

Keywords: legal rule-based system, criminal domain ontology, rule modelling, swrl rules, rule-based reasoning.

1. Introduction

Generally, legal AI systems are categorized in legal retrieval and legal analysis systems[1]. The legal analysis systems can be judgment machines or legal expert systems which are decision support systems. The judgment machines tend to replace judges. However, legal expert systems cannot and should not be used to replace human decision-makers[2]. Any legal expert system, known as legal knowledge based systems (LKBS)[3], must be capable of legal reasoning[1]. Thus, the system must be based upon a model of legal reasoning by describing the norms that operate within the legal system[4]. Legal reasoning, applied earlier in various approaches for decision making

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Peer-review under responsibility of KES International
10.1016/j.procs.2017.08.109

purposes, describes how legal expert system takes legal decisions with the help of rules[5]. Accordingly, legal reasoning is considered as a rule-guided activity, where most part of it consists of applying legal rules to interpretations of cases[6,7]. This kind of reasoning is called rule-based reasoning performed by rule-based expert systems where the reasoning process is based on a set of *if-then* rule statements[2] used to describe certain patterns of the giving domain such as legal norms.

Generally, legal norms are expressed in textual sources such as legislations and codes and have basically the following structure[8,9]:

If *A1,…,A2* then *B*;

where "A1,…,A2" are the conditions of the norm, "B" is the legal effect and "if…then" is a normative conditional. This view highlights an immediate link between the concepts of the norm and the rules[10]. This link relies on ontologies since they are used for *filling the gap* between document representation, expressed in natural language, and rules modelling using logical formalisms[11]. Thus, the legal rules are considered as legal interpretation and modelling of the meaning of texts by transforming the legal norms to logical rules for permitting reasoning[12]. For this purpose, the main challenges are building well-founded domain ontology for modelling the legal norms and modelling the legal norms based on this ontology.

This work presents a proposed legal expert system, named CORBS, which performs rule-based reasoning in the criminal domain. The system is considered as assistant to legal experts and not substitutes for them. CORBS is grounded on a criminal domain ontology, which is constructed using a middle-out approach, and a set of logic rules, formalized in SWRL rule language. The domain ontology and the rules are integrated together to form the legal reasoning model of CORBS.

In section 2, the rule-based expert systems are overviewed. The integration of rules and ontologies is discussed in section 3. The proposed legal rule-based expert system CORBS is presented in section 4. The sections 5 and 6 outline the main components of the legal reasoning model of CORBS: the knowledge base and the rule engine. The section 7 discusses the related work. Finally, the paper is concluded in section 8.

2. Rule-Based Expert Systems

Rule-based systems are the most prevalent legal AI expert systems[13]. A rule-based system relies on a model of deductive reasoning[14] by applying a rule of law to a given problem in order to obtain an answer *A*. The system declares *A* is the answer based on the principle of law articulated by the governing authorities that mandates it[15]. This process of determining which rules should be applied and how they should be interpreted is often referred to as legal reasoning[2] which is applied for decision making purposes in various approaches[16,17]. Examples of legal rule-based expert systems: McCarty's Taxman[18], Anne Gardener's system[6] and Susskind[14].
Generally, rule-based expert systems have advantages and disadvantages[19,20]:

- Advantages:
  - Natural knowledge representation in the form of *if-then* rules that reflect the problem-solving procedure explained by the domain experts.
  - Uniformity of structure where all the rules are expressed in the same format.
  - Modularity of structure where each rule is an independent piece of knowledge.
  - Separation of knowledge from its process.
  - Justification of the determinations by explaining how the system arrived at a particular conclusion and by providing audit trails.
- Disadvantages:
  - Opaque relations between rules because of the uniformity and modularity of their structure.
  - Inability to learn from experience.

In this context, a limitation to cite, that concerns not only rule-based systems but all legal expert systems, which is the problem of how to model vague or "open-textured" concepts. For instance, uncertain and fuzzy legal concepts such as "reasonable" and "intentional" cannot be modelled in a way analogous to human thinking. What constitutes reasonable behaviour will vary from time to time, place to place and person to person[2]. In this context, some authors in the field[21] considered that "open texture problems are functional to adequate regulations and should not be resolved by automatic legal reasoning systems. They form the human interface between case and regulation and should be implemented as such in legal reasoning systems, i.e. as a task for the user".

Despite these limitations, there are still many problems that can be solved by rule-based systems. The goal of these systems is not to solve all legal automation problems, but there are ideal for encoding legal principles found in statutes and regulations where the law is explicit and knowable, but logically complicated[20].

3. Integration of Rules and Ontologies

Rules and ontologies represent two main components in the semantic web vision[22]. They ensure that information available on the World Wide Web is machine-readable[23]. Ontologies, or conceptual models, are considered as the common and distinctive conceptualizations of a domain of knowledge[24]. They comprise five main modelling primitives: concepts, taxonomical relations (sub-class relations), non-taxonomical relations, axioms and instances (individuals). OWL (Web Ontology Language) is the standard representation language of ontologies.
Meanwhile, rules are represented using *inferential links* according to the following pattern:

IF *precondition* THEN *conclusion*.

The role of inferential links is to govern the reasoning, they are considered as "rules for judging". The reasoning is processed by the evaluation of the left side of the rule with reference to the knowledge base, and if this succeeds, the action specified by the right side is performed[8]. Reasoning with rules and ontologies affects the *Ontology* and *Rule* layers of the semantic web layer cake[25].

For building rule-based expert systems, the integration of ontologies and rules remains a challenging task in the knowledge engineering domain. Several approaches have been discussed according to the degree of integration between ontologies and rules[26,27,28,29,30,22,31]. Two main integration approaches have been distinguished: Homogeneous, which are monotonic approaches, and hybrid, which are non-monotonic approaches[32].

- Homogeneous: the integration between ontologies and rules is defined over a tight semantic integration where ontologies and rules are embedded in a common logical language (Fig. 1). Ontologies are treated as external sources of information, which are accessed by rules. Ontology concepts and properties may be defined through the rules[32]. The most typical homogeneous paradigms are:
    - Combination of OWL ontologies with SWRL rules expressed in First Order Logic (FOL) which is family of monotonic Knowledge Representation (KR) formalisms.
    - Description Logic programs (DLP) which is a Knowledge Representation (KR) contained within the intersection of Description Logic (DL), which is the basis of ontology languages, and Logic Programs (LP), which is the basis of rules languages[27].

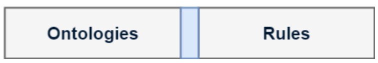

Fig. 1. Homogeneous integration of rules and ontologies.

- Hybrid: the integration between ontologies and rules is defined over a strict semantic separation where the ontology elements and the rules predicates are separated (Fig. 2). Ontology elements, such as concepts and properties, represent the conceptualization of the domain. Rules cannot define them but some application-specific relations. Thus in the hybrid approach, the ontology remains unchanged and rules are built on top of ontologies[22]. In this strategy, rules are expressed in Logic Programming LP formalism which is family of non-monotonic Knowledge Representation (KR). The most typical hybrid approaches are, among others, Answer Set programming (ASP)[33], *dl-programs*[28] and DL+*log*[34].

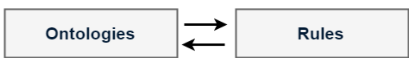

Fig. 2. Hybrid integration of rules and ontologies.

4. CORBS: a Proposed Rule-Based System

The main goal of this paper is to propose a legal rule-based system for the criminal domain, named CORBS, grounded on the integration of a legal domain ontology and set of logical rules. The challenges of this work are building well-founded domain ontology for modelling the legal norms and integrating it with the rules to form the reasoning model of the system. In this section, the domain application of CORBS as well as the legal reasoning model will be overviewed.

4.1 Domain Application

The domain application of this study is the Lebanese criminal law. Law may mean the sources of law, such as legislation and case decisions[13], but often it covers also the legal system, in particular: legal courts and their ruling. Several distinguished legal theorists have come to the conclusion that law is, essentially, a body of rules[2]. Moreover, legal formalist commentators maintain that law cannot be divorced from the concept of a rule[35].

In constructing legal knowledge-based systems, knowledge engineers simply assume that the legal source to be modeled is a legally valid one[36]. Thus the legal source of the current research is restricted to the English version of the Lebanese criminal code that consists of legal norms (rules) represented in unstructured natural language texts. The code contains the general criminal laws distributed on 770 articles. Two main types of knowledge are represented in the legal rules of the Lebanese criminal code: terminological and normative. The terminological knowledge consists in definitions of some of the concepts of the criminal domain that are used to describe the criminal facts. For instance, the concept perpetrator is defined in article 212 of the Lebanese criminal law as: *"The perpetrator of an offence is anyone who brings into being the constituent elements of an offence or who contributes directly to its commission"*. Meanwhile, the normative knowledge connects the legal consequences to descriptions of certain facts and situations, such as in article 217: "*Anyone who induces or seeks to induce another person to commit an offence shall be deemed to be an instigator*". From the perspective of computer science, these legal rules are the form in which the criminal law is specified and can be viewed as constraints upon how a legal system should operate.

4.2 Legal Reasoning Model of CORBS

Legal expert systems are built on the assumption that the user of their technology will provide the current facts to which the legal expert will apply the law[14]. In this context, McCarty, *father of AI and law*, claims that a LKBS must be able to represent the *facts* that involve all the complexities of daily life (human actions, beliefs, intentions, motivations, etc.) and the *law* that consists of a system of "concepts" and "rules" [4,37].
Most of the LKBS attempt to develop and implement complex models of legal reasoning[38]. However, a LKBS need to be based upon a simple, but expressive, model in order to produce useful reasoning or decision. The power and utility of such systems rely on two main parts: a significant domain knowledge base and an intelligent reasoning module, or inference engine[39].

The domain knowledge base, which is acquired from the domain experts and sources, is composed of two separated models[40]: domain and problem-solving. Domain knowledge is about the objective realities in the domain of interest (Objects, relations, events, states, causal relations, etc.). Problem-solving knowledge is about how to use the domain knowledge to achieve various goals. This knowledge is often in the form of a problem solving method (PSM) or set of rules in a rule-based LKBS. This separation has several advantages such as the domain models can be developed independently of specific tasks and problems, and can therefore have a high degree of reusability[41]. Meanwhile, the reasoning module tends to combine facts of a given case with the knowledge base to solve a giving problem. Based on this perspective, and inspired by some studies[42,43,44], the legal reasoning model of CORBS consists of three main layers (Fig. 3):

- User interface: provide list of facts as input. Facts are considered as instances of the domain objects.

- Knowledge base: contains the domain knowledge useful for problem solving. Generally, in a rule-based expert system, the knowledge is represented as a set of rules represented in *IF (condition) THEN (action)* structure. In CORBS, the knowledge base is composed of *domain ontology* and *rule base*:
    - Domain ontology: representing the conceptual model of the criminal domain, the criminal domain ontology has been developed earlier as grounds to build the knowledge base for the legal decision support system.
    - Rule base: set of formal rules developed based on the criminal domain ontology by mentioning vocabulary specified by this ontology. The rules are independent, self-contained chunks of knowledge. Thus, each rule can be changed or updated without requiring the modification of other rules or affecting the entire system. Moreover, the performance of the system is affected by their reliability.
- Reasoning, or rule, engine: drives legal reasoning by retrieving the facts (input) submitted to the system and matching them with the rule base to identify the rule, or rules that satisfy the input. Thus, new values for facts are set according to the satisfied rule.

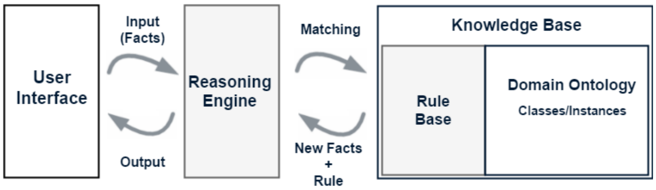

Fig. 3. Legal Reasoning Model of CORBS.

5. Knowledge Base of CORBS

Generally, the knowledge base contains the domain knowledge useful for problem solving. In CORBS, the knowledge base is composed of two main components: domain knowledge, which is the criminal domain ontology, and set of formal rules that compose the rule base.

5.1 Criminal Domain Ontology

In the legal domain, the purpose of building ontologies is to describe the facts of legal cases at a comfortable level of abstraction and the "law" of the domain application which consists of "rules" and "concepts"[37]. Legal ontologies are defined as social constructs that can be used to express shared meaning within a community of practice[24].

In rule-based expert systems, ontologies are used for *filling the gap* between document representation and rules modelling[11]. Thus, In CORBS, the aim of the criminal domain ontology is modelling the legal norms of the Lebanese criminal domain serving as a basis for legal knowledge and legal reasoning.
In this context, an issue must be recognized is that there is no agreement on the basic conceptualization(s) of the legal domain. Thus, the same domain can be conceptualized in different ways. What is needed is rather for the ontologies to be sufficiently clearly stated[45]. Moreover, research in this field should not concentrate on creating one ontology of the legal domain but on the creation of a library that contains several dedicated ontologies at different abstraction levels and supports their combination to create a composite ontology. In addition to this, building ontologies is not an easy task due to the complexity, difficulty and time-consuming of the building process.

From these perspectives, a modular middle-out approach has been proposed to simplify the ontology building process as well as to obtain a composite reusable and well-founded ontology[46]. The middle-out approach is composed of two complementary strategies *top-down* and *bottom-up* where the criminal domain ontology is modularized in four independent modules which are themselves ontologies: *upper*, *core*, *domain* and *domain-specific* (Fig. 4). The *upper* and *core* modules are built by applying the *top-down* strategy that is considered as a conceptual modelling process performed by reusing existent foundational ontology (UFO)[47] and legal core ontology (LKIF-Core)[48]. Meanwhile, the *domain* and *domain-specific* modules are extracted by applying the *bottom-up* strategy as an ontology learning process from the Lebanese criminal code[49]. The modules are then integrated together to compose the whole ontology.

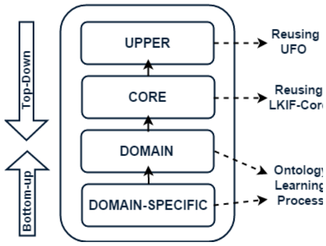

Fig. 4. Middle-out approach for building the criminal domain ontology.

In the following, the modules are overviewed briefly.

Upper ontology module

The *upper* ontology module of the criminal domain ontology consists of general concepts and relations that are effectively independent of any specific domain. This module is constructed by a partial reuse of the Unified Foundational Ontology (UFO) in order to facilitate and speed up the ontology development process by preventing to reinvent the wheel of the basic categories[50]. In Fig. 6 (a), an excerpt of the *upper* module concepts, such as `Event`, `Action`, `Interaction` and `Action_Contribution`, is illustrated.

Core ontology module

The *core* ontology module 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. The legal core ontology (LKIF-Core) is partially reused to build the *core* module. In Fig. 6 (b), an excerpt of the *core* module concepts, such as `Medium`, `Legal_Document`, `Legal_Source`, `Code` and `Regulation`, is illustrated.

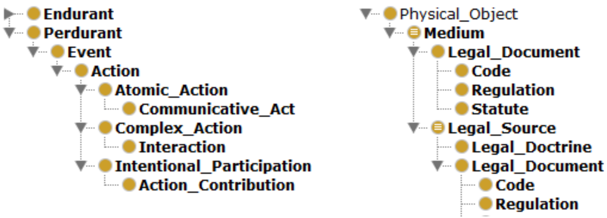

Fig. 6 (a) Excerpt of the Upper module; (b) Excerpt of the Core module.

Domain and Domain-specific ontology modules

The *domain* and *domain-specific* modules are composed of categories that are related mainly to the criminal domain. These modules are extracted semi-automatically from the Lebanese criminal code by applying an ontology learning process with the help of natural language processing techniques (NLP). Furthermore, a reengineering process is applied to correct, prune and enrich the results. In Fig. 7 (a), an excerpt of the *domain* module concepts, such as `Judge`, `Magistrate`, `Defender`, `Offender` and `Victim`, is illustrated. In the Lebanese criminal system, there are two main types of penalties for contraventions and misdemeanours: fine and imprisonment. Thus, the domain concepts: `Contravention_Penalty` and `Misdemeanour_Penalty` are specified respectively in the following domain-specific concepts: `Fine_Contravention_Penalty`, `Imprisonment_Contravention_Penalty`, `Fine_Misdemeanour_Penalty` and `Imprisonment_Misdemeanour_Penalty` (see Fig. 7 (b)).

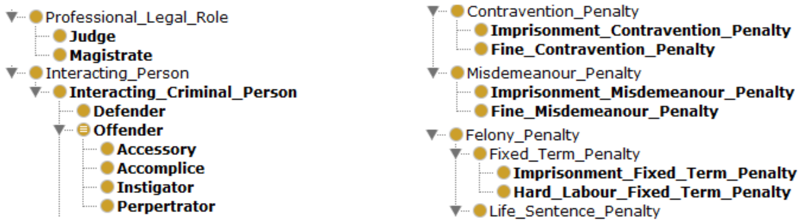

Fig. 7 (a) Excerpt of the Domain module; (b) Excerpt of the Domain-specific module.

5.2 Rule Base

Rule base stores the knowledge in form of rules[5]. 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[51]. The representation of legal norms is obviously crucial for representing legal documents, regulations and other sources of law[10].
Representing legal contents though *obligation rules* comports with the widespread idea that legal norms typically have the conditional form:

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

Indeed, obligation rules provide the most widespread and successful representational model for legal knowledge where the concepts of the legal norms are linked to the rules[52]. For representing them, a modelling process is needed, as well as a rule language.

In the literature, there is a variety of languages for modelling rules such as: RuleML, SWRL, KIF, etc. In this study, SWRL is selected because of its simplicity and compatibility with the OWL syntax. Additional reason is that the legal norms of the Lebanese criminal code can almost be expressed in first-order logic. Therefore, the rules modelling process in CORBS is based on a homogeneous integration of the SWRL rules with the criminal domain ontology.
SWRL (Semantic Web Rule Language) is probably the most popular formalism in Web community for expressing knowledge in the form of rules. This language is based on a combination of Rule Mark-up Language (known as RuleML)[53] and OWL (Web Ontology Language)[54]. SWRL extends OWL axioms to include Horn-like rules. It is the only approach that gathers ontology and rules in product development[55] where users are permitted to write rules that can be expressed in terms of OWL concepts and that can reason about OWL individuals[56]. In SWRL, rules are of the form of an implication between an antecedent (body) conjunction and a consequent (head) conjunction in the following form[32]:

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

where description logic expressions can occur on both sides, "$\wedge$" is an operator for the logical AND, "$\rightarrow$" is an operator for drawing the conclusion and a_i and b_i are OWL atoms such as, among others, concepts, object properties, data properties, sameAs, and differentFrom.

The intended interpretation of SWRL rules is in classical first-order logic: whenever the conditions specified in the antecedent hold, then the conditions specified in the consequent must also hold.
Meanwhile, SWRL suffers from some limitations such as the problem of undecidability that is possibly solved by introducing the notion of DL-*safe* rules which restricts the application of SWRL rules only to individuals[57]. Moreover, OWL2, successor of OWL, added new features based on DL $\mathcal{SROIQ}$[58] which can completely internalize DL rules as decidable fragment of SWRL. Another limitation is noticed that is SWRL does not support the negation as failure. This can be solved using classical negation with the class description owl:complementOf. In this regard, the legal norms of the Lebanese criminal code are expressed in SWRL as *obligation rules* based on the concepts and relations of the criminal domain ontology. In Table 1, some examples of SWRL rules, expressed using ontology concepts, object properties, data properties and instances, are presented.

Table 1.Excerpt of the Lebanese criminal code articles 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. Reasoning Engine

Legal expert systems solve legal problems through the application of two main reasoning strategies[59]: deductive logic and inductive logic that are called respectively forward chaining, or data-driven, and backward chaining, or goal-driven[60]. Forward chaining starts from existing facts and applies rules to derive all possible facts, while backward chaining starts with the desired conclusion and performs backward to find supporting facts.
In rule-based expert systems, the inference engine applies rules with data to reason and derive new facts. When the data match the rules conditions, the inference engine can modify the knowledge base or execute functions such as display the derived facts. This process of determining which rules should be applied and how they should be interpreted is often referred to as legal reasoning[2]. Generally, researchers view legal reasoning as essentially deductive in character[2]. The most known rule-based reasoning engines are, among others, Pellet[60], Jess[61] and Jena2[62]. In the current work, the SWRL rules are written in the rule plug-in in Protégé. Thus, the semantic reasoning engine Pellet is used. In Fig. 8, the inferences of the SWRL rules associated to the articles 547 (a) and 213 (b) are shown.

Fig. 8. Inferences of the rules associated to the articles (a) 547; (b) 213.

7. Related Work

This work is related to the domain of rule-based expert systems where rule reasoning models are based on the integration of domain ontologies and SWRL rules. Several works in the literature tend to use rule reasoning models in different domains such as maize disease[63], brain anatomy[64] and power plant design[65]. For the maize disease case study, the authors tend to build a domain ontology and enrich it with the expressive ability of SWRL reasoning rules in order to improve the disease diagnosis. The same application is used in the case of brain anatomy ontology, where the SWRL rules are used for enhancing the expressivity of the ontology, and power plant design where SWRL allows additional rules expression. Therefore, these studies have integrated domain ontologies with SWRL rules for expressivity purposes. Meanwhile, in our work, the expressive ability of SWRL is used mainly for modelling the legal norms of the criminal domain based on the domain ontology constructed in a simple strategy which is the modular middle-out approach. Thus, SWRL rules form the rule base of the system and based on it the reasoning engine will perform its functions. Therefore, the performance of the system is affected by the quality of the domain ontology and the rules as well as their integration.

8. Conclusion

In this paper, a proposed rule-based legal expert system, named CORBS, is presented. The system is grounded on a homogenous integration of a criminal domain ontology and a set of logic rules. The legal reasoning model of CORBS relies on an efficient domain knowledge base which is composed of domain ontology and rule base. The domain ontology represents the conceptual model of the domain application of this work which is the Lebanese criminal system. In order to simplify the complexity of the ontology building process and to obtain a well-founded criminal domain ontology that affects the performance of the reasoning capabilities of the proposed system, a middle-out approach is applied. The middle-out approach applies modularization techniques to divide the ontology into four independent modules: upper, core, domain and domain-specific. Moreover, a reuse process is used to prevent reinventing the wheel while building the ontology. Furthermore, the rule base contains a set of logic rules composed of atoms that are defined based on the ontology elements and formalized using SWRL as a modelling phase for the legal norms. SWRL is used because it is better suited to express *deductive* knowledge by rules composed of atoms[66]. Finally, the reasoning engine drives the legal reasoning by retrieving the facts submitted and matching them with the rule base. Thus le legal reasoning model of CORBS is a rule-guided activity.

Acknowledgements

This project has been funded with the support from the European Union with the European Regional Development Fund (ERDF), the National Council for Scientific Research in Lebanon (CNRS) and Lebanese University.

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