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A Methodology for a Criminal Law and Procedure Ontology for Legal Question Answering

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Abstract. The Internet and the development of the semantic web have created the opportunity to provide structured legal data on the web. However, most legal information is in text. It is difficult to automatically determine the right natural language answer about the law to a given natural language question. One approach is to develop systems of legal ontologies and rules. Our example ontology represents semantic information about USA criminal law and procedure as well as the applicable legal rules. The purpose of the ontology is to provide reasoning support to an legal question answering tool that determines entailment between a pair of texts, one known as the Background information (Bg) and the other Question statement (Q), whether Bg entails Q based on the application of the law. The key contribution of this paper is a clear and well-structured methodology that serves to develop such criminal law ontologies and rules (CLOR).

Keywords: Ontology · Legal rules · Bar examination.

1 Introduction

To develop question answering systems, ontologies can be used to develop domain-specific semantic information. However, capturing human-created semantic information from text for automated processing is not a linear process. In this paper, we consider legal reasoning such as from legal facts and rules to legal determinations as found in legal cases. Our ultimate aim is to (semi or fully) automate the process of judging legal case. We take a legal ontology along with rules to be core elements in this process as the link all the necessary legal elements of a case and support automated reasoning. However, making ontologies and rules is a difficult endeavour. To facilitate this, our main contribution is an engineering methodology for criminal legal ontologies and rules (CLOR).

We organise the analysis around a textual entailment task to question–answering as it is used in the US Bar exam [**?**], our benchmark of choice. More formally, we can state that given a theory text T and hypothesis text H, we can determine whether or not from T one can infer H [**?**,**?**]. A range of approaches can be applied to the textual entailment task, e.g. machine learning, lexical information as well syntactic and semantic dependencies. However, these techniques lack the sort of legal knowledge and reasoning required to determine and explain entailment in the text representing bar examination questions.

The original bar exam questions are organized in the form of background information (Bg), which is the theory T, and multiple-choice question statements (Q), each of which we take as an hypotheses H. The objective is to select the correct H, given T. That is, given the background information, one must either accept or reject each multiple-choice question statement based on the application of the law[3] For the purposes of this paper, we illustrate the issue with one Bg and Q example pair (See Table 1). The question is, from the information in Bg, can one infer an answer (indicated here with Q).

Bg	After being fired from his job, Mel drank almost a quart of vodka and decided to ride the bus home. While on the bus, he saw a briefcase he mistakenly thought was his own, and began struggling with the passenger carrying the briefcase. Mel knocked the passenger to the floor, took the briefcase, and fled. Mel was arrested and charged with robbery. The mistake of Mel negated the required specific intent.
Q	Mel should be acquitted.

Table 1. Sample bar examination criminal law question (adapted).

An ontology and rule set for criminal law and procedure is large, complex, and evolving. Our contribution develops an interesting and relevant fragment, which can be developed further. In addition, an important research contribution is our incremental methodology for the criminal legal ontology and rule (CLOR) development, wherein we start with some initial ontology and rules and build upon them to account for further bar examination questions. The idea is that within this process, we come to identify specific or repeated patterns of legal reasoning, which then lead towards further generalization and application of legal rules. This is demonstrated later, where an initial system is developed on the basis of a limited set of data, then applied to further examples which had not be considered in the initial system.

The current paper builds on [?], which provided an initial criminal law ontology along with SWRL rules to draw inferences; we provided preliminary results from an initial experiment. In addition, the approach used NLP techniques to extract textual information from the source text. However, that paper did not have a clearly articulated methodology which be useful for further development of the ontology and rules. The novelty of this paper is the description of articulated methodology for ontology and rule construction, further development of the ontology and rules, and some further evaluation of the quality of the ontology.

The rest of the paper is organized as follows. Section **??** discusses legal ontologies, and closely related works. Section **??**, describes the criminal law and procedure ontology. The methodology applied in constructing the ontology is explained in Section **??**. Section **??** presents the Semantic Web Rule Language and legal rules; an illustration of how the rules are applied to ontological information is in Section **??**. Section **??** outlines how the ontology was evaluated. We conclude with some discussion in Section **??**.

[3] See [?] for further discussion of the full dataset and the manipulations on it.

2 Related Work

Osathitporn et al. [?] describe an ontology for Thai criminal legal code with concepts about crime, justification, and criminal impunity. It aims to help users to understand and interpret the legal elements of criminal law. However, the focus of the ontology as well as its structural and hierarchical organization differs from an ontology for legal question answering. Bak et al. [?] describe an ontology as well as rules that capture and represent the relationship existing between legal actors and their different roles in money laundering crime. It includes relational information about companies, entities, people, and actions. Ceci and Gangemi [?] present an OWL2-DL ontology library that describes the interpretation a judge makes of the law in providing a judgment while engaged in a legal reasoning process to adjudicate a case. This approach is based on a theoretical model and some specific patterns that use some newly introduced features of OWL2. This approach delivers meaningful legal semantics while the link to the source document is strongly maintained (that is, fragments of the legal texts). Gangemi et al [?] describe how new legal decision support systems can be created by exploiting existing legal ontologies. Legal ontology design patterns were proposed in [?], wherein they applied conceptual ontology design patterns (CODePs). However, this work differs from legal question answering in which legal rules need to be applied to facts extracted from legal text to reason with to determine an answer.

Several ontology development methodologies have been proposed. However, these different methodologies have not delivered a complete ontology development standard as in software engineering. Suarez-Figueroa et al [?] present the NeOn ontology development methodology. NeOn is a scenario-based approach that applies a different insight into existing ontology construction methodologies. However, this approach does not specify a particular workflow for the ontology development, rather it recognizes nine scenarios for collaborative ontology construction, re-engineering, alignment, and so on. De Nicola and Missikoff [?] proposed the Unified Process for ONtology (UPON Lite), an ontology construction methodology that depends on an incremental process to enhance the role of end users without requiring any specific ontology expertise at the heart of the process. The approach is established with an ordered set of six steps. Each step displays a complete and independent artefact that is immediately available to end users, which serves as an input to the subsequent step. This whole process reduces the role of ontology engineers.

An overview of ontology design patterns was presented in [?] exploring how ontologies are constructed in the legal domain. Current approaches on ontology development can be categorized as either “top-down” or “bottom-up”. The manual development of ontologies from scratch by a knowledge engineer and with the support of domain experts is known as the top-down approach [?], which is later used to annotate existing documents. When an ontology is extracted by automatic mappings or extraction rules or by machine learning from vital data sources [?], then this is regarded as a bottom-up approach. Much of the research works on legal data harmonization, applying a standardized formal language to express legal knowledge, its metadata, and its axiomatization. With respect to a top-down approach, Hoekstra et al. [?] present the Legal Knowledge Interchange Format (LKIF), an alternative schema that can be seen as an extension of MetaLex. It is more expressive than OWL and includes LKIF rules that support axiomatization. Related, Athan et al. [?] propose the LegalRuleML language that is an extension of the XML based markup language known as RuleML. It can be applied for expressing and inferencing over legal knowledge. In addition, Gandon et al. [?] proposed an extension of the LegalRuleML that supports modeling of normative rules. There has not been an instantiation of LKIF and LegalRuleML at scale or used for formalizing or annotating the content of a legal corpora either automatically or manually. Also, different theoretical approaches have argued that laws can be formally defined and reasoned with by applying non-classical logics like defeasible logic or deontic logic, of which their application involves the manual encoding of some specific parts of a legislative document, that may not scale to a full legal corpus [?,?].

3 Ontology of Criminal Law and Procedure

The goal of the legal ontology is to design a terminological knowledge base and a rule base for legal reasoning. For the terminological knowledge base, we establish terminological relationships like subclass, is-part-of and so on. In our process, the schematic information is translated into an RDF [?] or OWL format to make it machine-processable.[4] The rule base represents legal rules for reasoning about the elements of crime and the statutory information. The Semantic Web Rule Language (SWRL) is used to express the rules, which makes use of the vocabulary of the OWL ontology in order to consistently reason. CLOR is expressed in the $\mathcal{ALCH}(\mathcal{D})$ description logic, with about 90 classes and 130 properties.

Methodologically, we work with a limited set of questions (16 questions and with multiple choices answers, yielding 64 question answer pairs), which are extracted from a larger corpus of 400 questions [?]. The purpose is to engineer solutions and incrementally augment them for more complete coverage of the data. Furthermore, we manually extract legal knowledge from domain experts, bar examination preparatory materials, and some law textbooks [?,?,?,?]. The purpose of the manual process is to ensure a proper consultation with domain experts. Moreover, the manual method of ontology development is more precise and accurate compared to an automatic information retrieval or machine learning techniques, which do not provide sufficient level of accuracy [?,?] especially for legal text. The manual process allows us to maintain a reference to the model and close to the process of legal reasoning. Where possible, existing legal [?,?,?,?,?] and common-sense ontologies were reused [?,?].

4 Methodology

In this section, we present our methodology, first with some general points, then with more specific considerations. This methodology consists of 18 steps that

[4] The OWL file is available upon request.

lead to the creation of a legal ontology and a corresponding set of rules. We selected source material about criminal law and legal procedures from exam preparation material[**?**,**?**,**?**,**?**], information from domain experts, and twelve randomly selected bar exam questions (questions 7, 15, 61, 66, 76, 98, 101, 102, 103, 107, 115 and 117) from a set of 200 questions [**?**]. The bar exam questions come with an answer key, which constitutes the benchmark for our methodology.

The selected questions contain criminal law and procedural notions such as: acquit, robbery, larceny, felony murder, arson, drug dealing and motion moving in criminal procedure. The idea is to ensure that all the information necessary for applying the law are extracted and represented in the ontology. That means, we systematically analyse the questions in order to identify and extract concepts, properties and relationships relevant for applying the legal rules for making legal decisions.

Due to the challenging nature of ontology and rule authoring [**?**,**?**], we decompose the analysis into a series of simpler *competency questions* (CQ) [**?**,**?**], each of which is aimed at collecting some specific information and can be used to ensure quality control of the knowledge base [**?**,**?**]. The domain expert seeks to answer the questions with respect to the corpus of bar exam questions and answers. These questions play a crucial part in the knowledge acquisition phase of the ontology development life cycle, as they describe the requirements of the intended ontology (see sample competency questions in Table **??**). Next, we created a methodology consisting of 18 steps (see Figure **??**). Some steps process the text in order to provide material for further analysis, e.g. *Select all nouns*. Other steps filter or process information, e.g. *Identify relevant nouns* (given some notion of relevance) and *Identify atomic and definable classes* (given some notions of *atomic* and *definable*), and yet other steps further select information in response to particular *competency questions*. Thus, for each step, we process or seek to identify specific information from the bar exam question material and extract it into an ontology.

Table 2. Sample competency question.

1.	What are the elements of robbery?
2	Under what conditions should x be convicted?
3.	Under what conditions should x be acquitted?
4.	What are the differences between robbery and X (such as theft)?
5.	What are the similarities between robbery and X (such as theft)?
6.	What element(s) of robbery is necessary?
7.	What element(s) of robbery is sufficient?
8.	What elements(s) of robbery is optional?
9.	What are the defenses for robbery?
10.	What are the penalties for robbery?
11.	What is the sentencing for robbery?

Steps 1 and 2: We identified and created competency questions relevant for extracting necessary information from the textbooks describing law and proce-

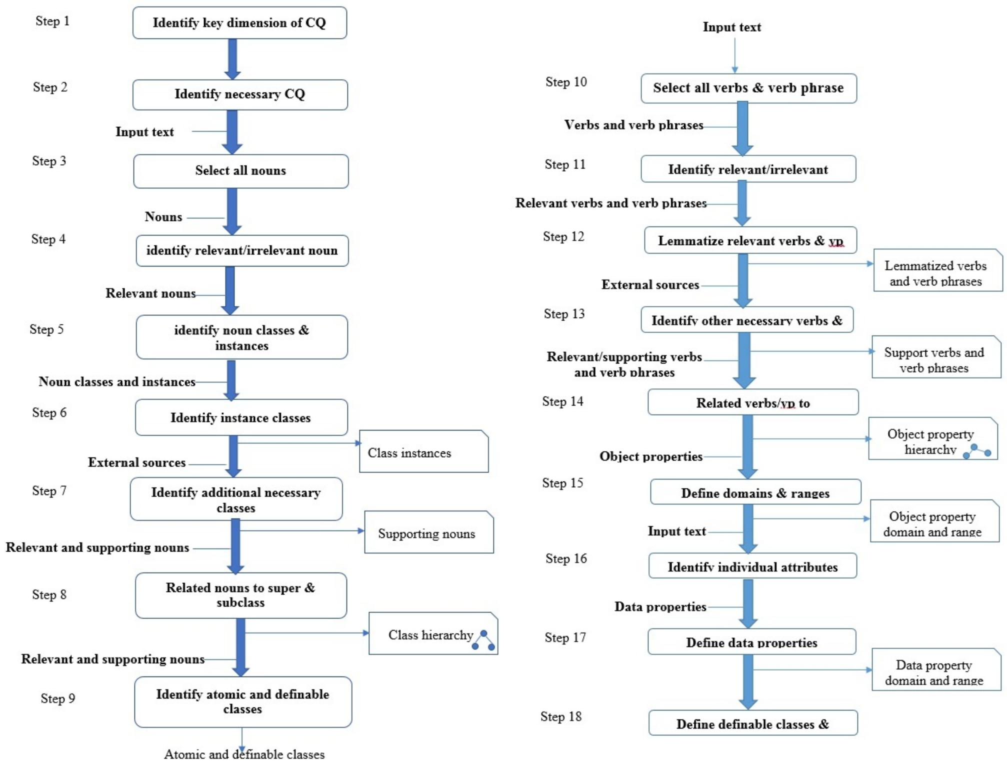

Fig. 1. Ontology design procedure

dures [?,?,?,?]. For example, the relevant information for competency questions 1, 2, and 3 above could be retrieved from these textbooks:

1. The elements of robbery are: "property is taken from the person or presence of the owner; and the taking is accomplished with the application of physical force or putting the owner in fear. A threat of harm will suffice." [?,?].
2. To convict someone, the crime has at least three elements: criminal act (actus reus), criminal intent (mens rea), and occurrence = act + intent [?].

Using the *competency questions* and other elements of our methodology, we extract legal concepts from these texts for our ontology.

Step 3: We start by identifying and collecting all the nouns in a particular bar exam question (question 7) without minding their relationships, the overlap between them, the characteristic attributes of the nouns or whether the nouns should be in a class or not. We want to know the elements of a crime which we would like to reason with. Hence, the following nouns were identified and collected from the bar exam question text (see table **??**) - *Job, Mel, Quart, Vodka, Bus, Home, Briefcase, Passenger, Floor, Robbery, Threat, Intoxication, Mistake, Defense, Voluntary action*, and *Intent* are extracted in relation to the elements of robbery and elements of crime as in CQ 1 and CQ 2 above along with some useful legal key terms.

Step 4: We separate the relevant nouns from the irrelevant ones (see Figure **??**). The relevant nouns *Mel, Vodka, Briefcase, Passenger, Robbery, Threat, Intoxication, Mistake, Defense, Voluntary-action, Intent* are extracted in relation to the elements of robbery and elements of crime as in CQ 1 and CQ 2 above, along with some useful legal key terms. We are looking for nouns that are related to the selected questions CQ 1-3 which bear on the notions robbery, acquittal and conviction. The irrelevant ones *Job, Bus, Home, Floor* may be relevant to other crimes, but are not relevant to reason with in this particular robbery crime (question 7). Once we are able to identify all the relevant concepts, we can then apply them for legal reasoning while discarding the irrelevant ones.

Step 5: After identifying the relevant and irrelevant nouns, from the relevant ones we determine the type of nouns which we could describe as classes and instances (see Figure 1). We identified the nouns *Passenger, Robbery, Threat, Intoxication, Mistake, Defense, Voluntary-action*, and *Intent* as classes, whereas *Mel, Vodka* and *Briefcase* are ground level objects, which are instances of a class.

Step 6: Here, we identify the classes of the objects Mel, Briefcase and Vodka as Person, Property and Alcoholic-beverage, respectively. Robbery is described as forcible stealing [**?**]. It means a person taking something of value from another person by applying force, threat or by putting the person in fear. From our text, Mel forcefully collected the briefcase from the passenger who was in possession of the briefcase by knocking the passenger down on the floor. As such, we extract Mel as the person and briefcase as the valuable thing or property. Likewise, vodka is a fermented liquor that contains ethyl alcohol which corresponds to the concept of Alcoholic beverage.

Step 7: While creating the class hierarchy, it is necessary to identify other classes, which are not in the selected bar exam questions, but are needed to create clear class hierarchies (see Figure 1). For example, classes such as *Person, Alcoholic-beverage, Crime, Felony, Controlled-material* and so on are created as conceptual "covers" of the particular terms in our examples. More generally, the task is to classify a set of named entities in the texts as persons, organizations, locations, quantities, times, and so on. Here, Mel is a name of a person and, therefore, a Person concept. Alcoholic beverages like liquor are controlled materials, therefore, we create the Controlled-Material class as a superclass of the Alcoholic-beverage class, and define vodka as an instance of this class.

Step 8: In creating the class hierarchy, the class Robbery is a subclass of Felony ($R \sqsubseteq F$) and Felony a subclass of Crime ($F \sqsubseteq C$) (see Figure **??**). Furthermore, has-committed-robbery ($HCR \sqsubseteq J$), should_be_acquitted ($SBA \sqsubseteq J$), and should-be-convicted ($SBC \sqsubseteq J$) are subclasses of the Judgement class, and Alcoholic-beverage is a subclass of Controlled-material ($AB \sqsubseteq CM$).

Step 9: The above identified concepts are classified into atomic and defined classes. Atomic classes have no definitions and are used types of instances. These are self-explanatory concepts and cannot be derived using other classes or properties. For example, *Mel* is a person and so Mel is a member of the

Person class. Definable classes can be defined by using other classes and properties. For example, an *Offense* is defined as consisting of both *a guilty act* and *a guilty mind*. Often definable classes do not have direct instances; instead, objects can be classified as their instances by reasoning. Here, the definable classes are *has-committed-robbery, should-be-acquitted, and should-be-convicted*. In order to define the definable classes, we need to use properties (cf. the next steps).

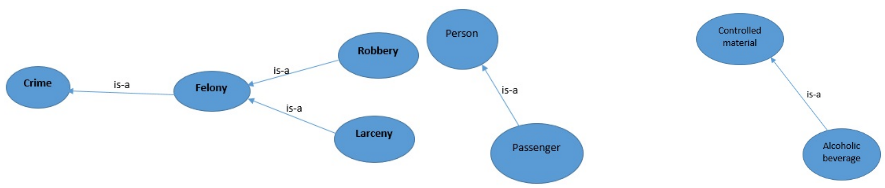

Fig. 2. Fragments of our Legal Ontology

Step 10: For object property identification, we start by identifying and extracting all the main verbs in the text (see Figure 1). We do not consider verb phrases – a verb together with objects. Such objects are related to subjects in the ontology as below. For example, from the text we identify *being fired, decide to ride, carrying, knocked, took, was charged with, and negated required.*

Step 11: Amongst the extracted verbs, we determine the relevant ones by identifying the ones that link the identified nouns together in our earlier concept identification phase. The ones that do not link the selected concepts are the irrelevant ones. Here, in relation to our example text in Table 1 and the element of robbery and crime as in CQ 1 and CQ 2 above, the following verbs are relevant: *carrying, knocked, took, was charged with, and negated required*. They link together the concepts identified earlier. These relations are helpful in defining the elements of robbery and crime in which criminal law and procedural rules can be applied. Furthermore, verb phrases such as "being fired", "decide to ride" and some others are irrelevant since they do not link the extracted concepts together.

Step 12: The relevant verbs extracted are lemmatised to eliminate inflectional forms except the "to be" verbs. For example, from the extracted relations, we have *carry, knock, take, be charge with*, and *negate require*. We keep compound verbs, which are those together with selected prepositions.

Step 13: Other verbs that may be useful and necessary for linking some of the relevant concepts are identified in order to answer our competency question, for example, *forced* and *in-possession-of*.

Step 14: The retrieved verbs are then related into super and sub-property relations, thereby creating the object-property hierarchy. It is important to point out that due to the peculiarity of legal text, verbs that define a unary relationship are classified as classes. Such class names may also appear as a relation where that verb describes a binary or n-relationship. For example, the main verb *arrested* in the text *Mel was arrested* describes a unary relationship. To solve this peculiarity, the verb *arrested* is identified as a class in its base form. This means we have *Arrested* as a class. However, in a case of binary relationship, for example, *Mel was arrested for robbery*, the main verb *arrestedFor* is treated as a relation linking Mel to robbery as *Mel was arrested for robbery.* As such, the verb assumes a class position when it defines a unary relationship and an object property when it defines a binary relationship.

Step 15: We define domains and ranges of the identified relations as well as the characteristics as a way of restricting the relation. Since, object properties connect individuals from the domain to individuals from the range. For example, the relation carry-property has Person class as domain and Property as range ($\exists$carry-property.$\top \sqsubseteq$ Person, $\exists$carry-property$^{-}.\top \sqsubseteq$ Property); force-person has Person class as domain and range ($\exists$force-person.$\top \sqsubseteq$ Person, $\exists$force-person$^{-}.\top \sqsubseteq$Person). Also, relation hierarchies are created in order to relate them into superproperties and subproperties. For example, the relation knock-person is a subproperty of force-person (knock-person $\sqsubseteq$ force_person).

Step 16: In same way, we identify datatype properties. These are the properties that links individuals to datatypes. Here, we identify drink-volume as datatype property.

Step 17: From the datatype properties, we identify the respective domains and ranges. For example, the domain and range of the datatype property drink-volume are Person ($\exists$drink-volume.$\top \sqsubseteq$ Person) and xsd:string ($\exists$drink-volume$^{-}.\top \sqsubseteq$ xsd:string) respectively.

Step 18: Here, we define the definable classes, which can be defined using OWL axioms or SWRL rules (cf. Sec 5). Rules are often more intuitive to construct. Similar to definable classes, there are definable properties too, which can be defined using SWRL rules (cf. Sec 5).

5 Legal Rule Acquisition and Representation

Rules can be used to define definable classes and properties. In our case, we captured criminal law and procedure rules from bar examination preparatory material [**?**,**?**,**?**,**?**] and in consultation with domain experts. The expression of legal rules in SWRL is not a simple task and requires interpreting and formalising the source text.

The acquired rules were then expressed in the Semantic Web Rule Language (SWRL), which makes use of the vocabulary defined in our OWL ontology. The rules may be triggered in either a forward or backward chaining fashion. The essence is to ensure a consistent way of reasoning in order to exploit both the ontology and rules to draw inferences. SWRL rules are in the form of Datalog, where the predicates are OWL classes or properties. Moreover, rules may interact with OWL axioms, such as domain and range axioms for properties. For example, given the legal rule:

$$own\_property(?x, ?pr) \wedge decide\_to\_steal(?y, ?pr) \wedge take\_property(?y, ?pr) \\ \wedge differentFrom(?x, ?y) \rightarrow has\_committed\_larceny(?y)$$

The proeprty *own_property* has a domain of Person ($\exists own\_property.\top \sqsubseteq$ Person) and a range of Property ($\exists own\_property^{-}.\top \sqsubseteq$ Property) as defined in the ontology. They add implicit constraints on variable $?x$ and $?pr$, which must be instances of Person and Property, respectively.

All atoms in the premises need to be satisfied for the rule to be triggered. For example, for the crime of robbery, suppose P1 is *taking*, P2 is *by force*, P3 *use of weapon*, and P4 *robbery*. Suppose we have the legal rule (simplified by removing the variables): P1 ∧ P2 ∧ P3 → P4. Assuming that we have only P2 and P3 hold in the knowledge base, then we cannot assert that robbery. The fact that there was an application of force on someone and the presences of a a weapon does not constitute a robbery, since taking is not involved. Martin and Storey [**?**] describe the elements of robbery as "theft by force or putting or seeking to put any person in fear of force." Therefore, the elements: theft and force are the main focus and must be explicitly defined in the rule. The extracted and transformed robbery rule from [**?**,**?**] and *Panel Law art 160* in relation to our ontological concepts and properties is given as:

$$in\_possession\_of(?y, ?pr) \wedge force\_person(?x, ?y) \wedge take\_property(?x, ?pr) \\ \wedge\, differentFrom(?x, ?y) \rightarrow has\_committed(?x, robbery).$$

Due to domain and range axioms, the variables *?x* and *?y* are instances of the Person class while *"?pr"* is an instance of the Property class. The rule can be read as:

> If person *?y* is in possession of property *pr* and person *?x* forced *?y* and take property *?pr* and *?x* is different from *?y* then *?x* has committed robbery.

Also, Martin and Storey describe the elements of crime as "*actus reus + mens rea = offense*" [**?**] – the concurrence of the two elements *actus reus* and *mens rea*. We translate these elements into rules, where an *offense* is:

$$has\_committed(?x, ?y) \wedge has\_intent(?x, ?i) \rightarrow guilty\_of\_offense(?x)$$

Here, due to the domain and range axioms from the ontology, *?x* is an instance of the Person class, *?y* is an instance of the Crime class, and *?i* is an instance of the Intention class. The atom *has_committed(?x, ?y)* corresponds to the *actus reus* and *has_intent(?x, ?i)* to *mens rea* as the elements of crime. The rule can be read as:

> "If person *?x* has committed a crime *?y* and person *?x* had intention *?i* to commit a crime *?y*, then person *?x* is guilty of an offense".

A more complex example enables reasoning to acquital. Note the chaining of rules between conclusions and premises, where the conclusion of rule (a) is a premise of rule (c), and the conclusion of rule (c) is a premise of rule (d).

(a) $carry\_property(?x, ?p) \wedge Property(?p) \rightarrow in\_possession\_of(?x, ?p)$
(b) $has\_committed(?x, ?r) \wedge negate\_required(?m, ?i) \wedge Intent(?i)$
$\rightarrow did\_not\_intend(?x, ?r)$
(c) $force\_person(?x, ?y) \wedge take\_property(?x, ?p) \wedge in\_possession\_of(?y, ?p)$
$\wedge\, charge\_with(?x, ?r) \wedge differentFrom(?x, ?y) \rightarrow has\_committed(?x, ?r)$

(d) $has\_committed(?x, ?r) \wedge did\_not\_intend(?x, ?r) \wedge Crime(?r)$
$\rightarrow should\_be\_acquitted\_of(?x, ?r)$

The importance of using this approach is that legal rules defined are reusable and the whole process could lead to generalization of the rules. Some rules could be applicable to other legal subdomains. In addition, having a clear rule set will be helpful to automate legal rule development process in future.

6 Application of the CLOR

To understand the dependencies between the rules, we tested each of the rules individually with a populated ontology. Our queries are formulated in the Semantic Query-Enhanced Web Rule Language (SQWRL), which is based on SWRL and provides SQL-like operators for querying information from OWL ontologies. We assumed the following ABox assertions.

carry_property(passenger, briefcase), take_property(Mel, briefcase), knock_person(Mel, passenger), Crime(robbery), perform_bymistake(Mel, robbery), Intention(intent), differentFrom(Mel, passenger)

from the example question in Table **??**. In effect, the SQWRL queries enable assessment of the ontology relative to the competency questions as well as the relevant to rule firing.

We have the following queries for the ontology:

- The query $in\_possession\_of(?x, ?r) \rightarrow sqwrl : select(?x, ?r)$ is used in querying the possession rule (a) and the output is *(?x=passenger, ?r=briefcase)*.
- The query $has\_committed(?x, ?r) \rightarrow sqwrl : select(?x, ?r)$ is used for querying the robbery rule (c) and the output is *(?x=Mel,?r= robbery)*;
- The query $did\_not\_intend(?x, ?r) \rightarrow sqwrl : select(?x, ?r)$ for querying the did not intend to commit rule (b) and the output is *(?x=Mel, ?r=robbery)*;
- The query $should\_be\_acquitted(?x, ?r) \rightarrow sqwrl : select(?x, ?r)$ for the acquit rule in (d) and the output is *(?x=Mel, ?r=robbery)*.

However, to be sure that the rules satisfy the dependencies in sequence to arrive at the final conclusion, we altered the ABox fact *carry_property(passenger, briefcase)* in the ontology. Then we executed the same queries and examine the output, which did not generate any results. In addition, we altered the fact *knock_person(Mel, passenger)*, leaving all others intact. As a result, the query

$$in\_possession\_of(?x, ?r) \rightarrow sqwrl : select(?x, ?r)$$

returned *(?x=passenger, ?r=briefcase)*, while the rest did not generate any results. Also, we kept all facts intact and altered *perform_bymistake(Mel, robbery)*. In executing the queries, we observed that the last two queries did not generate any result. Finally, we also tested the situation where we had all facts intact and altered *Crime(robbery)* fact. We observed that all rules work as usual, due to the fact that the Crime class is the range of has_committed, thus even if we do not have *Crime(robbery)* explicitly stated, it is entailed by the ontology. This shows that the dependencies amongst the rules were executed in the right order.

7 Ontology Evaluation

While the criminal law and procedure ontology and rule sets are still under development, we evaluated them in three ways: task-based, competency questions, and ontology evaluation tools. We note that while the results in Table **??** is incrementally better than previously reported, this has been done in the context of a systematic and transparent methodology. The advantage now is that in error analysis, we can trace the problem to a particular part of the methodology and revised that component, then rerun and test. We should emphasise that CLOR was developed on 12 multiple choice questions out of 16, which constitute the training data (results below), then applied to 4 new questions (for a 30 % increase of data), which constitute the testing data, as they had not been included amongst the questions used to develop the ontology. Of the 4 testing data, CLOR accounted for three, while CLOR required slight modifications to take the fourth question into account. This demonstrates that our iterative approach to the development of CLOR is feasible.

Firstly, we took a task-based approach, assessing the performance of CLOR with respect to benchmark answers to the bar examination questions. A semantic interpretation is said to be accurate if it produces the correct answer based on the question with respect to the application of the law. We present a preliminary experimental results from 16 MBE questions, each with four possible answers, constituting a total of 64 question-answer pairs. CLOR was evaluated against our previous work [**?**]. See evaluation result in Table **??**. Secondly, we evaluated

Table 3. Evaluation results

Index	Previous work	CLOR
True positive	15.0	16.0
False positive	16.0	16.0
True negative	32.0	32.0
False negative	1.0	0.0
Precision	0.48	0.5
Recall	0.93	1.0
Accuracy	0.73	0.75
F-measure	0.63	0.66

the system against our competency questions in the development stage. The ontology is evaluated with respect to how its concepts match with the respective terms in the competency questions. Here, we want to ascertain the completeness of the ontology in relation to the competency questions and whether the ontology answers the list of previously formed competency questions or not.

Finally, we used several ontology evaluation tools. To ensure the ontology is consistent and its general qualities are sustained, we applied the Pellet reasoner and the OntOlogy Pitfall Scanner (OOPS)[**?**,**?**]. The ontology is consistent. The OOPS is a web based evaluation tool for evaluating OWL ontologies. Its evaluation is mainly based on structural and lexical patterns that recognize pitfalls in ontologies. Currently, the tool contains 41 pitfalls in its catalogue, which are applied worldwide in different domains. OOPS evaluates an OWL ontology against its catalogue of common mistakes in ontology design and creates a single issue in Github with the respective summary of the detected pitfalls with an extended explanation for more information. Each of the OOPS pitfalls are evaluated into three categories based on its impact on the ontology:

a) Critical means that the pitfall needs to be corrected else it may affect the consistency and applicability of the ontology, amongst others.
b) Important means that it is not critical in terms of functionality of the ontology but it is important that the pitfall is corrected.
c) Minor means that it does not impose any problem. However, for better organization and user friendliness, it is important make correction.

Not all the pitfalls in [?] are relevant for evaluating our ontology. Moreover, some of these pitfalls depend on the domain being modeled while others on the specific requirements or use case of the ontology.

Our criminal law and procedure ontology was evaluated against the 41 pitfalls in OOPS (see evaluation result in Figure ??). The evaluation is to ensure that our ontology is free from the critical and important pitfalls. On evaluating our ontology we observed that critical pitfalls polysemous elements are not present in the ontology as well as synonymous classes. Other pitfalls like "is" relations, equivalent properties, specialization of too many hierarchies and primitive and defined classes are not misused. Also, the naming criteria is consistent and so on. However, it returned an evaluation report of 3 minor pitfalls as shown in Figure ??) (P04, P08, and P13). P04 is about creating unconnected ontology elements, P08 is missing annotations while P13 is about inverse relations not explicitly declared. At this initial evaluation, these pitfalls appear to be irrelevant, since the construction of the ontology is still in progress.

8 Conclusion

We have developed a methodology for a criminal law ontology in OWL with legal rules in SWRL to infer conclusions. The resulting CLOR ontology represents legal concepts and the relations among those concepts in criminal law and procedure. As far as we know, this is the first fine-grained methodology for constructing legal OWL ontologies with SWRL rules. We envision that such methodology can be applied to other domains and applications of textual entailments, such as fake news detection [?]. However, it is important to emphasize that the system does not address a range of challenging issues such as defeasible reasoning complex compound nouns, polysemy, legal named entity recognition, and implicit information in legal text. In the future, NLP techniques will be adopted to automate our methodology. Ontology learning techniques [?,?] might be used to learn further OWL axioms, which can be used together with SWRL rules. Due to the uncertainties introduced by NLP and ontology learning techniques, we will consider some uncertainty/fuzzy extensions of OWL [?] and SWRL [?] in our future work. We will develop a Legal NER system to serve in identifying

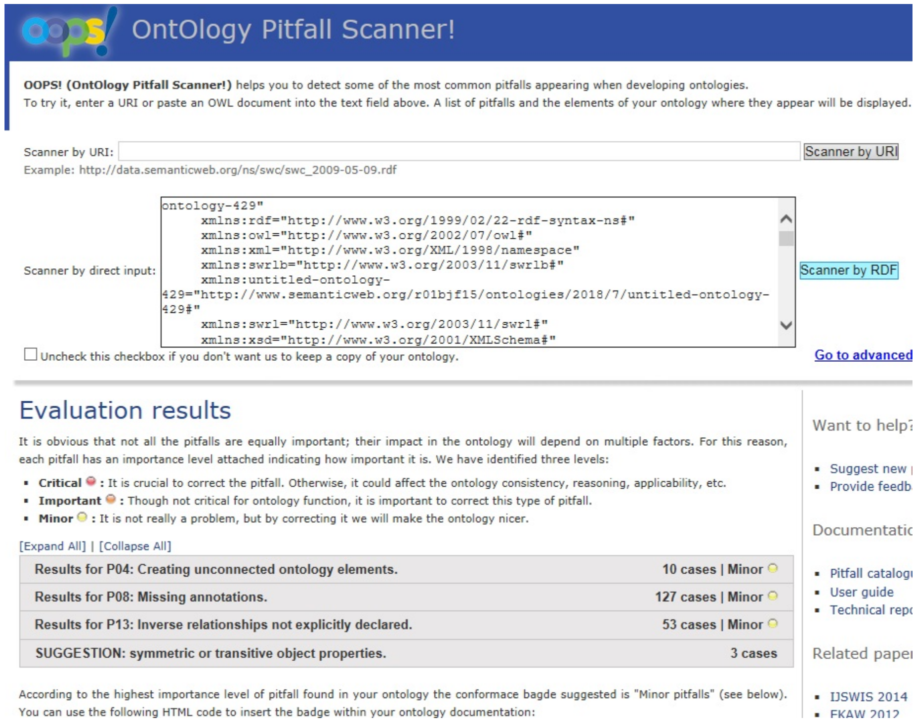

Fig. 3. OOPS evaluation summary

legal named entities such as Judge, Barrister and so on and other issues such as scalability for wider coverage.

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