CERIAS Tech Report 2008-14

Solving Normative Inconsistencies of Multi-Agent Environment Under Ontological Framework

by Olga Krachina, Victor Raskin
Center for Education and Research
Information Assurance and Security
Purdue University, West Lafayette, IN 47907-2086

Solving Normative Inconsistencies of Multi-Agent Environment under Ontological Framework[1]

Olga Krachina, Victor Raskin

CERIAS, Purdue University
West Lafayette, Indiana 47906, USA
{okrachin, vraskin}@purdue.edu

Abstract. This paper addresses resolution of normative inconsistencies in privacy regulation resulting from merging documents of various kinds. The solution we propose is similar to the past approaches [4], in that we also resort to the implementation of a certain priority in order to resolve actual contradiction. At the core of the processing conflicts lies text-meaning-representation (TMR) module. Conflict detection explores modalities as well as OPPOSITE/NOT relation of corresponding principal heads of the TMR(s). Additionally, we claim that unlike purely axiomatic frameworks used [2], ontological semantics accounts for semantic heterogeneity and does not place a restriction on the type of regulation that can be processed.

1 Introduction

It is common that a particular organization has to enforce several different regulations, in which case in its security regulation the company has to accommodate requirements from multiple sources. Merging these requirements into a single regulation is likely to produce contradictions. Certain contradictions should be resolved from legal standpoint, while others can be reconciled via Natural Language Processing (NLP)[2]. Such NLP approach is the focus of this work. Even though classification of possible conflicts is quite broad, main focus in the literature has been on what in deontic logic terms is known as normative conflicts; in other words, conflicts of constraints on actions or roles performed by agents. For example, the same action is permitted according to one document and forbidden according to another one.

First, we have to consider following assumptions with respect to the set of regulations:

1. each document is consistent within itself, i.e. no normative conflict within a role [1];
2. completeness of a particular document is not guaranteed;

[1] The research was supported in part by the National Science Foundation CyberTrust Research Grant No. 0430274 to CERIAS/Purdue University.

[2] Here by NLP we mean any computational method that is applied to the input data in natural language format.

3. if applicable, documents have been assigned a classification, as in the multilevel security policy [3].

Thus, staying in line with Cholvy and given the above assumptions, the conflicts can arise only when an agent is forced to play a composite role [1]. Due to the scope of this paper we will not present a solution for entire conflict classification, as outlined by Cholvy [5].

1.1 Related Work

The most recent method presented by Cholvy and Cuppens suggests using axiomatic role-based approach, where "each individual is associated with a set of roles which represents the behavior of the individual is playing in a given situation. Each role defines the permissions, obligations and prohibitions laid upon the role-holder" [5]. In conjunction, they implement SOL-resolution (consequence-finding technique, for details see [2], and [6]) to complete the regulation statement as well as detect a conflict. To apply SOL-resolution, all modalities need to be translated into predicates. The priority within a composite role is determined based on the rank of roles each separately with respect to each other; in most cases setting the rank of roles involves human intervention.

The main limitation of this approach is that it introduces additional assumption, namely, it allows merging only those regulation that can be represented in terms of sets of deontic literals, in other words, application of role-based approach to any general regulation, e.g. disjunctive norms [4], might lead to inconsistencies. Among other problematic issues is the semantic heterogeneity, i.e. there is no systematic way in the proposed model to account for the same concept being expressed in different words across different documents of different formats and styles. In the remaining part of this paper we will show how these limitations are not relevant to OntoSem.

2 OntoSem Description

Ontological Semantics is a framework designed as a comprehensive, deep semantic basis for NLP. The following components comprise such system: the language-independent ontology, domain-specific lexicons and onomasticons, the fact-database (FDB). The text meaning representation (TMR) module automatically assigns a meaning approximating human understanding to each sentence, using frames, each of which has a head to a frame, a pointer to another frame, a simple value or a more complex combination for defaults, semantic types, relaxable types, etc. Each TMR is a set of six kinds of frames: one or more propositions, zero or more discourse relations, zero or more modalities, one style, zero or more references, and one TMR time. Deontic notions are encoded through an appropriate modality. It is worth noting that TMR construction is a result of interaction of various system resources, which ensures semantic heterogeneity in that synonymous sentences will result in the same TMR. After the basic TMR is constructed, it is further used in application-specific inference engine which produces an output in the form of an extended TMR. The output TMR in turn is an input in for the answer-formulating unit, the unit producing

final output in natural language form. The application specific inference engine is the component of interest, i.e., this is the main unit where the following discussion applies.

2.1 Conflict Detection

The idea behind conflict detection is similar to that of Cholvy's approach: conflicts are determined via consequence finding. The difference lies in the nature of the framework, hence, the methods used and cases handled. The basis for inference making process within OntoSem is the expansion of the input text TMR from the FDB and ontological hierarchy [7]. However, the primary emphasis of this application is on basic TMR *expansion* of the merged regulation, and *premise set procedure* [7]. Compared to previous work, there is less reliance on FDB search, due to the fact that, ideally, the regulation document is not only fairly complete and consistent but also restrictive, and the entire FDB knowledge cannot be blindly used to make inferences. Rather, the FDB is populated with the proper documents and, potentially, some pre-TMR human input, as discussed in section 2.2.

Within OntoSem there are two mechanisms that indicate antonymic meaning: OPPOSITE slot in ontological concepts specification of events and NOT slot in both events and objects. Our conflict detection unit implements the modality check and substitution method which exposes actual[3] conflicts through modality mismatches and OPPOSITE/NOT field matches, respectively. A modality mismatch occurs when both TMRs have the deontic modality associated with the particular same events and thus is a simple case: to detect a conflict in this case, all that is necessary is a comparison of the modality values. In case when the lexical entry indicates mapping to two or more concepts that are connected via conjunction[4], substituting each of the concepts into the other's principle heads will reveal a contradiction if the OPPOSITE/NOT fields of any events associated with the same agent match. Note that in this paper, as mentioned in the introduction, we are focusing on agents forced to play different roles, hence the multiple concepts in the specification of lexical-semantic entry refer to either of two cases: a multiply-linked object or an event with multiple agents.

2.2 Conflict Resolution

The fact that a conflict is detected in our framework indicates that it is the actual conflict, i.e. not *a prima facie* one. To resolve actual conflicts we propose to define a priority, similar to Cholvy's and Cuppens's approach. To reiterate, they introduce a notion of composite role, i.e., the priority within the composite role is determined by the priority of each role separately with respect to the other roles. This priority is established through a regulation officer who is automatically called upon to adjust the

[3] We assume that prima-facie conflicts are taken care, i.e. the focus of this paper is actual conflict detection and resolution.

[4] Most likely in this case in that particular document there are no conflicts between the two concepts.

priority list if it cannot be established from the given TMR-ized set of regulations within the FDB (after the adjustment, the process is fully automatic).

Hence, assume that a single agent takes on n roles with a certain priority[5] $P(r_1 > r_i > r_n)$. Then the new entity is an agent of the multiple events with the same priority. If the entity is an agent of conflicting events, the one with the higher priority is selected for the merged TMR, which is a union of the non-conflicting heads.

To demonstrate ideas discussed above we will consider two hypothetical examples below. Example 1 emphasizes the idea that correct resource acquisition may lead to elimination of conflicts, while example 2 briefly illustrates an actual regulation contradiction and its resolution using the methods discussed in this section.

2.3 Application to Examples

Example 1.
A user is an agent who is permitted to read and create public files but is not allowed to downgrade them. A security officer is an agent who is allowed to downgrade files.

In Cuppens and Cholvy, it is necessary to define priority in this case as it follows that the security officer is a user from the domain axiomatics and, hence, a contradiction arises with respect to the predicate "downgrade". In our approach, the user and security officer as lexical entries would be linked to two different concepts under COMPUTING-ROLE which associates them with the computer system as the common instrument of defining activity. The distinction in properties is what ensures the absence of a normative conflict. If ontology had only a taxonomic structure, this scenario would have resulted in a conflict as well.

Example 2.
The university is waived from insuring undergraduate students, but workers must be insured. Undergraduate students employed by university are paid the minimum wage[6].

Corresponding TMR of the first statement is given in listing 1.a.

Listing 1. Relevant portions of TMR corresponding to Example 2

1.a. TMR of the first input statement

UNIVERSITY	
AGENT-OF	INSURE, WAIVE
EMPLOYER-OF	WORKER
LOCATION-OF	ACADEMIC-EVENT
	UG-STUDENT
INSURE	
AGENT	UNIVERSITY
BENEFICIARY	WORKER
EFFECT	OWN
MODALITY	

1.c. Merged TMR

INSURE-1	
AGENT	UNIVERSITY
BENEFICIARY	WORKER
	UG-STUDENT-1
	UG-STUDENT-2
EFFECT	OWN, LACK
MODALITY-1	
SCOPE	INSURE-1
TYPE	DEONTIC
VALUE	0.9

[5] We assume a total order in this paper.

[6] For the sake of space, TMR of the second sentence is not going to be listed here, just the relevant part of the lexical entry indicating lexical-semantic mapping will be given.

```
  SCOPE              INSURE
  TYPE               DEONTIC
  VALUE              0.9
  ATTRIBUTED-TO      AGENCY-X

OWN
  AGENT              WORKER
  THEME              PROTECT-SERVE
  OPPOSITE           LACK

WAIVE
  AGENT              UNIVERSITY
  THEME              INSURE
  EFFECT             LACK

LACK
  AGENT              UG-STUDENT
  THEME              INSURE-1
  OPPOSITE           OWN

WORKER
  EMPLOYED-BY        UNIVERSITY
  BENEFICIARY-OF     INSURE
  ROLE-FOR-ACTIVITY  WORK-ACTIVITY

UG-STUDENT
  ROLE-FOR-ACTIVITY  ACADEMIC-ACTIVITY
```

1.b. Lexical entry corresponding to the second input statement

```
STUDENT-WORKER (CAT N) <…>
    SEM-STRUC (UNDERGRADUATE-STUDENT, WORKER)
```

```
 ATTRIBUTED-TO AGENCY-X

OWN
AGENT        WORKER,
               UG-STUDENT-2
  THEME      PROTECT-SERVE
  OPPOSITE   LACK

WAIVE (remains the same)

LACK
  AGENT      UG-STUDENT-1
  THEME      INSURE
  OPPOSITE   OWN

UG-STUDENT-2[7]
   ROLE-FOR-ACTIVITY
        ACADEMIC-ACTIVITY
        WORK-ACTIVITY
```

The TMR does not contain a contradiction, since the AGENT slot fillers of the respective events are not the same. This conflict will emerge as such only when insurance policy of university is being defined within the regulation. TMR in listing 1 will be checked for consistency with the TMR of statement (2) where UG-STUDENT and WORKER are assumed under the same agent entity (or case-role), i.e. initially of the same priority level as indicated in the lexical entry. The next step is substitution of each of the concepts listed in SEM-STRUC into the existing TMR of the regulation, which does produce a conflict situation: the same agent is listed in the events that have the filler of OPPOSITE slot cross-linked.

Further, assume the following priority applies for insurance purposes: WORKER > UG-STUDENT. The merged TMR contains an additional property (BENEFICIARY) for INSURE which represents a composite role with the given priority. To resolve the conflicting EVENTS, the one that has a higher priority agent is included in the new TMR, see listing 1.b.

At the last stage, the resulting TMR goes through the answer-formulation component which translates TMR into natural language taking into account style and other linguistic parameters.

[7] Or alternatively a WORKER; the answer formulating component will account for the actual surface realization.

3 Conclusion and Results

To summarize, we have outlined how to handle normative conflicts within ontological semantics framework. The problem has two stages: detecting normative conflicts and conflict resolution. Within OntoSem conflicts are detected through a modality comparison and, in case of an object being linked to multiple concepts, through substitution and subsequent OPPOSITE/NOT slot examinations of the merged TMR. Such a merged TMR is the union of the principle heads of the TMRs corresponding to the statements of two different regulations (or parts thereof) dealing with the same aspect of a regulatory policy. If an actual conflict occurs, human interference is required to define a priority that determines which principled heads should be included in the merged TMR.

Heterogeneity does not arise as an issue in our framework due to the nature of TMR (for more detail on TMR see [8]). We have also demonstrated that our framework is able to handle a variety of inputs, i.e. not only in deontic form as is the case with former approaches.

To date around 500 lexical entries along with about 50 concepts were acquired in the domain of privacy policies, as a part of the CyberTrust grant. In the future, we plan to update the classification of conflicts; in this work, we used a classification which applies to the regulations that can be represented in deontic form. Even though, in this paper, we have considered a non-deontic statement, a larger set of policies needs to be examined to determine a more detailed classification of conflicts and how they can be handled. Partial order within roles may be of interest as well. Systematic querying for inconsistencies is a desirable functionality to implement under OntoSem for this project.

References

1. Cholvy, L., Cuppens, F.: Analyzing Consistency of Security Policies. In: IEEE Symposium on Security and Privacy, pp. 103-112, IEEE Press (1997).
2. Cholvy, L.: An Application of SOL-resolution: Checking Regulation Consistency. Poster (1997).
3. Cholvy, L., Cuppens, F., Saurel, C., Carrere J.: Merging Regulations: Analysis of a Practical Example. In: International Journal of Intelligent Systems, pp. 1223-1243. John Wiley and Sons, Inc. (2001)
4. Cholvy, L., Cuppens, F.: Reasoning About Norms Provided by Conflicting Regulations. In: 7th International Conference on Artificial Intelligence, pp. 73-79. (1999).
5. Cholvy, L., Cuppens, F.: Solving Normative Conflicts by Merging Roles. In: 5th International Conference on Artificial Intelligence and Law, pp. 201-209. (1995)
6. Demolombe, R.: Answers About Validity and Completeness of Data : Formal Definitions, Usefulness and Computation Technique. In: Flexible Query Answering Systems (1998). LNCS, vol. 1495, pp. 138-147. Springer, Heidelberg (2004)
7. Krachina, O., Raskin, V.: Ontology-Based Inference Methods. In: Proceedings of MCLC 2006.
8. Nirenburg, S., Raskin, V.: Ontological Semantics. MIT Press (2004).