Position Paper Towards ODRL Formal Semantics

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1. Introduction

The W3C Permissions and Obligations Expression (POE) Working Group has been chartered to create recommendations for expressing permissions and obligations statements for digital content. This working group has used as starting point the latest version of the ODRL policy expression language.

After having collected *Use Cases and Requirements*[2], the working group is in the process of editing an "*ODRL Information Model*"[3] and an "*ODRL Vocabulary & Expression*"[4] specifications. These to-be W3C Recommendations shall be complemented by two additional W3C Notes, "*ODRL Best Practices Guide*" and "*ODRL Formal Semantics*". This document intends to be a first contribution for the latter.

2. Related work

2.1 Documents on semantics in W3C specifications

The W3C has produced several "Semantics" documents each of them with a different objective.

The "*RDF1.1. Semantics"*[5]defines a model-theoretic semantics to determine the validity of RDF inference processes. A similar approach is followed by the OWL Semantics[6], a recommendation providing the direct model-theoretic semantics for OWL 2 and definingthe most common inference problems.

XPath (XML Path Language) is a language that can be used to navigate through elements and attributes in an XML document. XQuery (XML Query) is a query and functional programming language to query XML data. The *"XQuery and XPath Formal Semantics"*[7] intends to complement the specification by defining the meaning of XQuery/XPath expressions with mathematical rigor; thus clarifying the intended meaning of the English specification, and ensuring that no corner cases are left out. For that regard grammar productions are given.

The POWDER specification providesa mechanism to describe and discover Web resources, and italso includes a "*Formal Semantics*" document[8]. POWDER documents are XML documents which can be automatically converted, through a GRDDL transform, into a semantically rich version in RDF (POWDER-S). The "semantics" document describes how to make such transformation.

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[2] POE Use Cases and Requirements W3C Working Group Note 21 July 2016. https://www.w3.org/TR/poe-ucr/
[3] ODRL Vocabulary & Expression W3C First Public Working Draft 21 July 2016 https://www.w3.org/TR/odrl-model/
[4]ODRL Vocabulary & Expression W3C First Public Working Draft 21 July 2016 https://www.w3.org/TR/vocab-odrl/
[5]*RDF 1.1 Semantics* W3C Recommendation 25 February 2014
[6] OWL 2 Web Ontology Language Direct Semantics W3C Recommendation 27 October 2009
[7]*XQuery 1.0 and XPath 2.0 Formal Semantics* (Second Edition) W3C Recommendation 14 December 2010 (revised 7 September 2015)
[8]Protocol for Web Description Resources (POWDER): Formal Semantics W3C Recommendation 1 September 2009

The PROV Ontology Working Group has produced 12 specifications to facilitate the interchange of provenance information in the Web (where provenance is …*information about entities, activities, and people involved in producing a piece of data or thing, which can be used to form assessments about its quality, reliability or trustworthiness"*). Besides having published a PROVO Ontology[9] to facilitate the expression of provenance as RDF, the family of documents also define an EBNF notation "*which allows serializations of PROV instances to be created in a compact manner*", a set of constraints to "*ensure that a PROV instance represents a consistent history of objects and their interactions that is safe to use for the purpose of logical reasoning*" and statements in the PROV Data Model are seen "*as atomic formulas in the sense of first-order logic […and…]the constraints and inferences specified in PROV-CONSTRAINTS as a first-order theory*".

2.2 Formalization of ODRL

ODRL was created in in the early 2000's as an XML dialect to represent rights expressions to be used in the framework of Digital Rights Management systems; and its version 1.1 gained much spread [ODRL02]. Different ODRL profiles extended the vocabulary to satisfy the needs in different sectors. In 2011, an ODRL W3C Community Group was established, publishing soon after a new version 2.1 with major changes which included a new information model [Ianella15], a vocabulary [Ianella15b] and an Ontology [McRoberts15]. ODRL 2.1 became then a policy language.Other specifications in XML and similar to ODRL were MPEG-21 Rights Expression Language [Wang94], XACML[10] or MPEG-21 Contracts Expression Language [Rodríguez15]. The MPEG-21 Media Contracts Ontology [Rodriguez16] defines an ontology to guide the generation of contracts as RDF, with a similar philosophy to that of the ODRL Ontology.

RDF documents instantiating the "Policy" class of the ODRL Ontology or using the XML or JSON syntaxes are called simply "*ODRL Policies*". The ODRL Ontology is already a formalization of the ODRL information model and vocabulary. The ontology of the version 2.1 consists of 1111 axioms with low complexity, but a comprehensive definition of each element (classes and relations) and a systematic definition of domains and ranges for the properties. Some ODRL concepts are represented as SKOS concepts ordered in SKOS collection. Reasoning with the ontology would be computationally inexpensive, but the usefulness of the possible reasoning tasks with the ontology is very limited.

The ODRL 2.1 Ontology is not the first ODRL Ontology and other ontologies had been proposed before [García05][Kasten10]. However, neither these ontologies nor the ODRL 2.1 Ontology directly supported any reasoning tasks of practical use. Other more generic rights ontologies exist, claiming to comprise the concepts of ODRL, with the ambition of facilitating *interoperability*. Thus, Delgado (2003) and Nadah (2007) have proposed ontologies as a bridge to make transformation between rights expression languages like ODRL and MPEG-21 REL, whereas Rodríguez (2013) underlined the similarities of seven policy languages with an ontology design pattern. Other alternative means of achieving interoperability do not require ontologies, as Guth did (2003) defining an abstract object model.

Some other formalizations of ODRL have been proposed with the purpose of determining whether a request is permitted given a set of policies and a certain history of events: we can name this task as the *authorisation decision*. With that purpose, Gunter and Pucella had defined general logics for rights (2001 and 2002 respectively). Pucella then extended his work to model ODRL1.1 statements (2004) as formulas in a many-sorted first-order logic with equality, to determine whether a permission was implied by a set of ODRL statements. Holzer et al. (2004) also enriched the authorisation decision modelling the dynamic aspects of licenses with finite-automata like structures (useful when the property of an asset is transferred, or when the number of plays is limited to a certain number of times). Chong et al. (2006) modelled

[9]https://www.w3.org/TR/prov-o/

[10]http://docs.oasis-open.org/xacml/3.0/

licenses with multiset rewriting and logic programming (Prolog), including the ability to evaluate and merge licenses and to track the *dynamic* aspects of the rights evolution. Barth and Mitchell (2006) observed that the authorisation decision of a sequence of actions given a set of ODRL licenses is NP-complete because of the interval constraints, and proposed using propositional linear logic to grant efficient computability. Sheppard and Sfavi(2009) defined an algorithm for the authorisation decision with some of the most common ODRL elements, giving the pseudo-code for a virtual machine. Steyskal and Polleres (2015) defined an abstract syntax for expressing ODRL policies, where the dependencies among ODRL actions and the different conflict resolution strategies were explicitly considered in the rules for taking the authorisation decision.

Besides the problems of facilitating interoperability and making the authorisation decision, other problems of interest have been modeled with formalizations of ODRL. One of them is how to evaluate the *compatibility and composition* of licenses, useful when handling with differently licensed content or data. In this line, Gangadharan et al. (2007)proposed a matchmaking algorithm to analyze the compatibility of licenses and make license compositions; Jamkhedkarand Heileman (2008) showed how the combination of ODRL, CreativeCommons REL and the XrML (embryo of the MPEG-21 REL) licenses was possible with an abstract model and several rules. Villata and Gandon (2012) also defined a framework with algorithms to validate compatibility and to obtain composite licenses. Rotolo et al. (2013) defined a deontic logic system for the composition of licenses, with strict rules, defasible rules and defeater rules.

It is evident that some policies can be used to grant automated access to resources. For example, verifying the execution of a payment can be automatically done. However, the satisfaction of some constraints cannot be digitally evaluated. Policies then play a double role, as automatable expressions in a computer system and as constracts with a certain legal value. Steyskal and Kirrane (2015) show how to use ODRL to specify access requests, data offers and agreements, distinguishing between enforceable and non-enforceable access policies, proposing an algorithm to auto-generate contracts for the latter.

3. Reasoning tasks

Unlike other policy languages as XACML (2003), there is no endorsed reference software around ODRL (nor specified nor implemented). One might conceive tools and systems of practical interest, listed below. Each of these functionalities might be automatable by means of a systematic method or reasoning task.

(1) **Validator**. to validate that ODRL policies are syntactically valid.
The validator might be a set of SHACL constraints. Perhaps a "minimal subset" of ODRL might be defined, and the validation would grant that an ODRL policy adheres to that "minimal subset".
The validator might be a set of SWRL rules.
The validator might be a reasoning task in a transposition of ODRL to FOL?

(2) **Converter**. to transform from one syntax to another (JSON-XML-RDF)
This might be done via software. Converters might be all-to-RDF and RDF-to-all, enabling each of the 6 possible combinations.
XML-->RDF might be done with GRDDL
JSON-LD --> RDF
RDF-->XML
RDF-->JSON

(3) **Profiler**. to check whether an ODRL policy participates in one profile or not.
An algorithm detecting vocabulary?

(4) **Satisfiability checker**. to validate whether a permission can be satisfied given a set of policies Algorithm? Reasoning task in a transposition of ODRL to FOL?

(5) **Authoriser**. to check whether a request should be authorized considering a policy and a context. Algorithm? Reasoning task in a transposition of ODRL to FOL?

Additionally, an advanced modeled might want to describe those pieces of knowledge not gathered in the ODRL Ontology. Also, we can define an abstract ODRL policy notation with a EBNF grammar as in PROV-N[11].

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