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Introduction to the formal semantics of ODRL policies

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My Short Bio

- Since September 2017, I am **Lecturer and Researcher** at the Institute of Digital Technologies for Communication, Faculty of Communication, Culture and Society at Università della Svizzera italiana (USI), Lugano, Switzerland
- My research is focused on the field of **Agents and Multiagent Systems** and **Semantic Web**
- Since 2007, I am member of the Steering Committee of the **COINE** (Coordination, Organization, Institutions and Norms in agent systems) Workshop series
- Since 2021, I am Co-Chair of the W3C ODRL (Open Digital Rights Language) Community Group. I coordinate the activities of the group that is defining the **semantics of ODRL**
- In June 2025 I co-organized the **OPAL 2025** Workshop "ODRL and beyond: practical applications and challenges for policy-base access and usage control." at the **ESWC2025** (June 1 and 2, 2025 Portoroz, Slovenia)
- In July 2025 I organized with Marina De Vos, Munindar P. Singh, and Leon van der Torre, the Dagstuhl Seminar "Policy Modeling and Reasoning in Sociotechnical Systems" (Jun 29 – Jul 04, 2025)
- In May 2026 I co-organized the **OPAL 2026** Workshop and the ESWC2026 tutorial: "Policy Evaluation and Enforcement on the Web with ODRL"

The fundamental Requirement #1 of all policy languages

- Policies are written by some actors A, usually the assigner or creditor of the policy, and shall be **complied** with by other actors B, usually the assignee, or debtor, of the policy
- A and B **should understand the policy in the same way**, otherwise **compliance** is not possible even if B wants to comply
- This is a fundamental requirement also for policy negotiation
- Only **formal semantics** guarantees this, it must be unambiguous, a natural language formulation is not enough
- ODRL 2.2 Recommendation [2] does not include the specification of a formal semantics
- There is a sub-group within the ODRL Community Group that is working on a proposal starting from **concrete examples** of **policy types** [1]

Another crucial Requirement #2: Task Independence

- Policies are used for a variety of **tasks** (with a variety of names):
  - Access control / enforcement
  - Auditing / monitoring / usage control
  - Negotiation / agreement
  - Explanations (why / why-not / how-to / what-if queries)
- Semantics should be **task-independent** (what, not how) and define **one** correctness criterion for all tasks.
- E.g. if what-if says “ok the action is permitted” then access control permits, and monitoring does not notify violations

What I will and will not presenting (outline)

- Definition of the **semantics of ODRL** based on *ODRL Information Model 2.2* [2] as it is specified in [1], which is consistent with the "Model theoretic" declarative semantics based on simplified temporal Kripke structures (traces) is specified in [3]
- Covering the semantics of the main **rule types** of the language: **permissions, prohibitions, and obligations**
- Not covering history-dependent properties (e.g. count)
- Identifying ambiguities, **gaps**, and contradiction in the **informal** semantics [2] and discussing remarks and proposals for fixing problems as in [3]
- Discussing examples to validate the semantics from [1]

Compliance with Permissions, Prohibitions, and Obligations

In order to compute compliance we need to specify how an **ODRL Evaluator** could determine:

- Which Permissions, Prohibitions, and/or Obligations (collectively named Rules) are **active** on some **action** *a* in some **state of the world**. A Rule is said to be active if it is in effect;
- If an **action** *a* complies (or **is permitted by**) with a **Permission** in a given state of the world S;
- If an **action** *a* complies with a **Prohibition** in a given state of the world S, otherwise *a* is **prohibited** by the Prohibition;
- If an **action** *a* complies (fulfills) an **Obligation** in a given state of the world S, *a* is called the **fulfilling** action of the Obligation.

ODRL Evaluator

The ODRL Evaluator uses as **input**:

1. a **Policy**;
2. a formal description of the **State of the World** that lists the **events/actions** together with the **time** when they occur;
3. a formal description of an **Evaluation Request**, it represents a formal description of an **action** to be evaluated
4. an optional parameter specifying the **Behavior** of the system (open: anything that is not prohibited is permitted, or closed: anything that is not permitted is prohibited)

The ODRL Evaluator produces as **output**:

- The **Evaluation Report**.

Permissions and their intuitive semantics

- See [2] for the **ODRL Information Model** and [1,2] for **examples** of policies
- A **Rule** inside a **Policy** is characterized by:
  - An action class **α**, e.g. distribute, use, transfer; the action can be refined by refinements: **leftOperand operator (op) rightOperand**
  - A "target" asset **ob**;
  - An "assignee" party **p**;
  - Constraints **leftOperand op rightOperand** (e.g. dateTime lt 2018.01.01)
  - Permission may have **Duty/Conditions**: with action class **α2**, target **ob2**, assignee **p2**, refined by refinements, and constraints),
  - Other optional properties, e.g. assigner
- Intuitive meaning from [1]: "A Permission **allows** an action, with all refinements **satisfied**, to be **exercised** on an Asset if all constraints are **satisfied** and if all duties are **fulfilled**".

Semantics of Permissions (1)

- The ODRL Evaluator computes that the action **a** represented in the Evaluation Request **is permitted by a Permission** in the given State of the World **S if and only if all** the following conditions hold:
  1. The Permission is **active** on **action a** in state **S** (see next slide);
  2. The **action a** belongs to the permitted class of actions;
  3. The action's **target** is equal to the target of the Permission or it is contained in the collection of objects specified as target of the Permission;
  4. When the **assignee** of the permission is specified, the action's party is equal to the assignee of the Permission or it is contained in the collection of parties specified as assignee of the Permission;
  5. All the **refinements** (when they are specified) related to the regulated action, to the regulated target, and to the regulated assignee are satisfied by the action a, its target and its party.

Semantics of Permissions (2)

- The ODRL Evaluator computes that a Permission is **active** on some evaluated action ***a*** represented in the Evaluation Request and in some State of the World ***S*** **if and only if all** the following conditions hold:
    1. All the existing **Constraints** of the Permission are **satisfied** by the evaluated action ***a***; (for every constraint the value of the action's (or asset's) property leftOperand is op of the value denoted by the the rightOperand, e.g. "2017-12-19" It "2018-01-01")
    2. All the existing **Conditions** (Duties) of the Permission are **fulfilled** or **inactive** in state **S** with respect to the action **a**. Duties are **prerequisites**.
- If one of those conditions is not met, the Permission is **inactive**.
- Assumption: the ODRL Evaluator is able to compute the **satisfaction of constraints**, this requires a mapping between the properties of the policy, the evaluated action and the state of the world that may be formalized independently

Semantics of Conditions of Permission (1)

"All the existing **Conditions** (duties) of the Permission are **fulfilled** or **inactive** in state **S** with respect to the action **a**" (the action in the Evaluation Request).

- A Condition (duty) is **active** in state **S** with respect to the action **a if and only if one** of the following conditions holds:
  1. The Condition (duty) has no Constraints;
  2. Every **Constraint** of the Condition (duty) is **satisfied** by the action **a** (the evaluated action ***a*** represented in the Evaluation Request)

  Otherwise, the Condition is **inactive.**

Semantics of Conditions of Permission (2)

- A **Condition** (duty) is **fulfilled** by an action a2 in the state of the world S **if and only if all** the following conditions hold:
  1. The **Condition** (duty) is **active**;
  2. **There exist** an action **a2** in the **state of the world** S that belongs the class of actions **α2** regulated by the **Condition**;
  3. Such an action, **a2,** is performed **before** the evaluated action **a**
  4. Such an action, **a2,** satisfies all the **refinements** of the action regulated by the **Condition**;
  5. If a target object of the Condition is specified, the assets involved in action **a2** are exactly those specified in the target of the Condition and its refinements;
  6. If an assignee party of the Condition is specified, the parties that exercise action **a2** are exactly those specified in the assignee of the Condition and its refinements.
- An active Condition that is not fulfilled is **not-set**

Remark 1

- Alternative semantics for fulfilment of Condition (Duty)
  - (**current**) the action should be exercised **jointly** by all the specified assignees: e.g. *the contract shall be approved by all assignees*
  - (**alternative 1**) the action should be exercised by **any** of the specified assignees, e.g. *the payment shall be made by any of the assignees*
  - (**alternative 2**) **parallel**, each assignee should independently fulfil the conditon/duty: e.g. *all assignees shall register*

ODRL does not specify which of them is the correct one, *it should be possible to choose one alternative!*

Remark 2

- The semantics of a Duty, used as **Condition** of a Permission, could be different from the semantics of an **Obligation** to perform an action:
    1. The **constraints** of a **Condition** can be evaluated with respect to:
        - The **action a** in the Evaluation Request
        - The **action a2,** if it exists, that fulfils the Condition
    2. The **constraints** of an **Obligation** are evaluated always with respect to the **action a** in the Evaluation Request
- *It should be better to have two different classes: Obligation/Duty and Condition*
- *It should be necessary to introduce the possibility to specify on what action the constraint of a Condition should be evaluated*

Remark 3

- Duties are **prerequisites** for getting an **active Permission**; their fulfilment must occur **before** the permission is granted;
- This version **cannot model** duties that must be fulfilled **after** the permitted action is actually performed, e.g. personal data shall be deleted within one month from the access to them; for modelling this second case it would be fundamental to introduce the notion of **deadline**
- *It should be better to extend the model for being able to specify the temporal relations between the Permission and its Condition*

Remark 4

- In the previous semantics a **single fulfilment** of the duty is enough to perform **any number** of actions, e.g. After registering to a web site, a user may access all the content of the web site.
- In other use cases could be useful to say that **each** action execution requires a different fulfilment of the duty; e.g. Pay per view policies
- *It should be better to distinguish these two meanings*

Remark 5

- In the ODRL specification [1] there is written:
  “A Permission **allows** an action... if all duties are **fulfilled**”,
  but from the discussions within the Community Group, it emerged that if the **duty/condition** is **inactive**, it should be not relevant for computing if the action is permitted or not!
- *It should be better to clarify this point, maybe permitting both interpretations*

Activation of Prohibition/Obligation

- A Prohibition/Obligation is **active** **if and only if** **one** of the following conditions holds:
    1. The Prohibition/Obligation has no Constraints;
    2. Every **Constraint** of the Prohibition/Obligation is **satisfied** by the action **a**

  Otherwise, the Prohibition/Obligation is **inactive.**

Semantics of Prohibitions

- The ODRL Evaluator computes that the action **a** represented in the Evaluation Request **is prohibited by a Prohibition** in the given State of the World **S if and only if all** the following conditions holds:
  1. The Prohibition is **active** on **action a** in state **S** (see next slide);
  2. The **action a** belongs to the prohibited class of actions;
  3. The action's **target** is equal to the target of the Prohibition or it is contained in the collection of objects specified as target of the Permission;
  4. When the **assignee** of the Prohibition is specified, the action's party is equal to the assignee of the Prohibition or it is contained in the collection of parties specified as assignee of the Prohibition;
  5. All the **refinements** (when they are specified) related to the regulated action, to the regulated target, and to the regulated assignee are satisfied by the action a, its target and its party.

Semantics of Obligations

- An Obligation (duty) is **fulfilled** by an action a in the state of the world S **if and only if all** the following conditions holds:
    1. The **Obligation** (duty) is **active**;
    2. **There exist** an action **a** in the **state of the world** that belongs the class of actions **α** regulated by the **Obligation**;
    3. Such an action **a** satisfies all the **refinements** of the action regulated by the **Obligation**;
    4. If a target object of the Obligation is specified, the assets involved in action **a** are exactly those specified in the target of the Obligation and its refinements;
    5. If an assignee party of the Obligation is specified, the parties that exercise action **a** are exactly those specified in the assignee of the Obligation and its refinements.
- An active Obligation that is not fulfilled is **not-set**

Semantics of a Policy

- An ODRL **policy** may contain one or more **rules** (permissions, prohibitions, conditions (duties), obligations) and a property "**conflict**" (with possible values perm, prohibit, invalid (default)).
- A State of the World **S complies** with an ODRL **policy** if and only if **all** the following conditions hold:
  - For all **active obligations** there **exists an action** in S that fulfills them
  - For **all actions a in S** at least **one** of the following conditions hold:
    a. Action a is either a fulfilling action for an obligation or for the condition (duty) of a permission;
    b. Action a is permitted by one of the permissions of the policy (closed behaviour) and conflict = perm or action a is not prohibited

Remark 6

While defining when a *state of the world* complies with an ODRL policy we may ask: **which actions have to comply with which policy?**

The fulfilling actions of obligations and conditions (duties) may have to be permitted but they may fall outside the **scope** of the policy.

For example one policy may state a file can be played after fulfilling the duty to pay 2 euros, but the payment could be permitted by another policy of another assigner, the bank.

It should be clarified the scope of the policy and the interplay among different policies that in principle may also overlap with possible conflicts

References

[1] Fornara, Nicoletta, Víctor Rodríguez-Doncel, Beatriz Esteves, Simon Steyskal, Benedict Whittam Smith, and Yassir Sellami, Andrea Cimmino Arriaga. **ODRL Formal Semantics** (Draft Community Group Report) https://w3c.github.io/odrl/formal-semantics/.

[2] Iannella, Renato, and Serena Villata. **ODRL Information Model 2.2** (W3C Recommendation 15 February 2018). https://www.w3.org/TR/odrl-model/.

[3] Piero A. Bonatti, Nicoletta Fornara, and Andreas Harth. **Towards a Formal Semantics of the Open Digital Rights Language (ODRL 2.2)**. ODRL and Beyond: Practical Applications and Challenges for Policy-Based Access and Usage Control (OPAL 2025), Co-Located with the Extended Semantic Web Conference 2025 (ESWC 2025), 2025. https://ceur-ws.org/Vol-3977/OPAL2025-4.pdf.

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