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Institut für Offene Kommunikationssysteme

Aspect-Oriented Ontologies

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Aspect-Oriented Ontology Development

- KR paradigm and ontology development method for
  - Modularizing ontologies and **making the module's description explicit**
  - **Representing context** in an ontology, such as
    - Temporal, spatial, topological context
    - Views
      - ✓ Aspects of interest
      - ✓ Opinion
      - ✓ Competing definitions
      - ✓ …
    - Epistemic context
      - ✓ Agent's state of knowledge about axioms/facts
    - Deontic context
      - ✓ Permission, obligation and prohibition

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AspectOWL

- AspectOWL is an extension to W3C OWL 2 DL

- New:

    - Axioms carry context information (aspects).

    - Semantics: The model-theoretic interpretation of the axiom (truth valuation) is restricted to only hold within the context.
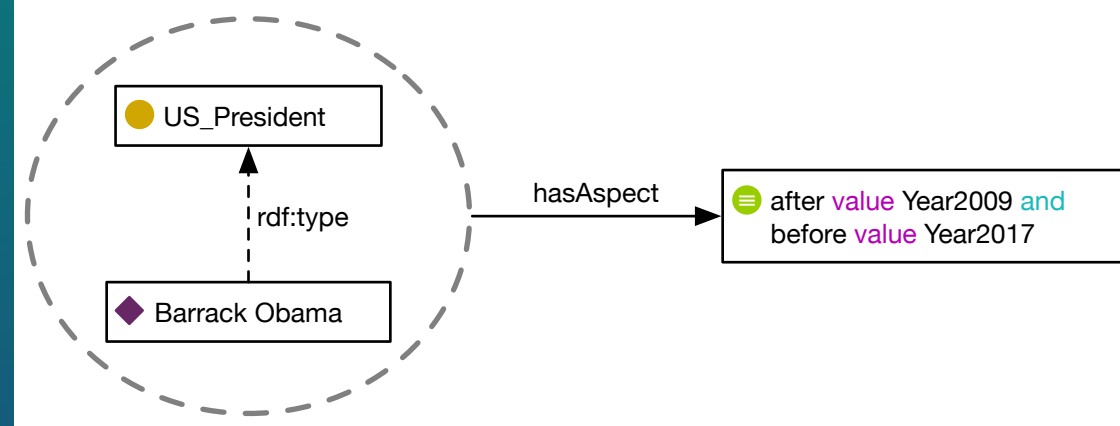
AspectOWL Semantics

- AspectOWL Semantics are defined in terms of multi-dimensional (SROIQ_{Kripke}) interpretations

$$\mathcal{J} := (W, R, L, \cdot^{\mathcal{J}}, \Delta, (\cdot^{\mathcal{I}_w})_{w \in W})$$

- W: set of possible worlds
- R: set of accessibility relations
- L: Kripke interpretation (assigning truth values to propositional symbols in each world)

$$(\text{hasAspect}(\alpha, A))^{\mathcal{J}} \rightarrow A^{\mathcal{J}} \subseteq C^{\mathcal{J}} := \{w \in W \mid \mathcal{I}_w \models \alpha\}$$

- α: a DL (OWL) axiom
- A : a concept description (OWL class expression)

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Modal Logic Family

Name	Modal Axiom	Condition on Frames	R is...	DL Axiom
(D)	$\Box A \to \Diamond A$	$\forall w \exists u : wRu$	Serial	$\top \sqsubseteq \exists R.\top$
(M)	$\Box A \to A$	$\forall w : wRw$	Reflexive	$\top \sqsubseteq \exists R.\mathsf{Self}$
(4)	$\Box A \to \Box\Box A$	$(wRv \wedge vRu) \Rightarrow wRu$	Transitive	$\mathsf{Trans}(R)$
(B)	$A \to \Box\Diamond A$	$wRv \Rightarrow vRw$	Symmetric	$\mathsf{Sym}(R)$
(5)	$\Diamond A \to \Box\Diamond A$	$(wRv \wedge wRu) \Rightarrow vRu$	Euclidean	$R^{-1} \circ R \sqsubseteq R$ [a]
(CD)	$\Diamond A \to \Box A$	$(wRv \wedge wRu) \Rightarrow v = u$	Functional	$\top \sqsubseteq (\leqslant 1R.\top)$
$(\Box M)$	$\Box(\Box A \to A)$	$wRv \Rightarrow vRv$	Shift Reflexive	$\exists R^{-1}.\top \sqsubseteq \exists R.\mathsf{Self}$
$(C4)$	$\Box\Box A \to \Box A$	$wRv \Rightarrow \exists u(wRu \wedge uRv)$	Dense	$R \circ R \sqsubseteq R \wedge \top \sqsubseteq \nexists R.\mathsf{Self}$ [a]
(C)	$\Diamond\Box A \to \Box\Diamond A$	$wRv \wedge wRx \Rightarrow \exists u(vRu \wedge xRu)$	Convergent	— [b]

[a] falls under OWL 2 restriction

[b] Not possible in pure DL. See Section 1.3 for a workaround involving SWRL.

Table 1. Modal Logic axioms and corresponding conditions on frames and OWL axioms
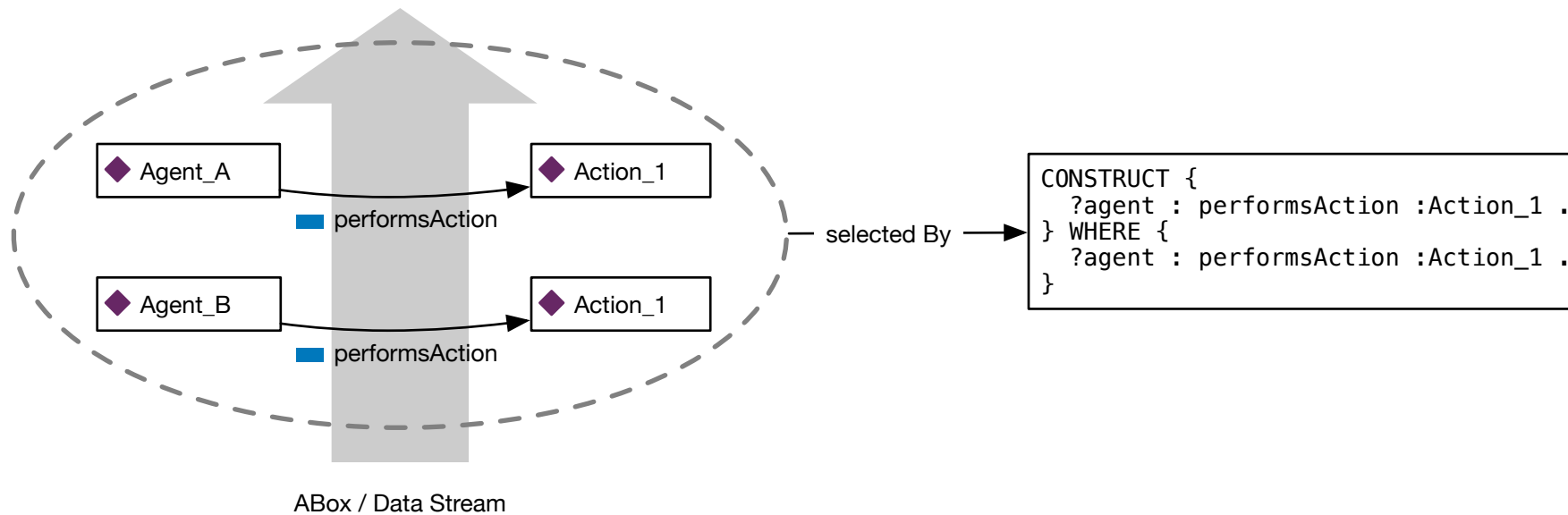
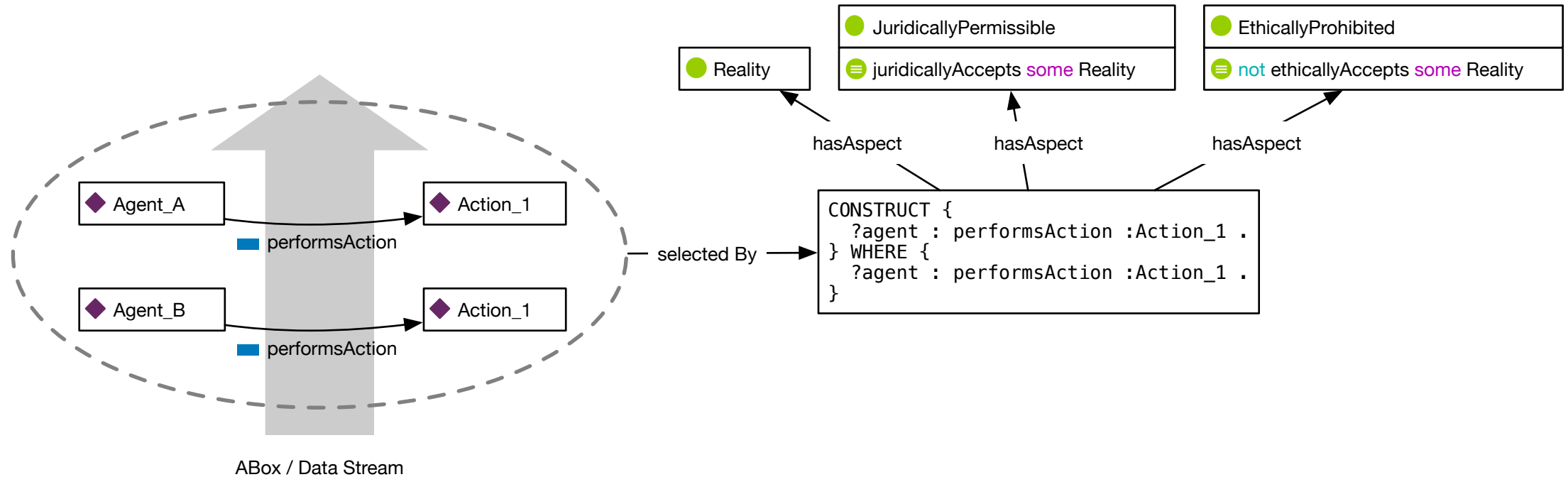# Temporal Aspect in Terms of OWL primitives
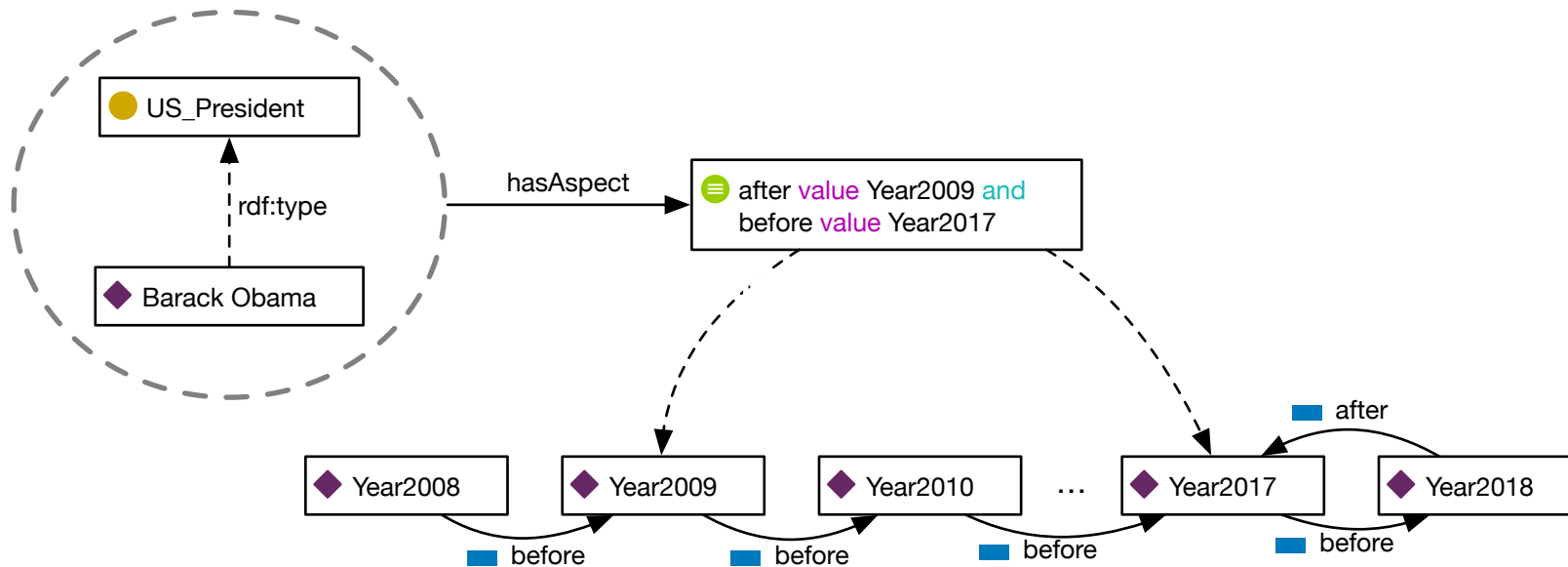
Axiom Selection Options

- Aspect target axioms may be selected
  - Explicitly, like in the preceding examples: **Join points**
  - By some sort of query: **Pointcut model**
    - SPARQL CONSTRUCT
    - Signature-based
    - DL Query

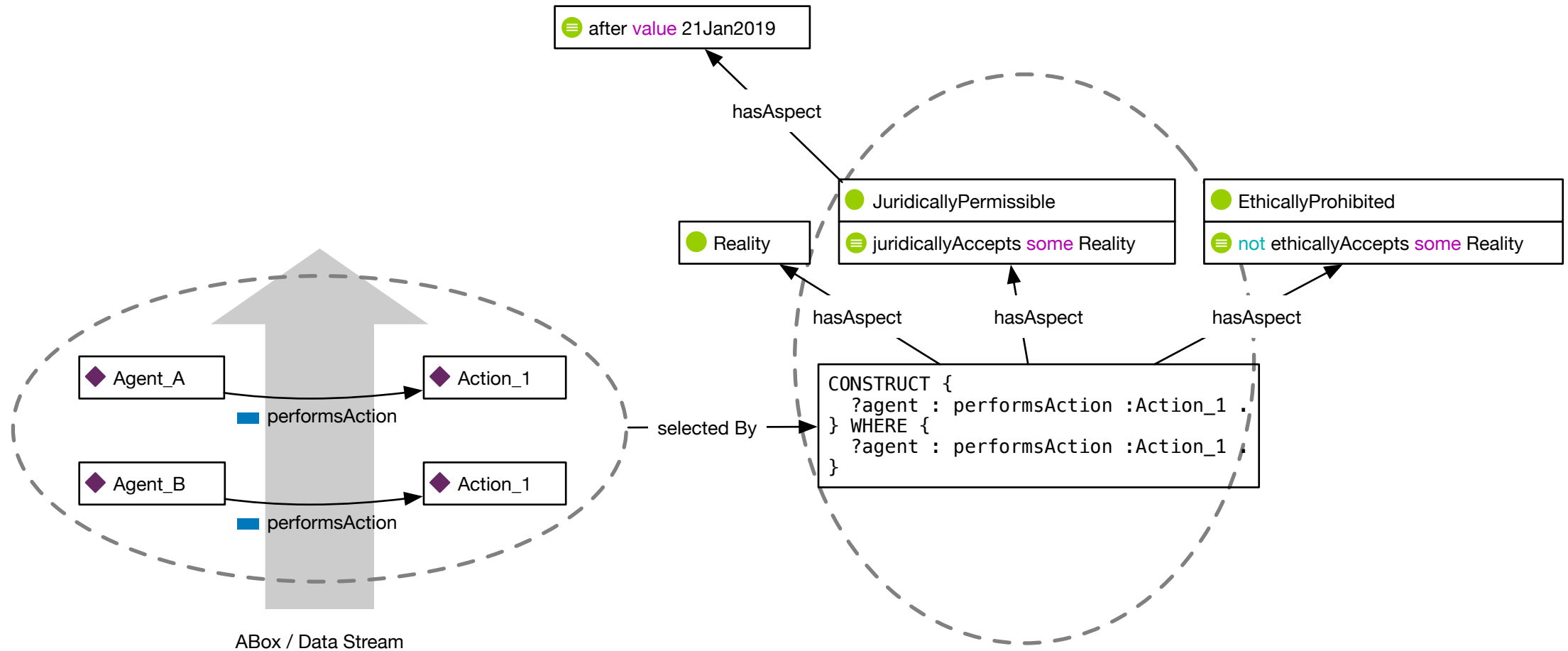AOP terminology

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Example: Temporalized Deontic Logic

ABox / Data Stream

```
CONSTRUCT {
    ?agent : performsAction :Action_1 .
} WHERE {
    ?agent : performsAction :Action_1 .
}
```

Example: Temporalized Deontic Logic

Example: Temporalized Deontic Logic

after value 21Jan2019

hasAspect

JuridicallyPermissible

juridicallyAccepts some Reality

EthicallyProhibited

not ethicallyAccepts some Reality

Reality

hasAspect

hasAspect

hasAspect

Agent_A

Action_1

performsAction

Agent_B

Action_1

performsAction

selected By

```
CONSTRUCT {
  ?agent : performsAction :Action_1 .
} WHERE {
  ?agent : performsAction :Action_1 .
}
```

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Example in extended OWL Functional Syntax

```
Ontology(<http://ontology.aspectowl.xyz/example/deontic>

1.  TransitiveObjectProperty(juridicallyAccepts)

2.  ReflexiveObjectProperty(juridicallyAccepts)

3.  TransitiveObjectProperty(ethicallyAccepts)

4.  ReflexiveObjectProperty(ethicallyAccepts)

5.  TransitiveObjectProperty(after)

6.  EquivalentClasses(EthicallyProhibited
    ObjectComplementOf(ObjectSomeValuesFrom(ethicallyAccepts Reality)))

7.  EquivalentClasses(JuridicallyPermissible ObjectSomeValuesFrom(juridicallyAccepts Reality))

8.  ObjectPropertyAssertion(Aspect(EthicallyProhibited) Aspect(Aspect(ObjectHasValue(after
    21Jan2019))) JuridicallyPermissible) Aspect(Reality) performsAction Agent_A Action_1)

)
```

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Example as First-Order Theory

1. $\forall x, y, z : (juridicallyAccepts(x, y) \wedge (juridicallyAccepts(y, z) \rightarrow (juridicallyAccepts(x, z))$

2. $\forall x : juridicallyAccepts(x, x)$

3. $\forall x, y, z : (ethicallyAccepts(x, y) \wedge (ethicallyAccepts(y, z) \rightarrow (ethicallyAccepts(x, z))$

4. $\forall x : ethicallyAccepts(x, x)$

5. $\forall x, y, z : (after(x, y) \wedge (after(y, z) \rightarrow (after(x, z))$

6. $\forall x : (JuridicallyPermissible(x) \leftrightarrow \exists y : juridicallyAccepts(x, y) \wedge Reality(y))$

7. $\forall x : (EthicallyProhibited(x) \leftrightarrow \forall y :\sim (ethicallyAccepts(x, y) \wedge Reality(y)))$

8. $\forall x : (EthicallyProhibited(x) \wedge temp\_JuridicallyPermissible(x) \wedge Reality(x) \leftrightarrow performsAction(Agent\_A, Action\_1))$

9. $\forall x, y : (after(x, 21Jan2019) \leftrightarrow temp\_JuridicallyPermissible(y)))$

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Tool Support: AspectOWL Protégé Plug-in

https://github.com/ag-csw/aspect-owl-protege
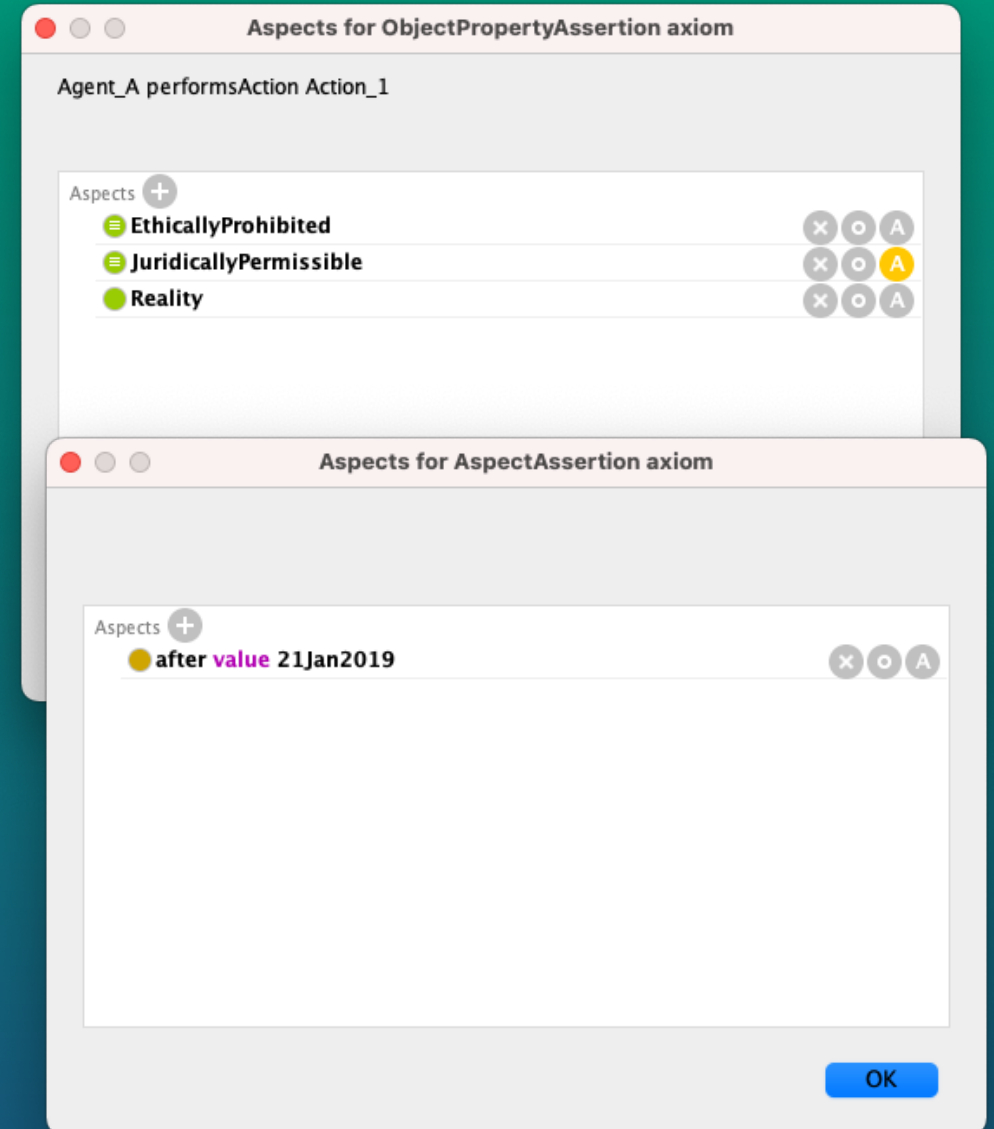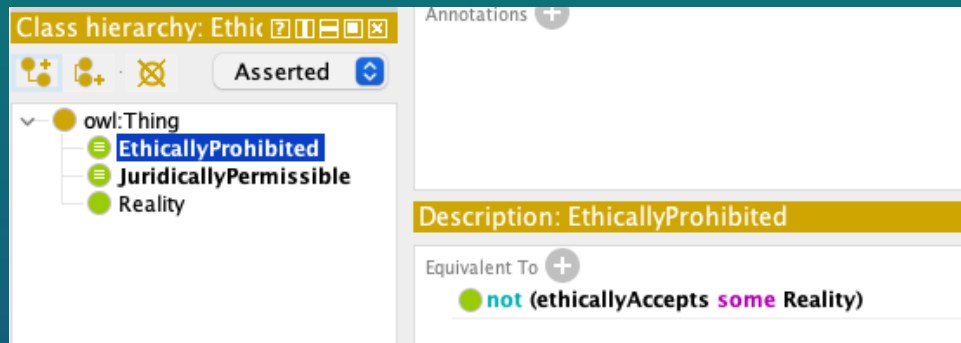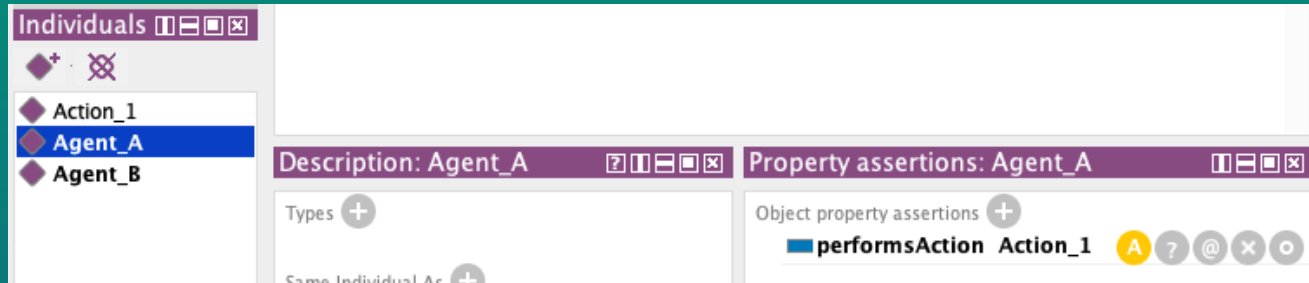
Tool Support: Aspect-Oriented OWLAPI Extension

```java
@OWLAspect("http://www.fu-berlin.de/csw/ontologies/aood/ontologies/aspect123")
public void doSomething () {
  Set<OWLAxiom> allAxioms = myOntology.getAxioms();
  ...}
```

Ralph Schäfermeier, Lidia Krus, and Adrian Paschke. An Aspect-Oriented Extension to the OWL API - Specifying and Composing Views of OWL Ontologies using Ontology Aspects and Java Annotations. In Proceedings of the 7th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management, pages 187–194, 2015.

https://github.com/ag-csw/aspect-owlapi-java

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Tool Support: OWL Aspect Weaver
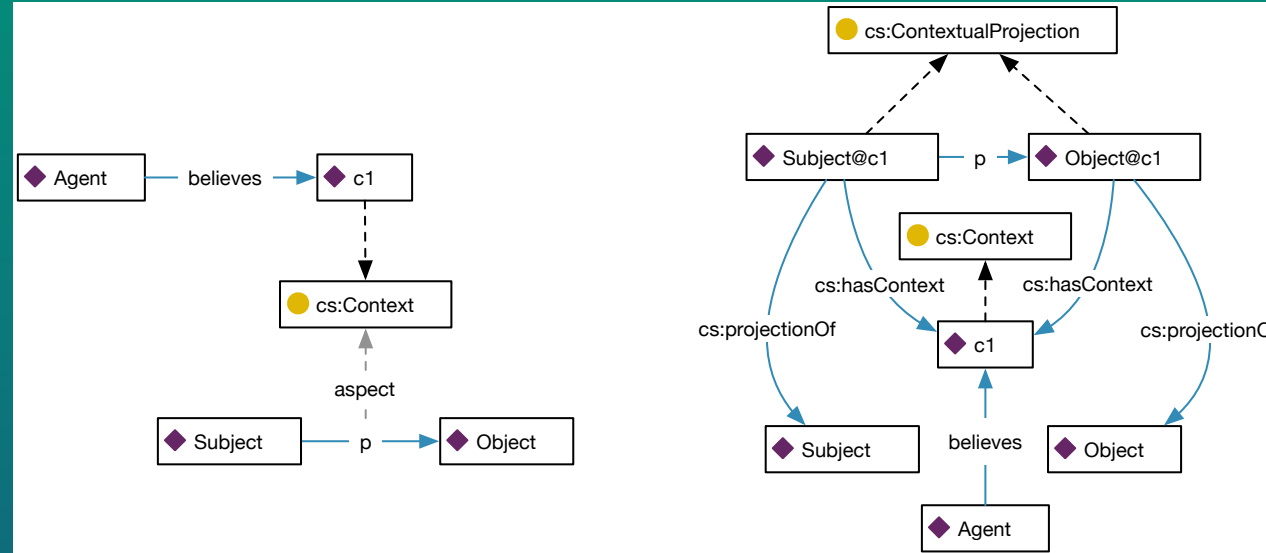
Ralph Schäfermeier and Adrian Paschke. Weaving Ontology Aspects Using a Catalog of Structural Ontology Design Patterns. In Maurizio Lenzerini and Rafael Peñaloza, editors, Proceedings of the 29th International Workshop on Description Logics, Cape Town, South Africa, April 22-25, 2016., volume 1577 of CEUR Workshop Proceedings. CEUR-WS.org, 2016.

Tool Support: OntoMaven

```xml
<build> <plugins> <plugin>
    <groupId>de.csw.ontomaven</groupId>
    <artifactId>OntoMvnApplyAspects</artifactId>
    <version>1.0-SNAPSHOT</version>
    <configuration>
        <userAspects>
            <aspect>http://example.org/reputation#Reputation123</aspect>
            <aspect>http://example.org/provenance#prov_789</aspect>
        </userAspects>
        <aspectsIRI>http://corporate-semantic-web.de/aspectOWL#hasAspect</aspectsIRI>
        <includeOriginalAxioms>true</includeOriginalAxioms>
    </configuration>
...
```

Adrian Paschke and Ralph Schäfermeier. Aspect OntoMaven — Aspect-Oriented Ontology Development and Configuration With OntoMaven. In Witold Abramowicz, editor, 3rd Workshop on Formal Semantics for the Future Enterprise (FSFE 2015), Business Information Systems Workshops, volume 228. Springer, 2015.

https://github.com/ag-csw/OntoMaven

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Thank you for your attention

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