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Institut für Offene Kommunikationssysteme

Aspect-Oriented Ontologies

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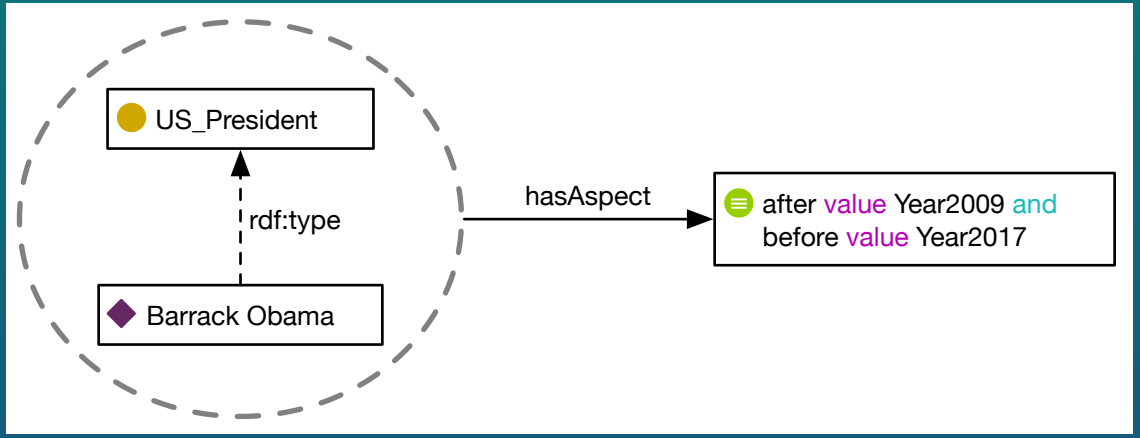
Aspect-Oriented Ontology Development

- 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

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.



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OWL 2 DL (SROIQ(D)) Semantics

	syntax	semantics
top concept	$\top$	$\Delta_I^{\mathcal{I}}$
negation	$\neg C$	$\Delta_I^{\mathcal{I}} \setminus C^{\mathcal{I}}$
conjunction	$C \sqcap D$	$C^{\mathcal{I}} \cap D^{\mathcal{I}}$
existential restriction	$\exists r.C$	$\{d \in \Delta_I^{\mathcal{I}} \mid$ there exists an $e \in C^{\mathcal{I}}$ with $(d,e) \in r^{\mathcal{I}}\}$
at-most restriction	$\leq_n r.C$	$\{d \in \Delta_I^{\mathcal{I}} \mid \#\{e \in C^{\mathcal{I}} \mid (d,e) \in r^{\mathcal{I}}\} \leq n\}$
nominal	$\{a\}$	$\{a^{\mathcal{I}}\}$
general concept inclusion	$C \sqsubseteq D$	$C^{\mathcal{I}} \subseteq D^{\mathcal{I}}$
concept assertion	$C(a)$	$a^{\mathcal{I}} \in C^{\mathcal{I}}$
role assertion	$r(a,b)$	$(a^{\mathcal{I}}, b^{\mathcal{I}}) \in r^{\mathcal{I}}$
role inclusion	$r \sqsubseteq s$	$r^{\mathcal{I}} \subseteq s^{\mathcal{I}}$
transitivity	$\mathsf{trans}(r)$	$(d,e) \in r^{\mathcal{I}}$ and $(e,f) \in r^{\mathcal{I}} \rightarrow (d,f) \in r^{\mathcal{I}}$
symmetry	$\mathsf{sym}(r)$	$(d,e) \in r^{\mathcal{I}} \rightarrow (e,d) \in r^{\mathcal{I}}$
reflexivity	$\mathsf{ref}(r)$	$(d,d) \in r^{\mathcal{I}}$ for all $d \in \Delta_I^{\mathcal{I}}$
role chain	$r \circ s$	$(d,e) \in r^{\mathcal{I}}$ and $(e,f) \in s^{\mathcal{I}} \rightarrow (d,f) \in (r \circ s)^{\mathcal{I}}$
inverse role	$\mathsf{Inv}(r,s)$	$(d,e) \in r^{\mathcal{I}} \rightarrow (e,d) \in s^{\mathcal{I}}$
disjoint roles	$r \sqcap s \sqsubseteq \neg\top$[9]	$r^{\mathcal{I}} \cap s^{\mathcal{I}} \subseteq \emptyset$

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)

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

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

Modal Logic Family

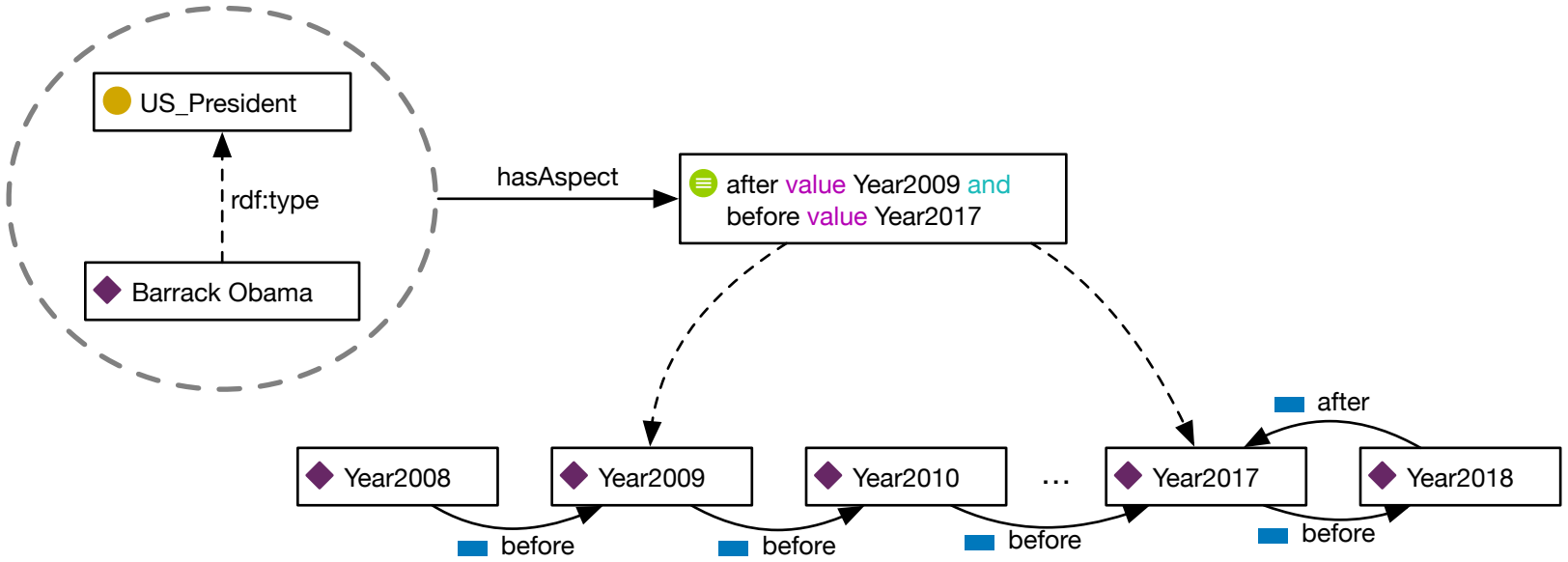
Name	Modal Axiom	Condition on Frames	R is...	DL Axiom
(D)	$\Box A \rightarrow \Diamond A$	$\forall w \exists u : wRu$	Serial	$\top \sqsubseteq \exists R.\top$
(M)	$\Box A \rightarrow A$	$\forall w : wRw$	Reflexive	$\top \sqsubseteq \exists R.\mathsf{Self}$
(4)	$\Box A \rightarrow \Box\Box A$	$(wRv \wedge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



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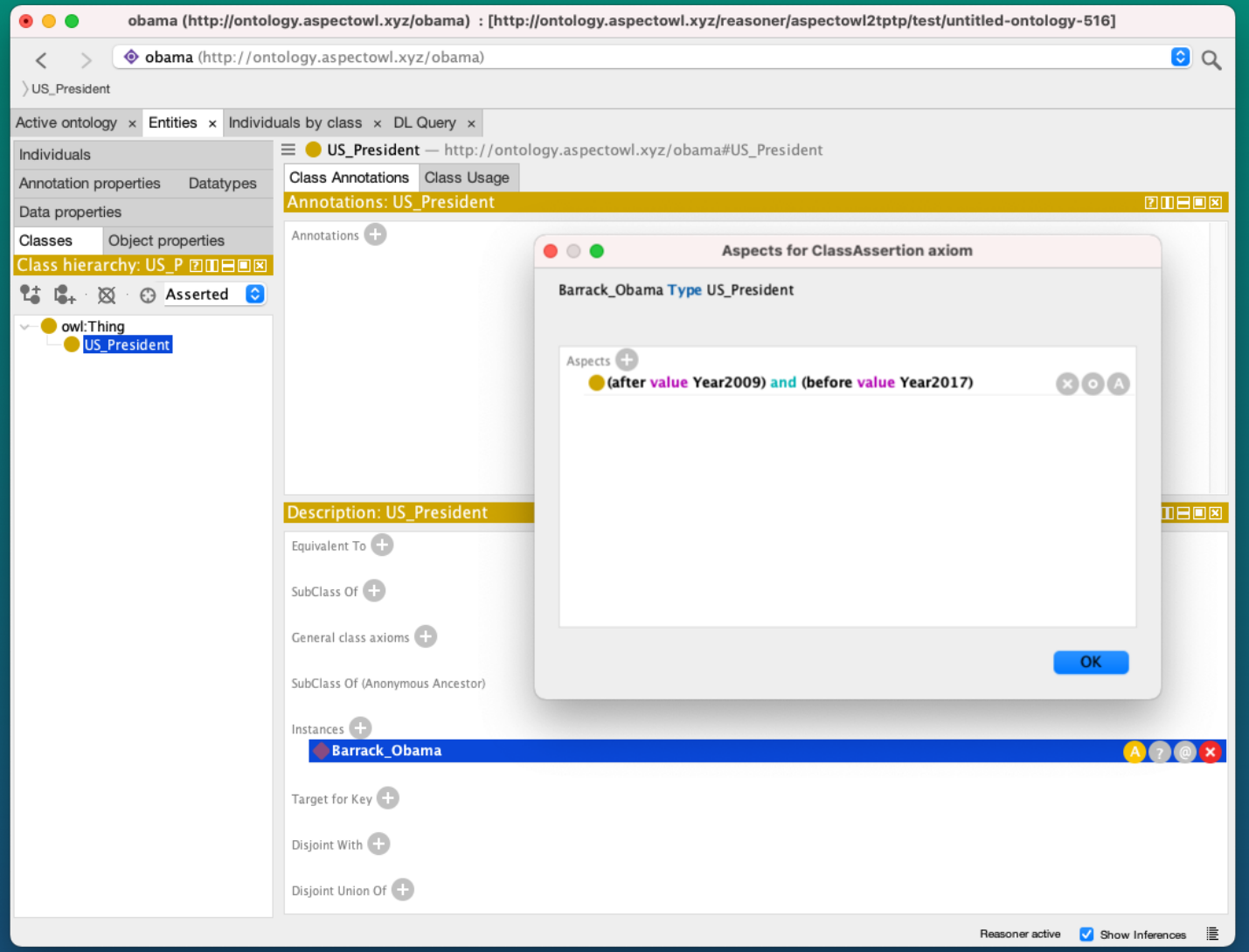
AspectOWL Protégé Plugin



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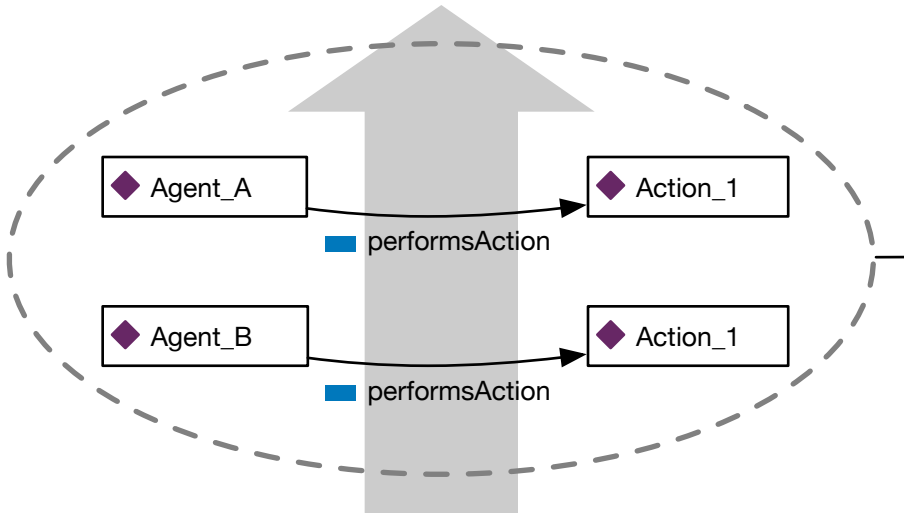
Axiom Selection Options

- 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

Example: Temporalized Deontic Logic



ABox / Data Stream

selected By

```
CONSTRUCT {
  ?agent : performsAction :Action_1 .
} WHERE {
  ?agent : performsAction :Action_1 .
}
```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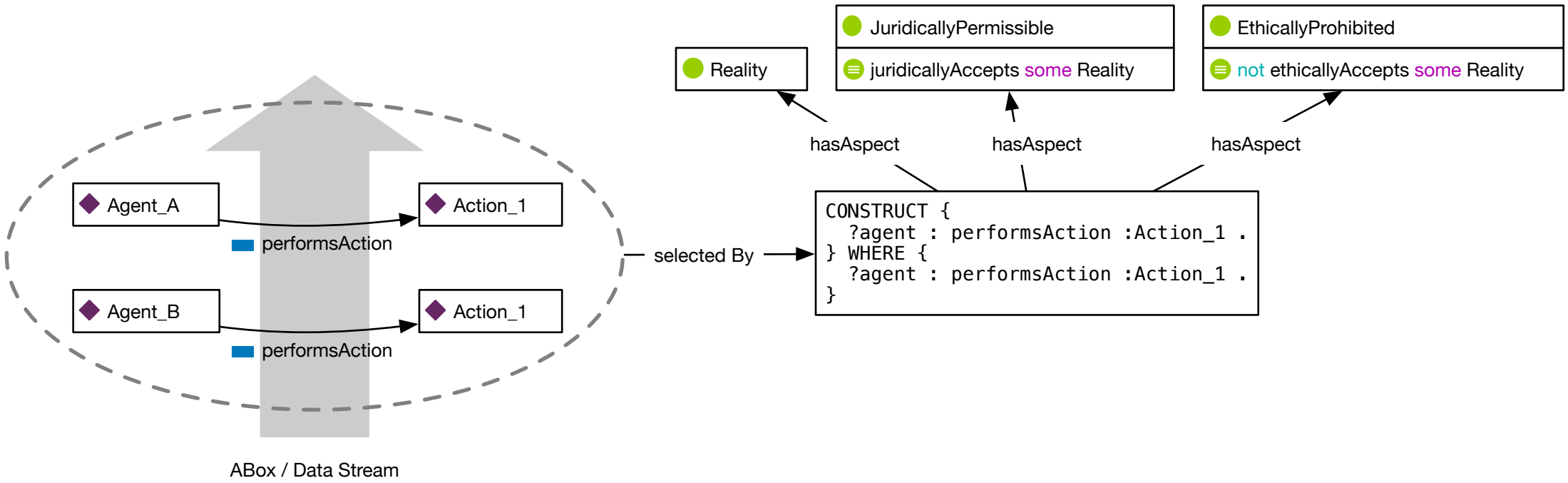
Example: Temporalized Deontic Logic



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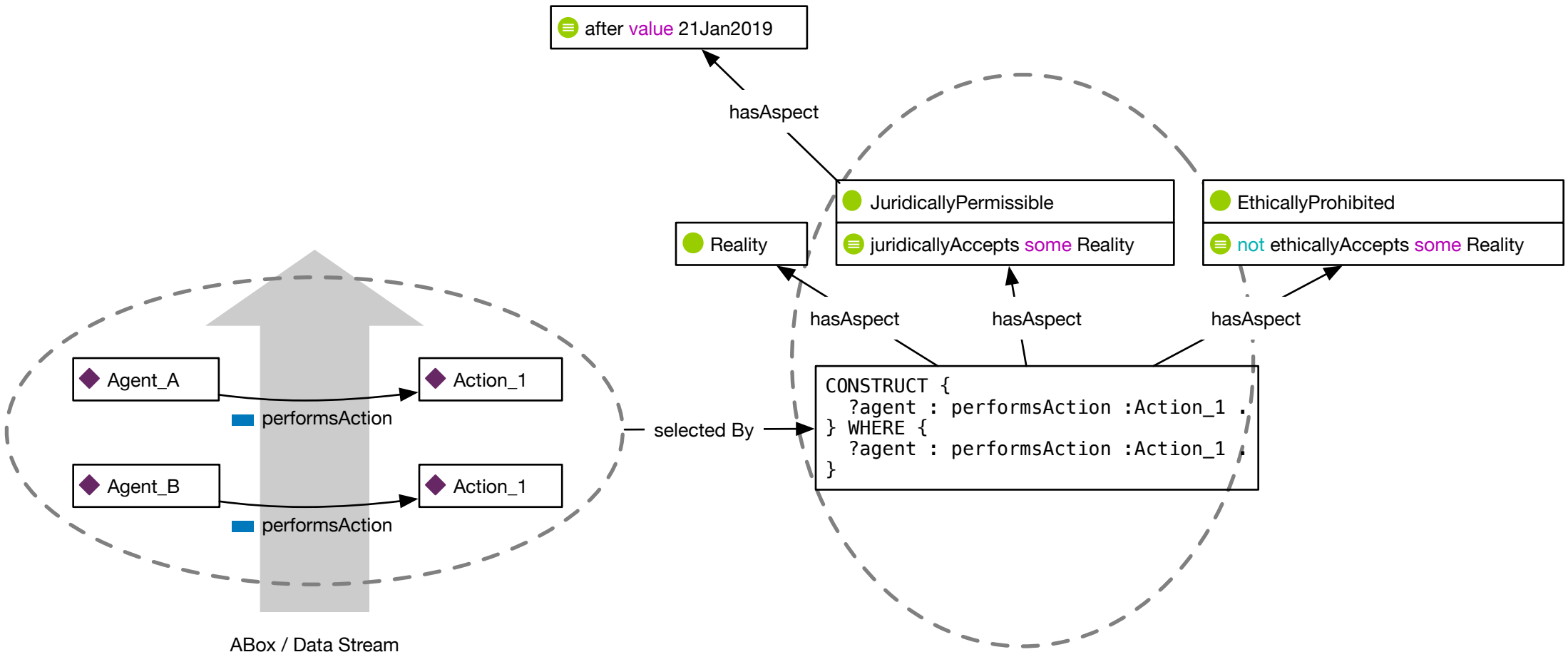
Example: Temporalized Deontic Logic



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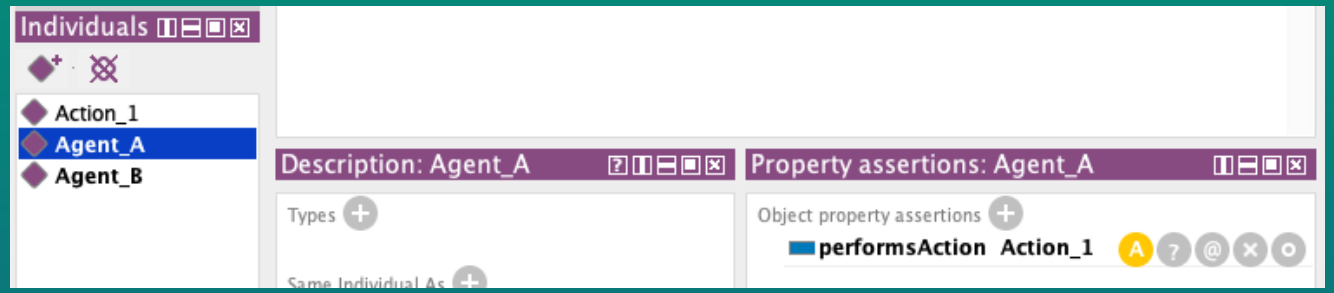
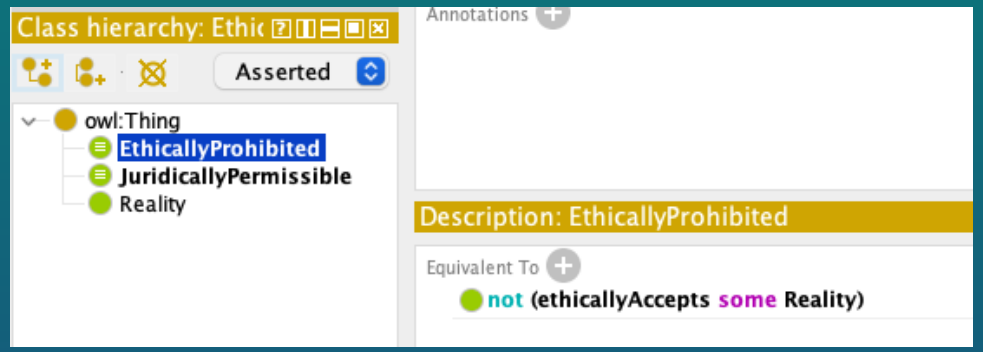
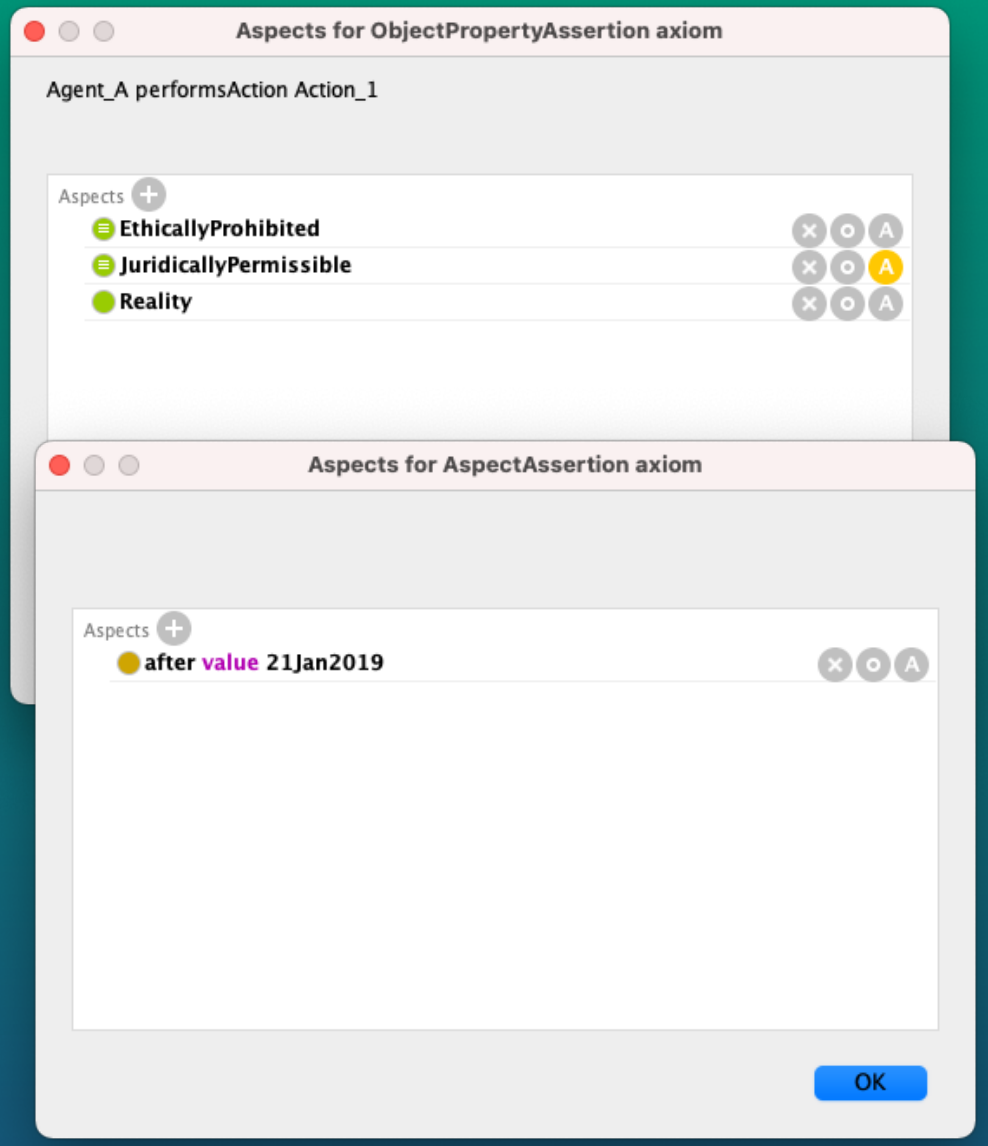
Example in Protégé







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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)

)
```

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

Thank you for your attention

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