TECHNISCHE UNIVERSITÄT WIEN

SHACL Validation and Static Analysis in Presence of Ontologies: an Overview

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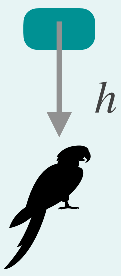
1. Problem

OWL
- implicit knowledge
- open-world assumption

SHACL
- check correctness of data
- closed-world assumption

OWL + SHACL
- combination mentioned in **SHACL specification** (W3C)
- challenging: how to combine open- and closed-world?
- feels natural: validation of data with **implicit knowledge**



$hasWingedPet$

ABox

$hasWingedPet \sqsubseteq hasPet$

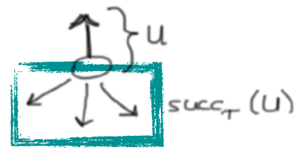
$\exists hasWingedPet^{-} \sqsubseteq Bird$

$\dots$

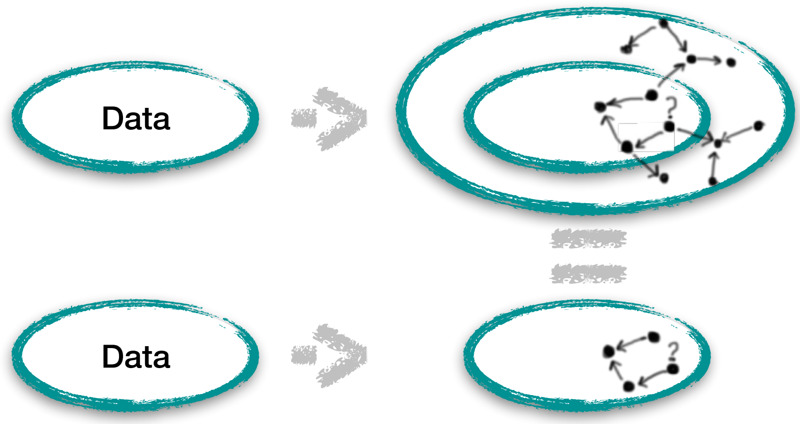
TBox

2. Validation

(1) **Validation:** compute (unique) core universal model, and check constraints over this universal model.



(2) **Rewrite** the constraints according to the ontological knowledge (TBox) such that they can be applied directly to the original data.



$$\varphi ::= c \mid A \mid \top \mid \neg\varphi \mid \varphi \wedge \varphi \mid \varphi \vee \varphi \mid \exists_{\geq n} E . \varphi \mid \forall E . \varphi \mid eq(E, r) \mid disj(E, r) \mid closed(R)$$

Shape expressions
- $s \leftarrow \varphi$
- intended meaning: $(s)^{\mathcal{J},S} = (\varphi)^{\mathcal{J},S}$

Shape assignment
- Set of shape literals:
- $s(a)$ or $\neg s(a)$

Semantics
- supported models
- stable model
- well-founded

3. Satisfiability

Plain SHACL (supported models): via **reduction** to DL fragments

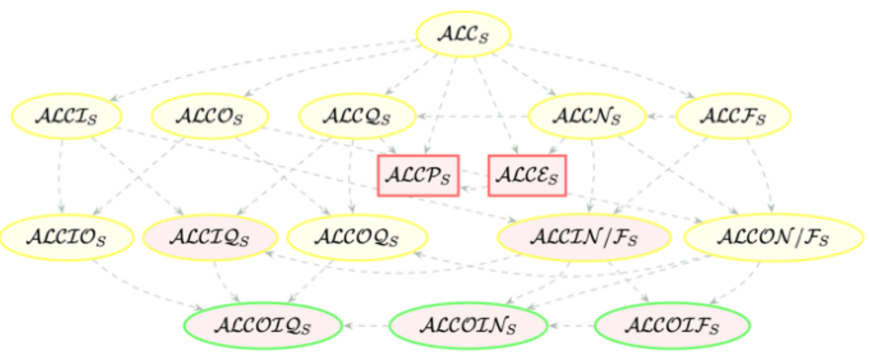


Figure 4: Decidability and complexity of SHACL fragments. Ellipse-shaped nodes denote (finite) satisfiability is decidable in ExpTime (yellow border), or NExpTime (green border). Squared-shaped nodes indicate satisfiability is undecidable. A yellow filling indicates the presence of the finite model property, whereas a red filling stands for the lack of it. Arrows indicate subsumption of fragments.

SHACL+DLs: same reduction of SHACL into DL fragment, take the least expressive fragment capturing both

4. Containment

Plain SHACL: via reduction to hybrid mu-calculus

(1) Supported model semantics (ALCIO-SHACL): **undecidable**

(2) Stable model semantics (ALCIO-SHACL): **undecidable**

(3) Well-founded semantics (ALCIO-SHACL): **EXPTIME-complete**

$$
\begin{aligned}
tr^{+}_{S,\mathcal{C}}(s \wedge s') &:= tr^{+}_{S,\mathcal{C}}(s) \wedge tr^{+}_{S,\mathcal{C}}(s') \\
tr^{+}_{S,\mathcal{C}}(s \vee s') &:= tr^{+}_{S,\mathcal{C}}(s) \vee tr^{+}_{S,\mathcal{C}}(s') \\
tr^{+}_{S,\mathcal{C}}(\exists r.s) &:= \langle r \rangle tr^{+}_{S,\mathcal{C}}(s) \\
tr^{+}_{S,\mathcal{C}}(\forall r.s) &:= [r] tr^{+}_{S,\mathcal{C}}(s) \\
tr^{+}_{S,\mathcal{C}}(A) &:= A \\
tr^{+}_{S,\mathcal{C}}(a) &:= a \\
tr^{+}_{S,\mathcal{C}}(\neg s) &:= tr^{-}_{S,\mathcal{C}}(s) \\
tr^{+}_{S,\mathcal{C}}(s) &:= \begin{cases} X_s & \text{if } s \in S \\ \mu X_s . tr^{+}_{S \cup \{s\},\mathcal{C}}(\mathcal{C}(s)) & \text{if } s \notin S \end{cases}
\end{aligned}
$$

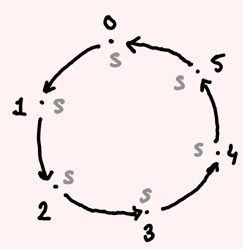
$$
\begin{aligned}
tr^{-}_{S,\mathcal{C}}(s \wedge s') &:= tr^{-}_{S,\mathcal{C}}(s) \vee tr^{-}_{S,\mathcal{C}}(s') \\
tr^{-}_{S,\mathcal{C}}(s \vee s') &:= tr^{-}_{S,\mathcal{C}}(s) \wedge tr^{-}_{S,\mathcal{C}}(s') \\
tr^{-}_{S,\mathcal{C}}(\exists r.s) &:= [r] tr^{-}_{S,\mathcal{C}}(s) \\
tr^{-}_{S,\mathcal{C}}(\forall r.s) &:= \langle r \rangle tr^{-}_{S,\mathcal{C}}(s) \\
tr^{-}_{S,\mathcal{C}}(A) &:= \neg A \\
tr^{-}_{S,\mathcal{C}}(a) &:= \neg a \\
tr^{-}_{S,\mathcal{C}}(\neg s) &:= tr^{+}_{pos(S),\mathcal{C}}(s) \\
tr^{-}_{S,\mathcal{C}}(s) &:= \begin{cases} X_{\bar{s}} & \text{if } \bar{s} \in S \\ \nu X_{\bar{s}} . tr^{-}_{S \cup \{\bar{s}\},\mathcal{C}}(\mathcal{C}(s)) & \text{if } \bar{s} \notin S \end{cases}
\end{aligned}
$$

SHACL+DLs: translate both into hybrid mu-calculus, for ALCIO-SHACL (WF) + ALCIO this results in **EXPTIME-completeness**

Constraint
- $s \leftarrow A \vee \exists r . s$

Target
- $s(0)$

Interpretation
- $r^{\mathcal{J}} = \{(0,1), \dots, (4,5), (5,0)\}$
- $A^{\mathcal{J}} = \varnothing$



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