Ontology Revision

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Evolution of a DL ontology

1. A DL ontology $= \mathcal{T} \cup \mathcal{A}$ where
   $\mathcal{T} = \{C \sqsubseteq D\}$ and $\mathcal{A} = \{C(a), R(a, b)\}$

2. Revision : expanding $\mathcal{T}$ to $\mathcal{T} \circ \mathcal{N}_e$ such that $\mathcal{N}_e$ holds

3. Contraction : contracting $\mathcal{T}$ to $\mathcal{T} \bullet \mathcal{N}_c$ such that $\mathcal{N}_c$ doesn't hold.
   Reduction of contraction to revision is possible for some DLs.
   $\neg(C \sqsubseteq D) \Leftrightarrow (C \sqcap \neg D)(a)$

4. Update : changing *ABox*

AGM postulates rephrased for DL ontology revision

- Alchourrón, Gärdenfors and Makinson : postulates for belief revision of a propositional KB [1985]
- Katsumo and Mendelzon : a model-theoretical characterization [1989]
- Qi, Liu and Bell : reformulation of the AGM postulates for DLs [2006,2009]

R1 $\mathrm{Mod}(\mathcal{O}) \neq \emptyset$ and $\mathrm{Mod}(\mathcal{N}) \neq \emptyset \Longrightarrow \mathrm{Mod}(\mathcal{O} \circ \mathcal{N}) \neq \emptyset$ (preservation)

R2 $\mathrm{Mod}(\mathcal{O} \circ \mathcal{N}) \subseteq \mathrm{Mod}(\alpha)$ for $\alpha \in \mathcal{N}$ (success)

R3 $\mathrm{Mod}(\mathcal{O}) \cap \mathrm{Mod}(\mathcal{N}) \neq \emptyset \Longrightarrow \mathrm{Mod}(\mathcal{O}) \cap \mathrm{Mod}(\mathcal{N}) = \mathrm{Mod}(\mathcal{O} \circ \mathcal{N})$ (inclusion)

R4 $\mathrm{Mod}(\mathcal{O}) = \mathrm{Mod}(\mathcal{O}')$ and $\mathrm{Mod}(\mathcal{N}_1) = \mathrm{Mod}(\mathcal{N}_2) \Longrightarrow$
$\mathrm{Mod}(\mathcal{O} \circ \mathcal{N}_1) = \mathrm{Mod}(\mathcal{O}' \circ \mathcal{N}_2)$ (syntax independence)

R5 $\mathrm{Mod}(\mathcal{O} \circ (\mathcal{N}_1 \cup \mathcal{N}_2)) = \mathrm{Mod}(\mathcal{O} \circ \mathcal{N}_1) \cap \mathrm{Mod}(\mathcal{N}_2)$ with
$\mathrm{Mod}(\mathcal{O} \circ \mathcal{N}_1) \cap \mathrm{Mod}(\mathcal{N}_2) \neq \emptyset$ (minimal change)

Model-based approaches (MBAs)

For DL-lite : De Giacomo et al. (2006), Qi et al. (2009), Wang et al. (2015), Zhuang et al. (2014, 2016), Zheleznyakov et al. (2019)

- A distance $d(\mathcal{I}, \mathcal{I}')$ where $\mathcal{I} \in \text{Mod}(\mathcal{O})$ and $\mathcal{I}' \in \text{Mod}(\mathcal{N})$
- A revision operator :
  $\text{Mod}(\mathcal{O} \circ \mathcal{N}) = \{\mathcal{I} \in \text{Mod}(\mathcal{N}) \mid \exists\, \mathcal{I}_0 \in \text{Mod}(\mathcal{O}),$
  $\forall \mathcal{I}' \in \text{Mod}(\mathcal{O}), \mathcal{I}'' \in \text{Mod}(\mathcal{N}) : d(\mathcal{I}, \mathcal{I}_0) \leq d(\mathcal{I}', \mathcal{I}'')\}$
- Such a revision operator satisfies all AGM postulates
- Building the resulting ontology from $\text{Mod}(\mathcal{O} \circ \mathcal{N})$

From DL-Lite to $\mathcal{SHIQ}$: challenges

1. How to reduce $\mathsf{Mod}(\mathcal{O})$ to a finite set ?

2. How to define a tractable (pre-order) distance over $\mathsf{Mod}(\mathcal{O}) \cup \mathsf{Mod}(\mathcal{N})$?

3. Unexpressibility issue : there may not exist an ontology expressible in the same logic that has exactly $\mathsf{Mod}(\mathcal{O} \circ \mathcal{N})$ as models

Solution for $\mathcal{SHIQ}$ (Dong et al.)

Reduction of Mod($\mathcal{O}$) to FM($\mathcal{O}$) generated by a new tableau method

Theorem (from infinity to finity)

Let $\mathcal{O}$ be an $\mathcal{SHIQ}$ ontology and α be an axiom/assertion written in $S(\mathcal{O})$. It holds that $\mathcal{I}(\mathcal{F}) \models \alpha$ for all $\mathcal{F} \in$ FM($\mathcal{O}$) iff $\mathcal{I} \models \alpha$ for all $\mathcal{I} \in$ Mod($\mathcal{O}$) where $\mathcal{I}(\mathcal{F})$ is the model obtained by unravelling from $\mathcal{F}$.

Solution for $\mathcal{SHIQ}$ (II)

Isomorphism and distance between $\mathcal{F}, \mathcal{F}' \in \mathsf{FM}(\mathcal{O})$ for computing $\mathsf{Mod}(\mathcal{O} \circ \mathcal{O}')$

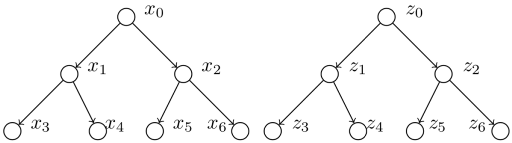

Figure 7: Two trees $T\langle x_0\rangle$ (left) and $T\langle z_0\rangle$ (right)

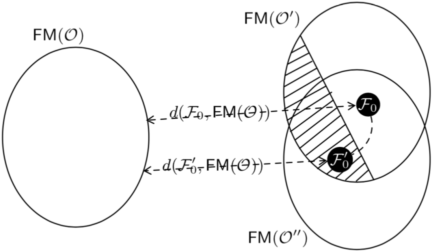

Figure 6: **(P5)** & **(P6)** ensure the principle of minimal change

Solution for $\mathcal{SHIQ}$ (III)

Unexpressibility : there may not exist any $\mathcal{SHIQ}$ ontology $\mathcal{O}'$ such that $\mathsf{FM}(\mathcal{O}') = \mathsf{FM}(\mathcal{O} \circ \mathcal{N})$

For this we need to compute an approximation ontology $\mathcal{O}^*$ that satisfies the following conditions (De Giacomo et al.) :

1. $S(\mathcal{O}^*) \subseteq S(\mathcal{O}) \cup S(\mathcal{N})$
2. $\mathsf{FM}(\mathcal{O} \circ \mathcal{N}) \subseteq \mathsf{FM}(\mathcal{O}^*)$
3. There does not exist any $\mathcal{O}''$ in $\mathcal{SHIQ}$ such that $\mathsf{FM}(\mathcal{O} \circ \mathcal{N}) \subseteq \mathsf{FM}(\mathcal{O}'') \subset \mathsf{FM}(\mathcal{O}^*)$

Complexity and Implementation

- Complexity
  - Tractable for DL-lite
  - Upper bound of revision in $\mathcal{SHIQ}$: triply exponential for $\mathcal{SHIQ}$
  - Lower bound of revision in $\mathcal{SHIQ}$: not known
- Implementation
  - Wang et al. (2015) for DL-Lite : non maintained ?
  - Dong et al. (2018) for $\mathcal{SHIQ}$: OntoRev

Formula-based approaches (FBAs)

- To compute $\mathcal{O} \circ \mathcal{N}$ with $\mathcal{O} \cup \mathcal{N}$ inconsistent, try to determine a maximal $\mathcal{O}_m \subseteq \mathcal{O}$ such that $\mathcal{O}_m \cup \mathcal{N}$ consistent. So, $\mathcal{O}_m$ may not be unique !
- $\mathcal{O} \circ \mathcal{N} = \mathcal{N} \cup \{ \bigvee_{\mathcal{O}_m \in \mathcal{M}(\mathcal{O},\mathcal{N})} (\bigwedge_{\varphi \in \mathcal{O}_m} \varphi)\}$ (Cross-Product)
- $\mathcal{O} \circ \mathcal{N} = \mathcal{N} \cup \{ \bigcap_{\mathcal{O}_m \in \mathcal{M}(\mathcal{O},\mathcal{N})} \mathcal{O}_m\}$ (When in Doubt Throw It Out)
- Issues :
  - Expressibility of the disjunction of ontologies (CP)
  - Emptiness (WIDTIO)
  - Satisfaction of AGM postulates

Future Work

- Reducing the size and the cardinality of FM($\mathcal{O}$)
  - A new distance needed
- Readability of the resulting ontology generated from FM($\mathcal{O} \circ \mathcal{N}$)
- Combination of MBA with FBA
  - Identifying a subset $\mathcal{O}' \subseteq \mathcal{O}$ that should be revised with $\mathcal{N}$
  - $\mathcal{O} \circ \mathcal{N} = (\mathcal{O} \setminus \mathcal{O}') \cup \mathcal{O}' \circ \mathcal{N}$