TECHNISCHE UNIVERSITÄT DRESDEN

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Optimal Fixed-Premise Repairs of $\mathcal{EL}$ TBoxes

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Funded by DFG in Project 430150274 (Repairing Description Logic Ontologies) and partially in Project 389792660 (TRR 248: Foundations of Perspicuous Software Systems).

ReDLO Repairing Description Logic Ontologies

CPEC CENTER FOR PERSPICUOUS COMPUTING

20th International Conference on Principles of Knowledge Representation and Reasoning (KR 2023, RPR Track), 2–8 September 2023

Repairs of $\mathcal{EL}$ TBoxes

An ontology can contain axioms that are incorrect in the underlying domain, especially if

- it was constructed from incomplete data
- or using inexact methods based on machine learning.

Such errors are detected when a reasoner generates consequences from the faulty axioms.

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An ontology can contain axioms that are incorrect in the underlying domain, especially if

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Definition. Given an $\mathcal{EL}$ TBox $\mathcal{T}$ and a repair request $\mathcal{P}$ (a finite set of concept inclusions), a **repair** of $\mathcal{T}$ for $\mathcal{P}$ is a TBox $\mathcal{T}'$ such that

R1 $\mathcal{T}' \not\models C \sqsubseteq D$ for each unwanted consequence $C \sqsubseteq D$ in $\mathcal{P}$.

R2 $\mathcal{T}'$ is somehow constructed from $\mathcal{T}$ or somehow related to $\mathcal{T}$ (to be specified).

A repair is **optimal** if there is no repair that is “better” w.r.t. R2.

State of the Art

Classical repairs:

R2 $\mathcal{T}' \subseteq \mathcal{T}$, i.e., $\mathcal{T}'$ is constructed from $\mathcal{T}$ by deleting axioms.

Gentle repairs:

R2 $\mathcal{T}'$ is constructed from $\mathcal{T}$ by weakening axioms,
i.e., for each $C' \sqsubseteq D'$ in $\mathcal{T}'$, there is some $C \sqsubseteq D$ in $\mathcal{T}$ such that $C \sqsubseteq D \models C' \sqsubseteq D'$.

Countermodel repairs:

R2 There is a countermodel $\mathcal{J}$ such that $\mathcal{T}' \models C \sqsubseteq D$ iff $\mathcal{T} \models C \sqsubseteq D$ and $\mathcal{J} \models C \sqsubseteq D$.

R. Reiter: **A theory of diagnosis from first principles.** Artif. Intell. (1987)
F. Baader, F. Kriegel, A. Nuradiansyah, R. Peñaloza: **Making repairs in description logics more gentle.** KR 2018
F. Kriegel: **Constructing and extending description logic ontologies using methods of formal concept analysis.** Doctoral thesis (2019)

Two New Types of Repairs

Inspired by the gentle repairs w.r.t. $\succ^{\text{sub}}$ as well as by the countermodel repairs, and in order to tackle their problems, a novel type of repairs is introduced.

Generalized-conclusion repairs (GC-repairs):

R2 For each $C' \sqsubseteq D'$ in $\mathcal{T}'$, there is $C \sqsubseteq D$ in $\mathcal{T}$ such that $C = C'$ and $\emptyset \models D \sqsubseteq D'$.

Theorem. For each TBox $\mathcal{T}$ and each repair request $\mathcal{P}$,

- **the set of all optimal GC-repairs can be computed in exponential time**,
- and **every GC-repair is entailed by an optimal one**.

F. Kriegel: **Optimal Fixed-Premise Repairs of $\mathcal{EL}$ TBoxes.** KI 2022 (German Conference on AI)

Two New Types of Repairs

We introduce yet another type of repairs which can retain more consequences than GC-repairs.

Fixed-premise repairs (FP-repairs):

R2 $\mathcal{T} \models \mathcal{T}'$ and for each $C' \sqsubseteq D'$ in $\mathcal{T}'$, there is $C \sqsubseteq D$ in $\mathcal{T}$ such that $C = C'$.

Theorem. For each TBox $\mathcal{T}$ and each repair request $\mathcal{P}$,

- **the set of all optimal FP-repairs can be computed in exponential time**,
- and **every FP-repair is entailed by an optimal one**.

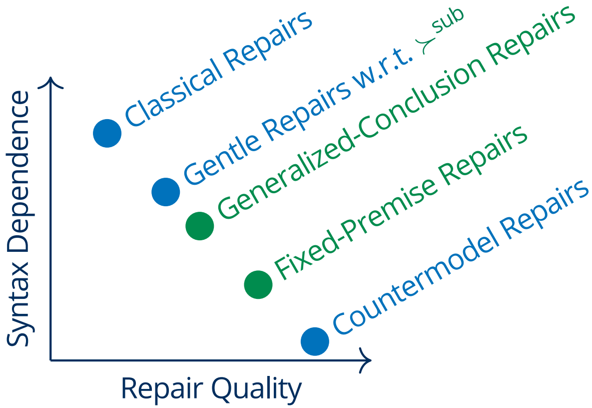
F. Kriegel: **Optimal Fixed-Premise Repairs of $\mathcal{EL}$ TBoxes.** KI 2022 (German Conference on AI)

Computing Repairs

Canonical GC- and FP-repairs can be constructed in almost the same way:

1. Choose a polynomial-size **repair seed** $\mathcal{S}$.
2. Construct the **induced countermodel** $\mathcal{J}_{\mathcal{S}}$.
3. For each concept inclusion $C \sqsubseteq D$ in $\mathcal{T}$,
   - GC: generalize D such that the resulting concept inclusion holds in $\mathcal{J}_{\mathcal{S}}$.
   - FP: replace D with the most specific concept E for which the concept inclusion $C \sqsubseteq E$ holds in $\mathcal{J}_{\mathcal{S}}$.

Comparison of $\mathcal{EL}$ TBox Repair Approaches



An Example with Bikes

Example. We consider the $\mathcal{EL}$ TBox

$$\mathcal{T}_{\text{Bike}} \coloneqq \{ \begin{aligned} \text{MountainBike} &\sqsubseteq \text{Bike}, \\ \text{Bike} &\sqsubseteq \exists \text{hasPart}.\text{SuspensionFork} \sqcap \exists \text{isSuitableFor}.\text{OffRoadCycling}, \\ \text{SuspensionFork} &\sqsubseteq \text{Fork}, \\ \text{OffRoadCycling} &\sqsubseteq \text{Cycling} \end{aligned} \}$$

The TBox $\mathcal{T}_{\text{Bike}}$ entails two faulty consequences

1. $\text{Bike} \sqsubseteq \exists \text{hasPart}.\text{SuspensionFork}$
2. $\text{Bike} \sqsubseteq \exists \text{isSuitableFor}.\text{OffRoadCycling}$

} repair request $\mathcal{P}_{\text{Bike}}$

An Example with Bikes: Classical Repair

Example. A classical repair of $\mathcal{T}_{\text{Bike}}$ for $\mathcal{P}_{\text{Bike}}$ is

$$\{ \quad \mathsf{MountainBike} \sqsubseteq \mathsf{Bike},$$

$$\sout{\mathsf{Bike} \sqsubseteq \exists \mathsf{hasPart}.\mathsf{SuspensionFork} \sqcap \exists \mathsf{isSuitableFor}.\mathsf{OffRoadCycling},}$$

$$\mathsf{SuspensionFork} \sqsubseteq \mathsf{Fork},$$

$$\mathsf{OffRoadCycling} \sqsubseteq \mathsf{Cycling} \quad \}$$

An Example with Bikes: Generalized-Conclusion Repair

Example. An optimal GC-repair of $\mathcal{T}_{\mathsf{Bike}}$ for $\mathcal{P}_{\mathsf{Bike}}$ is

$$\{ \quad \begin{aligned} \mathsf{MountainBike} &\sqsubseteq \mathsf{Bike}, \\ \mathsf{Bike} &\sqsubseteq \cancel{\exists \mathsf{hasPart}.\mathsf{SuspensionFork} \sqcap \exists \mathsf{isSuitableFor}.\mathsf{OffRoadCycling}}, \\ &\quad\ \exists \mathsf{hasPart}.\top \sqcap \exists \mathsf{isSuitableFor}.\top, \\ \mathsf{SuspensionFork} &\sqsubseteq \mathsf{Fork}, \\ \mathsf{OffRoadCycling} &\sqsubseteq \mathsf{Cycling} \quad \} \end{aligned}$$

It is also a gentle repair of $\mathcal{T}_{\mathsf{Bike}}$ for $\mathcal{P}_{\mathsf{Bike}}$ w.r.t. the weakening relation $\succ^{\mathsf{sub}}$.

An Example with Bikes: Fixed-Premise Repair

Example. An optimal FP-repair of $\mathcal{T}_{\mathsf{Bike}}$ for $\mathcal{P}_{\mathsf{Bike}}$ is

$$
\begin{aligned}
\{ \quad \mathsf{MountainBike} &\sqsubseteq \sout{\mathsf{Bike}}, \\
&\quad \mathsf{Bike} \sqcap \exists \mathsf{hasPart}.\mathsf{SuspensionFork} \sqcap \exists \mathsf{isSuitableFor}.\mathsf{OffRoadCycling}, \\
\mathsf{Bike} &\sqsubseteq \sout{\exists \mathsf{hasPart}.\mathsf{SuspensionFork} \sqcap \exists \mathsf{isSuitableFor}.\mathsf{OffRoadCycling}}, \\
&\quad \exists \mathsf{hasPart}.\mathsf{Fork} \sqcap \exists \mathsf{isSuitableFor}.\mathsf{Cycling}, \\
\mathsf{SuspensionFork} &\sqsubseteq \mathsf{Fork}, \\
\mathsf{OffRoadCycling} &\sqsubseteq \mathsf{Cycling} \quad \}
\end{aligned}
$$

Do you have questions or comments?