Erratum to: Optimal Repairs in the Description Logic $\mathcal{EL}$ Revisited

Franz Baader[1,2], Patrick Koopmann[1], and Francesco Kriegel[1]

[1] Theoretical Computer Science, Technische Universität Dresden, Dresden, Germany
firstname.lastname@tu-dresden.de
[2] Center for Scalable Data Analytics and Artificial Intelligence (ScaDS.AI)
Dresden/Leipzig, Germany

In the conference paper [1] and its extended version [2], we gave a brief recap of the definition of optimal repairs in Section 3 and presented on Page 13 of [1] and Page 18 of [2] the following condition on repair types:

(RT3[1, 2]) If C is an atom in $\mathcal{K}$ and $E \sqsubseteq F$ is a CI in $\mathcal{T}$ with $\mathcal{B} \models E(u)$[1] and $F \sqsubseteq^{\emptyset} C$, then there is an atom D in $\mathcal{K}$ such that $E \sqsubseteq^{\emptyset} D$.

This version differs from the one given in the original article [3] and its extended version [4]:

(RT3[3, 4]) If C is an atom in $\mathcal{K}$ and $E \in \mathsf{Sub}(\mathcal{R}, \mathcal{T})$ with $\mathcal{B} \models E(u)$ and $E \sqsubseteq^{\mathcal{T}} C$, then there is an atom D in $\mathcal{K}$ such that $E \sqsubseteq^{\emptyset} D$.

Unfortunately, this condition contained a typo w.r.t. the required subsumption relationship, and it is therefore insufficient to prove the results stated in [1, 3].

Counterexample. Consider the TBox $\{C \sqsubseteq \exists r. D,\ D \sqsubseteq E\}$, the input qABox $\exists \emptyset. \{C(a)\}$, and the repair request $\{(\exists r. E)(a)\}$. With respect to (RT3[1, 2]), the set $\{\exists r. E\}$ is already a repair type for a since neither C nor $\exists r. D$ are mandatorily included by this condition. A problem arises if we now construct the canonical "repair" induced by the repair seed $\mathcal{S}$ with $\mathcal{S}_a := \{\exists r. E\}$. Note that, for the given input, the saturation is the qABox $\exists \{x\}. \mathcal{B}$ with $\mathcal{B} = \{C(a), r(a, x), D(x), E(x)\}$. Then, in the "repair" induced by $\mathcal{S}$, the unique r-successor of a is the copy of x that is annotated with the repair type $\{D, E\}$. With respect to the empty TBox, the individual name a is thus no instance of $\exists r. D$ or $\exists r. E$, but is still an instance of C. Inference with the input TBox then restores the unwanted consequence $(\exists r. E)(a)$.

The correct formulation of the above condition must thus use subsumption w.r.t. $\mathcal{T}$ in place of subsumption w.r.t. the empty TBox, i.e., $F \sqsubseteq^{\emptyset} C$ in (RT3[1, 2]) must be replaced with $F \sqsubseteq^{\mathcal{T}} C$:

(RT3) If C is an atom in $\mathcal{K}$ and $E \sqsubseteq F$ is a CI in $\mathcal{T}$ with $\mathcal{B} \models E(u)$ and $F \sqsubseteq^{\mathcal{T}} C$, then there is an atom D in $\mathcal{K}$ such that $E \sqsubseteq^{\emptyset} D$.

[1] Recall that $\exists Y. \mathcal{B}$ is the saturation of the input qABox $\exists X. \mathcal{A}$ w.r.t. $\mathcal{T}$.

This version of Condition (RT3) is stronger than (RT3[1, 2]), but weaker than the original version (RT3[3, 4]). Due to the latter fact, it enables more efficient computation of the optimized repairs, which are equivalent to the canonical repairs (see Section 5 in [3, 4]). The reason is that all minimal repair types covering a given set of concept descriptions can be computed more efficiently, since fewer steps are necessary to close a set under the implication in (RT3), and thus these repair types are smaller in size.

For the strongest condition (RT3[3, 4]), we have proved in [3, 4] that the canonical repairs induced by repair seed are indeed repairs, and that they cover all repairs in the sense that every repair is entailed by a canonical repair. We have just seen that, for the weakest condition (RT3[1,2]), the canonical "repairs" need not be repairs w.r.t. the TBox. To show that the modified condition (RT3) introduced above suffices to obtain the results shown in [3,4], we will re-prove all the auxiliary results in [3] and its extended version [4] that rely on this condition, namely Lemmas XI, XII, and XIII.

Lemma XI. *If $\mathcal{K}$ is a repair pre-type for u and no atom in $\mathcal{K}$ subsumes C w.r.t. $\mathcal{T}$, then there is a repair type for u that covers $\mathcal{K}$ and that does not contain an atom subsuming C w.r.t. $\mathcal{T}$.*

Proof. If $\mathcal{K}$ satisfies Condition (RT3), then it is a repair type and we are done. Otherwise, there is a CI $E \sqsubseteq F$ in $\mathcal{T}$ with $\mathcal{B} \models E(u)$ and there is an atom D in $\mathcal{K}$ with $F \sqsubseteq^{\mathcal{T}} D$, but no atom in $\mathcal{K}$ subsumes E w.r.t. $\emptyset$. Since no atom in $\mathcal{K}$ subsumes C w.r.t. $\mathcal{T}$, we have $C \not\sqsubseteq^{\mathcal{T}} D$. It follows that $C \not\sqsubseteq^{\mathcal{T}} E$ and so there is $G \in \mathsf{Conj}(E)$ with $C \not\sqsubseteq^{\mathcal{T}} G$. We then replace $\mathcal{K}$ with $\mathsf{Max}(\mathcal{K} \cup \{G\})$. Obviously, the new $\mathcal{K}$ covers the old $\mathcal{K}$. After finitely many iterations the Condition (RT3) must be fulfilled, and then we have reached the desired repair type. □

Lemma XII. *Consider a repair seed $\mathcal{S}$ and an $\mathcal{EL}$ concept description C.*

1. *If the matrix of $\mathsf{rep}^{\mathcal{T}}_{\mathsf{QL}}(\exists X.\mathcal{A}, \mathcal{S})$ entails $C(\langle\!\langle u, \mathcal{K}\rangle\!\rangle)$, then the matrix of $\mathsf{sat}^{\mathcal{T}}_{\mathsf{QL}}(\exists X.\mathcal{A})$ entails $C(u)$ and no atom in $\mathcal{K}$ subsumes C w.r.t. $\emptyset$.*
2. *If the matrix of $\mathsf{sat}^{\mathcal{T}}_{\mathsf{QL}}(\exists X.\mathcal{A})$ entails $C(u)$ and no atom in $\mathcal{K}$ subsumes C w.r.t. $\mathcal{T}$, then the matrix of $\mathsf{rep}^{\mathcal{T}}_{\mathsf{QL}}(\exists X.\mathcal{A}, \mathcal{S})$ entails $C(\langle\!\langle u, \mathcal{K}\rangle\!\rangle)$.*

Proof. The first statement above is still the same as the only-if direction in the original Lemma XII and thus the same proof still works. We proceed with the second statement, by induction on C. Denote by $\mathcal{B}$ the matrix of $\mathsf{rep}^{\mathcal{T}}_{\mathsf{QL}}(\exists X.\mathcal{A}, \mathcal{S})$. Let the matrix of $\mathsf{sat}^{\mathcal{T}}_{\mathsf{QL}}(\exists X.\mathcal{A})$ entail $C(u)$ and assume that $\mathcal{K}$ does not contain an atom subsuming C.

- The case where $C = \top$ is trivial.
- Assume that $C = A$ for a concept name A. Since no atom in $\mathcal{K}$ subsumes A w.r.t. $\mathcal{T}$, we infer that $A \notin \mathcal{K}$ and so it follows from the very definition of $\mathcal{B}$ that the concept assertion $A(\langle\!\langle u, \mathcal{K}\rangle\!\rangle)$ is contained in $\mathcal{B}$, i.e., $\mathcal{B} \models A(\langle\!\langle u, \mathcal{K}\rangle\!\rangle)$.

- Let $C = C_1 \sqcap \cdots \sqcap C_n$ be a conjunction of atoms $C_1, \ldots, C_n$ where $n \geq 2$. The preconditions immediately imply that, for each index i, the matrix of $\mathsf{sat}_{\mathsf{QL}}^{\mathcal{T}}(\exists X.\mathcal{A})$ entails $C_i(u)$ and $\mathcal{K}$ does not contain an atom subsuming C_i w.r.t. $\mathcal{T}$ (otherwise there would be an atom subsuming C since $C \sqsubseteq^{\emptyset} C_i$). The induction hypothesis yields that $\mathcal{B} \models C_i(\langle\!\langle u, \mathcal{K} \rangle\!\rangle)$ for each i, and thus it follows that $\mathcal{B} \models C(\langle\!\langle u, \mathcal{K} \rangle\!\rangle)$.
- Consider the last case where $C = \exists r. D$ is an existential restriction. According to Lemma II, it follows from the preconditions that there exists some object v such that the matrix of $\mathsf{sat}_{\mathsf{QL}}^{\mathcal{T}}(\exists X.\mathcal{A})$ contains $r(u, v)$ and entails $D(v)$. Since $\exists r. D$ is not subsumed by an atom in $\mathcal{K}$ w.r.t. $\mathcal{T}$, it follows that $D \not\sqsubseteq^{\mathcal{T}} E$ for each $\exists r. E \in \mathcal{K}$. Thus for each $\exists r. E \in \mathcal{K}$, there is some atom $F_E \in \mathsf{Conj}(E)$ such that $D \not\sqsubseteq^{\mathcal{T}} F_E$. According to Lemma XI there exists a repair type $\mathcal{L}$ for v that covers the repair pre-type $\mathsf{Max}_{\sqsubseteq^{\emptyset}}(\{\, F_E \mid \exists r. E \in \mathcal{K}$ and the matrix of $\mathsf{sat}_{\mathsf{QL}}^{\mathcal{T}}(\exists X.\mathcal{A})$ entails $E(v)\,\})$ and that does not contain an atom subsuming D w.r.t. $\mathcal{T}$. Applying the induction hypothesis then yields that $\mathcal{B} \models D(\langle\!\langle v, \mathcal{L} \rangle\!\rangle)$. By the very construction of $\mathcal{L}$, it follows that the matrix $\mathcal{B}$ contains the role assertion $r(\langle\!\langle u, \mathcal{K} \rangle\!\rangle, \langle\!\langle v, \mathcal{L} \rangle\!\rangle)$. Thus, we conclude that $\mathcal{B} \models C(\langle\!\langle u, \mathcal{K} \rangle\!\rangle)$. □

Lemma XIII. *For each repair seed $\mathcal{S}$, the canonical repair induced by $\mathcal{S}$ equals its saturation, i.e.,* $\mathsf{rep}_{\mathsf{QL}}^{\mathcal{T}}(\exists X.\mathcal{A}, \mathcal{S}) = \mathsf{sat}_{\mathsf{QL}}^{\mathcal{T}}(\mathsf{rep}_{\mathsf{QL}}^{\mathcal{T}}(\exists X.\mathcal{A}, \mathcal{S}))$.

Proof. Since, for both query languages IQ and CQ, the $\sqsubseteq$-rule employed for constructing the saturations is the same, the following argumentation applies to both choices. We show that the $\sqsubseteq$-rule is not applicable to $\mathsf{rep}_{\mathsf{QL}}^{\mathcal{T}}(\exists X.\mathcal{A}, \mathcal{S})$. It is trivial that none of the other two rules is applicable, since the matrix $\mathcal{B}$ can never contain a concept assertion involving a complex concept description.

Consider an object $\langle\!\langle u, \mathcal{K} \rangle\!\rangle$ of $\mathsf{rep}_{\mathsf{QL}}^{\mathcal{T}}(\exists X.\mathcal{A}, \mathcal{S})$ and a concept inclusion $C \sqsubseteq D$ in $\mathcal{T}$. Further assume that the matrix of $\mathsf{rep}_{\mathsf{QL}}^{\mathcal{T}}(\exists X.\mathcal{A}, \mathcal{S})$ entails $C(\langle\!\langle u, \mathcal{K} \rangle\!\rangle)$. Lemma XII implies that the matrix of $\mathsf{sat}_{\mathsf{QL}}^{\mathcal{T}}(\exists X.\mathcal{A})$ entails $C(u)$ and no atom in $\mathcal{K}$ subsumes C w.r.t. $\emptyset$. Since the $\sqsubseteq$-rule is not applicable to $\mathsf{sat}_{\mathsf{QL}}^{\mathcal{T}}(\exists X.\mathcal{A})$, it follows that the matrix of $\mathsf{sat}_{\mathsf{QL}}^{\mathcal{T}}(\exists X.\mathcal{A})$ entails $D(u)$. Since $\mathcal{K}$ satisfies Condition (RT3), no atom in $\mathcal{K}$ subsumes D w.r.t. $\mathcal{T}$. A further application of Lemma XII yields that the matrix of $\mathsf{rep}_{\mathsf{QL}}^{\mathcal{T}}(\exists X.\mathcal{A}, \mathcal{S})$ entails $D(\langle\!\langle u, \mathcal{K} \rangle\!\rangle)$. □

An implementation that employs this more efficient version of Condition (RT3) is available from `https://github.com/francesco-kriegel/interactive-optimal-repairs`.

References

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