Consistent Query Answering in OBDA
Ontology-Based Query Answering (OBQA)

- Database
- Knowledge base
- Ontology

Existential rules:
\[ \forall x \forall y (\varphi(x,y) \rightarrow \exists z \psi(x,z)) \]

 Conjunctive queries:
\[ Q(x) : - R_1(v_1), \ldots, R_m(v_m) \]
A Simple Example

\[ D = \]
\[
\text{professor}(\text{John})
\]
\[
\text{fellow}(\text{John})
\]

\[ \Sigma = \]
\[
\forall x \ (\text{professor}(x) \rightarrow \exists y \ (\text{faculty}(x) \land \text{teaches}(x, y)))
\]
\[
\forall x \ (\text{fellow}(x) \rightarrow \text{faculty}(x))
\]

\[ Q : - (\text{teaches}(\text{John}, x)) \checkmark \]

\{\text{John }\rightarrow\text{John, } x \rightarrow\#\}
A Simple Example

\[ D = \]

professor(John)  
fellow(John)

\[ \Sigma = \]

\[ \forall x \left( \text{professor}(x) \rightarrow \exists y \left( \text{faculty}(x) \land \text{teaches}(x, y) \right) \right) \]

\[ \forall x \left( \text{fellow}(x) \rightarrow \text{faculty}(x) \right) \]

\[ \forall x \left( \text{professor}(x) \land \text{fellow}(x) \rightarrow \bot \right) \]

no model  \Rightarrow  every query is entailed
Handling Data Inconsistencies

• The data are likely to be inconsistent with the ontology

• **Standard semantics fails**: everything is inferred - not meaningful answers

• Two approaches to inconsistency-handling:
  – Resolve the inconsistencies - ideal, but not always possible
  – Live with the inconsistencies - **inconsistency-tolerant semantics**
ABox Repair (AR) Semantics

- Standard inconsistency-tolerant semantics

- **IDEA**: The query must be entailed by every database repair

  \[ \subseteq \text{-maximal consistent subsets of the database} \]
ABox Repair (AR) Semantics

AR-answers\( (Q, \langle D, \Sigma \rangle) = \bigcap_{R \in \{R_1, ..., R_n\}} \text{certain-answers}(Q, \langle R, \Sigma \rangle) \)
ABox Repair (AR) Semantics: Example

\[ D = \]

\[ \begin{array}{c}
\text{professor}(\text{John}) \\
\text{fellow}(\text{John})
\end{array} \]

\[ \Sigma = \]

\[ \forall x \ (\text{professor}(x) \rightarrow \exists y \ (\text{faculty}(x) \land \text{teaches}(x,y))) \]

\[ \forall x \ (\text{fellow}(x) \rightarrow \text{faculty}(x)) \]

\[ \forall x \ (\text{professor}(x) \land \text{fellow}(x) \rightarrow \bot) \]

\[ Q :\neg \text{faculty}(\text{John}) \quad \checkmark \]

\[ R_1 = \]

\[ \begin{array}{c}
\text{professor}(\text{John})
\end{array} \]

\[ () \in \text{AR-answers}(Q, \langle R_1, \Sigma \rangle) \]

\[ R_2 = \]

\[ \begin{array}{c}
\text{fellow}(\text{John})
\end{array} \]

\[ () \in \text{AR-answers}(Q, \langle R_2, \Sigma \rangle) \]
ABox Repair (AR) Semantics: Example

\[ D = \]

\[
\begin{align*}
\text{professor}(\text{John}) \\
\text{fellow}(\text{John})
\end{align*}
\]

\[ \Sigma = \]

\[
\begin{align*}
\forall x \ (\text{professor}(x) \rightarrow \exists y \ (\text{faculty}(x) \land \text{teaches}(x,y))) \\
\forall x \ (\text{fellow}(x) \rightarrow \text{faculty}(x)) \\
\forall x \ (\text{professor}(x) \land \text{fellow}(x) \rightarrow \bot)
\end{align*}
\]

\[ Q ::= \text{teaches}(\text{John},x) \quad \times \]

\[ () \in \text{AR-answers}(Q, \langle R_1, \Sigma \rangle) \]

\[ () \not\in \text{AR-answers}(Q, \langle R_2, \Sigma \rangle) \]
Consistent Query Answering in OBQA

\[ Q(x) : - R_1(v_1), ..., R_m(v_m) \]

existential rules + negative constraints

\[ \forall x \forall y (\varphi(x, y) \rightarrow \exists z \psi(x, z)) \]

\[ \forall x (\varphi(x) \rightarrow \bot) \]

conjunctive queries
Consistent Query Answering in OBQA

\[ \text{AR-answers}(Q, \langle D, \Sigma \rangle) = \bigcap_{R \in \text{drep}(D, \Sigma)} \text{certain-answers}(Q, \langle R, \Sigma \rangle) \]

\[ \{ D' \mid D \supseteq D', \text{ models}(D' \land \Sigma) \neq \emptyset, \text{ there is no } \alpha \in D \text{ such that models}(D' \cup \{\alpha\} \land \Sigma) \neq \emptyset \} \]
Consistent Query Answering in OBQA

Guess and check algorithm (for the complement of the problem)

Input: \( D, \Sigma, Q(x), \text{tuple } t \)

1. Guess \( R \subseteq D \) - a possible repair

2. Verify that \( R \) is a repair, i.e., \( \langle R, \Sigma \rangle \) is consistent and \( R \) is \( \subseteq \)-maximal

3. Verify that \( \langle R, \Sigma \rangle \) does not entail \( Q(t) \)

we exploit classical query answering

2.1. Check that for every \( \forall x \, (\varphi(x) \rightarrow \bot) \in \Sigma, \langle R, \Sigma \rangle \) does not entail \( Q : - \varphi(x) \)

2.2. Check that for every \( \alpha \in D \setminus R \), there exists \( \forall x \, (\varphi(x) \rightarrow \bot) \in \Sigma \), such that \( \langle R \cup \{\alpha\}, \Sigma \rangle \) entails \( Q : - \varphi(x) \)
Intersection ABox Repair (IAR) Semantics

- One of the basic sound approximations of the AR semantics

- **IDEA:** The query must be entailed by the intersection of the database repairs

\[ \subseteq \text{-maximal consistent subsets of the database} \]
Intersection ABox Repair (IAR) Semantics

\[ \text{IAR-answers}(Q, \langle D, \Sigma \rangle) = \text{certain-answers}(Q, \langle R_n, \Sigma \rangle) \]
Intersection ABox Repair (IAR) Semantics

\[ \text{IAR-answers}(Q, \langle D, \Sigma \rangle) \subseteq \text{AR-answers}(Q, \langle D, \Sigma \rangle) \]