Query Answering Explanation in Inconsistent Datalog+/- Knowledge Bases

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Outline

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Objective

- Proposing an interactive framework that, by considering a *knowledge base and a set of sameAs links which generate inconsistencies*, uses argument-based explanation to provide explanation of inconsistencies to the user. (Explanation Dialogue)

Claim

Th explanation dialogue would prompt the domain expert to eventually correct some erroneous data, or to revise the logical rules for the invalidation or, finally, to decide to change the initial linking strategy.
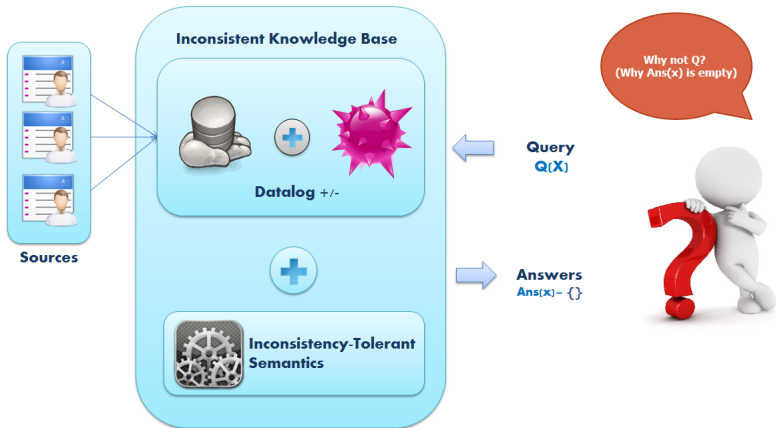
The general problem

Figure: Query Failure Explanation Problem (QFEP)

The general problem: which semantics ?

Definition (Brave-semantics)

Let $\mathcal{K} = (\mathcal{F}, \mathcal{R}, \mathcal{N})$ be a knowledge base and let Q be a query. Q is brave-entailed from $\mathcal{K}$, written $\mathcal{K} \models_{brave} Q$ if and only if:

$$\exists \mathcal{A} \in \mathcal{R}epair(\mathcal{K}) \text{such that } \mathtt{Cl}_{\mathcal{R}}(\mathcal{A}) \models Q$$

Definition (ICR-semantics)

Let $\mathcal{K} = (\mathcal{F}, \mathcal{R}, \mathcal{N})$ be a knowledge base and let Q be a query. Q is ICR-entailed from $\mathcal{K}$, written $\mathcal{K} \models_{ICR} Q$ if and only if:

$$\bigcap_{\mathcal{A} \in \mathcal{R}epair(\mathcal{K})} \mathtt{Cl}_{\mathcal{R}}(\mathcal{A}) \models Q$$

The general problem: formal definition

Given a knowledge base $\mathcal{K}$ and a boolean conjunctive query Q, the general problem is to explain why Q is not entailed by $\mathcal{K}$ under the ICR-semantics.

### Definition (Query Failure Explanation Problem $\mathcal{P}$)

Let $\mathcal{K}$ be a knowledge base, Q a boolean conjunctive query. $\mathcal{P} = \langle \mathcal{K}, Q \rangle$ is a query failure explanation problem (QFEP) iff :

  i $\mathcal{K}$ is inconsistent.

 ii $\mathcal{K} \models_{brave} Q$.

iii $\mathcal{K} \not\models_{ICR} Q$.

Outline

1. Context and Objectives

2. SameAs Query Failure Explanation Problem (QFEP)

3. Argumentation Framework

4. The Approach: Explanation Dialogue for sameAs QFEP

5. Preliminary Evaluation

6. What is Missing

The setting schemata
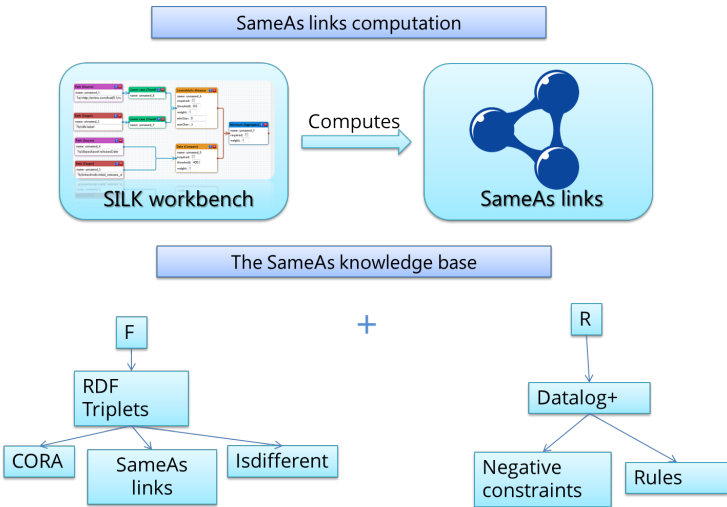
The setting: example

Facts (portion of $\mathcal{F}$)

$sameAs(124, 134), sameAs(134, 155), sameAs(155, 135), sameAs(a_1, a_2), sameAs(123, 134)$
$confName(123, \text{'proceedings aaai-98'})$
$confName(124, \text{'in proceedings aaai-98'})$
$confName(134, \text{'in proceedings of aaai'})$
$confName(135, \text{'in proc. aaai'})$
$isconfNameDiffLevenshtein(\text{'proceedings aaai-98'}, \text{'in proceedings of aaai'}, 0.73)$
$isconfNameDiffLevenshtein(\text{'proceedings aaai-98'}, \text{'in proceedings aaai-98'}, 0.73)$
$isconfNameDiffLevenshtein(\text{'in proceedings aaai-98'}, \text{'in proc. aaai'}, 0.73)$
$isconfNameDiffLevenshtein(\text{'proceedings aaai-98'}, \text{'in proc. aaai'}, 0.41)$
$isconfNameDiffJaccard(30, 15, 0)$
$published(a_1, 123), published(a_2, 124)$
$pageFrom(a_2, 15), pageFrom(a_1, 30)$

Rules (portion of $\mathcal{R}$)

$sameAs(x, y) \wedge published(x, w_1) \wedge published(y, w_2) \rightarrow sameAs(w_1, w_2)$
$sameAs(x, y) \wedge pageFrom(x, w_1) \wedge pageFrom(y, w_2) \rightarrow isEquiv(w_1, w_2)$
$sameAs(x, y) \wedge confName(x, w_1) \wedge confName(x, w_1) \rightarrow isEquiv(w_1, w_2)$
$sameAs(x, y) \wedge sameAs(y, z) \rightarrow sameAs(x, z)$
$sameAs(y, x) \rightarrow sameAs(x, y)$
$isDiff(y, x) \rightarrow isDiff(x, y)$
$isconfNameDiffLevenshtein(x, y, \sigma) \rightarrow isDiff(x, y)$
$ispageFromDiffJaccard(x, y, \sigma) \rightarrow isDiff(x, y)$

Negative Constraints (portion of $\mathcal{N}$ and implicitly derivable)

$isEquiv(x, y) \wedge isDiff(x, y) \rightarrow \perp$
[derivable negative constraints]
$sameAs(x, y) \wedge pageFrom(x, w_1) \wedge pageFrom(x, w_1) \wedge isDiff(w_1, w_2) \rightarrow \perp$
$sameAs(x, y) \wedge confName(x, w_1) \wedge confName(x, w_1) \wedge isDiff(w_1, w_2) \rightarrow \perp$

The sameAs query failure explanation problem

- Given an inconsistent sameAs knowledge base $\mathcal{K}$.

- A ground sameAs query $Q = sameAs(A, B)$ such that A and B are constants.

- sameAs QFEP amounts to explain why $\mathcal{K} \not\models_{ICR} sameAs(A, B)$ (i.e. why the link $sameAs(A, B)$ is not accepted under the ICR-semantics).

Outline

Some notations

Given a knowledge base $\mathcal{K} = (\mathcal{F}, \mathcal{R}, \mathcal{N})$, the corresponding argumentation framework $\mathcal{AF}_{\mathcal{K}}$ is a pair $(\texttt{Arg}, \texttt{Att})$

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Definition (Argument)

An argument is a tuple : $x = \langle H, C \rangle$.

- H is a set of consistent facts that entails C (considering $\mathcal{R}$).
- C is an atom or a conjunction of atoms.
- $\texttt{Supp}(x) = H$ is the hypothesis or the support of x, and $\texttt{Conc}(x) = C$ is the conclusion.

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Example (Argument and clarified argument)

• An argument x built over the sameAs knowledge base:
$x = \langle \{sameAs(134, 155), sameAs(155, 135)\}, sameAs(134, 135) \rangle$.
• A clarified argument C_x of x is as follows:
$C_x = \langle \{sameAs(134, 155), sameAs(155, 135)\}, \{sameAs(x, y) \wedge sameAs(y, z)$
$\rightarrow sameAs(x, z)\}, \{sameAs(134, 135)\} \rangle$.

Some notations

Definition (Attack)

$(y, x) \in \mathtt{Att}$ iff $\exists \varphi \in \mathtt{Supp}(x)$ s.t $\mathtt{Cl}_{\mathcal{R}}(\{\mathtt{Conc}(y), \varphi\}) \models \bot$.

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Example

The argument y attacks x:

- $x = \langle \{sameAs(123, 134)\}, sameAs(123, 134) \rangle$
- $y = \langle \{sameAs(134, 155), sameAs(155, 135)\}, sameAs(134, 135) \rangle$.

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- $y = \langle \{sameAs(134, 155), sameAs(155, 135)\}, sameAs(134, 135) \rangle$.

A deepening of this attack is the triggered negative constraint:

1. $sameAs(123, 135) \wedge confName(135, \textit{'in proc. aaai'}) \wedge$
   $confName(123, \textit{'proceedings aaai-98'}) \wedge$
   $isDiff(\textit{'in proc. aaai'}, \textit{'proceedings aaai-98'}) \rightarrow \bot$

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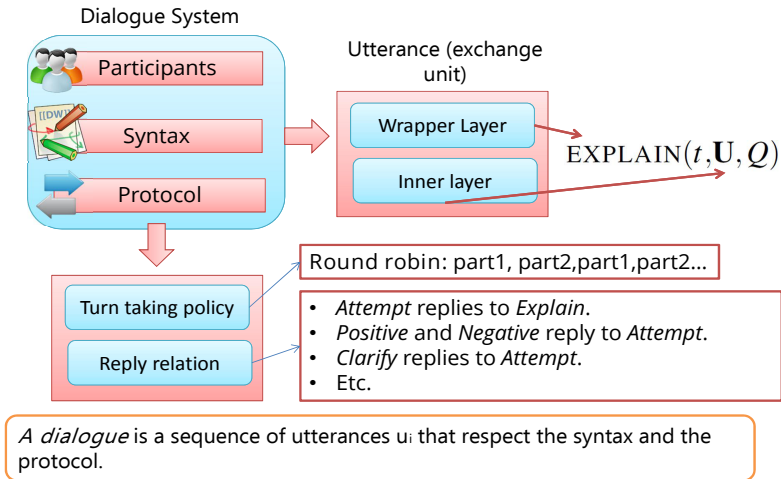 $isDiff(\text{'in proc. aaai'}, \text{'proceedings aaai-98'}) \rightarrow \perp$

Definition (Supports and opposition)

An argument $y = \langle H, C \rangle$ supports a query Q iff $C \models Q$. An argument x is against a query Q iff there exists an argument y that supports Q such that x attacks y.

Outline

The approach

Dialogue System

Participants

Syntax

Protocol

Utterance (exchange unit)

Wrapper Layer

Inner layer

$\text{EXPLAIN}(t, \mathbf{U}, Q)$

Turn taking policy

Reply relation

Round robin: part1, part2,part1,part2...

- *Attempt* replies to *Explain*.
- *Positive* and *Negative* reply to *Attempt*.
- *Clarify* replies to *Attempt*.
- Etc.

A dialogue is a sequence of utterances u$_i$ that respect the syntax and the protocol.

Dialogue example

Example

Consider the query $Q = sameAs(123, 134)$ involves two resources which describe two 'conferences' with title ($confName$) 'proceedings aaai-98'(a) and 'in proceedings of aaai'(b), respectively. Q is not ICR-entailed.

- Syntax: EXPLAIN(1, User, Q).
- Meaning: **explanation request** made by the User.
- Possible replies: {ATTEMPT()}.

1. User: Why 123 and 134 are not the same?

Dialogue example

Example

Consider the query $Q = sameAs(123, 134)$ involves two resources which describe two 'conferences' with title ($confName$) 'proceedings aaai-98'(a) and 'in proceedings of aaai'(b), respectively. Q is not ICR-entailed.

- Syntax: ATTEMPT(2, Reasoner, a) such that $a = \langle\{sameAs(134, 155), sameAs(155, 135)\}, sameAs(134, 135)\rangle$.
- Meaning: **explanation attempt** with an argument **against** Q
- Possible replies: $\{$CLARIFY(), DEEPEN(), POSITIVE(), NEGATIVE()$\}$

1. User: Why 123 and 134 are not the same?
2. Reasoner: Because 134 is the same as 135.

Dialogue example

Example

Consider the query $Q = sameAs(123, 134)$ involves two resources which describe two 'conferences' with title ($confName$) 'proceedings aaai-98'(a) and 'in proceedings of aaai'(b), respectively. Q is not ICR-entailed.

- Syntax: CLARIFY$(3, \text{User}, a)$
- Meaning: The User asks for a clarification of the argument a.
- Possible replies: $\{$CLARIFICATION$()$, POSITIVE$()\}$

1. User: Why 123 and 134 are not the same?
2. Reasoner: Because 134 is the same as 135.
3. User: Clarify?

Dialogue example

Example

Consider the query $Q = sameAs(123, 134)$ involves two resources which describe two 'conferences' with title ($confName$) 'proceedings aaai-98'(a) and 'in proceedings of aaai'(b), respectively. Q is not ICR-entailed.

- Syntax: CLARIFICATION(4, User, C_a) such that $C_a =$
  $\langle \{sameAs(134, 155), sameAs(155, 135)\},$
  $\{sameAs(x, y) \land sameAs(y, z)$
  $\rightarrow sameAs(x, z)\}, \{sameAs(134, 135)\} \rangle$.
- Meaning: presents a clarification.
- Possible replies:
  $\{DEEPEN(), POSITIVE(), NEGATIVE()\}$

1. User: Why 123 and 134 are not the same?
2. Reasoner: Because 134 is the same as 135.
3. User: Clarify?
4. Reasoner: 134 is the same as 155, 155 is the same as 135 *hence by transitivity* 134 is the same as 135.

Dialogue example

Example

Consider the query $Q = sameAs(123, 134)$ involves two resources which describe two 'conferences' with title ($confName$) 'proceedings aaai-98'(a) and 'in proceedings of aaai'(b), respectively. Q is not ICR-entailed.

- Syntax: DEEPEN$(5, \text{User}, a)$
- Meaning: a **deepening request** made by User.
- Possible replies: $\{$DEEPENING$()$, POSITIVE$()\}$

1. User: Why 123 and 134 are not the same?

2. Reasoner: Because 134 is the same as 135.

3. User: Clarify?

4. Reasoner: 134 is the same as 155, 155 is the same as 135 *hence by transitivity* 134 is the same as 135.

5. User: Why is this a problem?

Dialogue example

Example

Consider the query $Q = sameAs(123, 134)$ involves two resources which describe two 'conferences' with title ($confName$) 'proceedings aaai-98'(a) and 'in proceedings of aaai'(b), respectively. Q is not ICR-entailed.

- Syntax: DEEPENING$(6, \text{Reasoner}, D_a)$ such that: $D_a = sameAs(123, 135) \wedge$ $confName(135, b) \wedge confName(123, a) \wedge$ $isconfNameDiffLevenshtein(a, b, 0.41) \rightarrow \perp$
- Meaning: presents a deepening.
- Possible replies: $\{\text{NEGATIVE}(), \text{POSITIVE}()\}$

1. User: Why 123 and 134 are not the same?

2. Reasoner: Because 134 is the same as 135.

3. User: Clarify?

4. Reasoner: 134 is the same as 155, 155 is the same as 135 *hence by transitivity* 134 is the same as 135.

5. User: Why is this a problem?

6. Reasoner: $confName_{123}$ is 'proceedings aaai-98' (a) and $confName_{135}$ is 'in proc. aaai' (b). a, b have Levenshtein similarity of 0.41. It is impossible that 123 and 135 are the same thing and they have dissimilar conference names.

Dialogue example

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Consider the query $Q = sameAs(123, 134)$ involves two resources which describe two 'conferences' with title ($confName$) 'proceedings aaai-98'(a) and 'in proceedings of aaai'(b), respectively. Q is not ICR-entailed.

- Syntax: POSITIVE$(7, \text{User}, Q)$
- Meaning: the User acknowledges understanding.
- Possible replies: $\{\}$

1. User: Why 123 and 134 are not the same?

2. Reasoner: Because 134 is the same as 135.

3. User: Clarify?

4. Reasoner: 134 is the same as 155, 155 is the same as 135 *hence by transitivity* 134 is the same as 135.

5. User: Why is this a problem?

6. Reasoner: $confName_{123}$ is 'proceedings aaai-98' (a) and $confName_{135}$ is 'in proc. aaai' (b). a, b have Levenshtein similarity of 0.41. It is impossible that 123 and 135 are the same thing and they have dissimilar conference names.

7. User: Understood.

Dialogue example

Example

Consider the query $Q = sameAs(123, 134)$ involves two resources which describe two 'conferences' with title ($confName$) 'proceedings aaai-98'(a) and 'in proceedings of aaai'(b), respectively. Q is not ICR-entailed.

- Syntax: NEGATIVE(7, User, a') such that $a' = \langle \{sameAs(a_1, a_2), published(a_1, 123), published(a_2, 124), sameAs(124, 134)\}, sameAs(123, 134)\rangle$.

- Meaning: **negative feedback** made by the User with an argument that supports Q.

- Possible replies: $\{\text{ATTEMPT}(), \text{POSITIVE}()\}$.

⑦ User: the article a_1 is the same as a_2 and a_1 is published in 123 and a_2 is published in 124, and 124 is the same as 134 thus 123 is the same as 134.

Dialogue example

Example

Consider the query $Q = sameAs(123, 134)$ involves two resources which describe two 'conferences' with title ($confName$) 'proceedings aaai-98'(a) and 'in proceedings of aaai'(b), respectively. Q is not ICR-entailed.

- Syntax: ATTEMPT(8, Reasoner, a'') such that $a'' = \langle pageFrom(a_1, 30),$ $pageFrom(a_2, 15),$ *ispageFromDiffLevenshtein* $(30, 15, 0)\rangle$.

- Meaning: **explanation attempt** with an argument **against** Q (attacks a')

- Possible replies: $\{$CLARIFY($)$, DEEPEN($)$, POSITIVE($)$, NEGATIVE($)\}$

- **7** User: the article a_1 is the same as a_2 and a_1 is published in 123 and a_2 is published in 124, and 124 is the same as 134 thus 123 is the same as 134.

- **8** But a_1 has page from 30 and a_2 has page from 15 and the two values are different.

Dialogue example

Example

Consider the query $Q = sameAs(123, 134)$ involves two resources which describe two 'conferences' with title ($confName$) 'proceedings aaai-98'(a) and 'in proceedings of aaai'(b), respectively. Q is not ICR-entailed.

- Syntax: POSITIVE$(9, \text{User}, Q)$.
- Meaning: the User acknowledges understanding.
- Possible replies: {}

7. User: the article a_1 is the same as a_2 and a_1 is published in 123 and a_2 is published in 124, and 124 is the same as 134 thus 123 is the same as 134.

8. But a_1 has page from 30 and a_2 has page from 15 and the two values are different.

9. User: Understood.

Outline

Implementation

Mini architecture

Preliminary qualitative evaluation

Claim

Th explanation dialogue would prompt the domain expert to eventually correct some erroneous data, or to revise the logical rules for the invalidation or, finally, to decide to change the initial linking strategy.

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Experiment

- *Object: a modified CORA dataset with some sameAs statements.*
- *Method: "Wizard of Oz", partially operated by human (semi-automatic).*
- *Goal: a preliminary **confirmation** of the claim.*

Preliminary qualitative evaluation - results

1. Errors in data.

Example (case 1)

In some cases, errors in the data have been found (e.g. resource 1135 has $confYear$ property value 0, while other resources, describing the same thing: and linked to 1135 via sameAs, are conferences of the year 1995, or in another resource with 0021 the value of the property $pageFrom$ was 24.1, which is again an error since it should be 24).

Preliminary qualitative evaluation - results

- Supports for similarity functions update.

Example (case 2)

In some other tests, the explanation dialogue supported the expert to understand that an update of some similarity functions used in specific properties was necessary (e.g. Levensthein instead of Jaccard for $confName$), or that the threshold ϵ to determine "dissimilar literals" had to be lowered for some properties (e.g. $title$).

Preliminary qualitative evaluation - results

- Most problematic sameAs.

Example (case 3)

we used *Graal* to compute all the conflicts in the knowledge base. Then, we highlighted those sameAs that were more involved in conflicts (and sub-sequentially more present in attacks in the corresponding argumentation framework).

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Summary & Outlook

1. Improving the conflict computation tool (computational efficiency).

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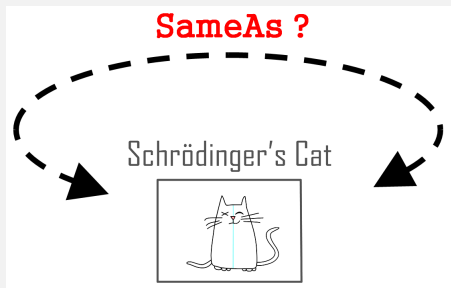4. Natural language module (e.g. a controlled English) to translate FOL formulae to NLS.

Figure: Madalina's cat :)

Thank You! Questions ?