Explanations for Ontology-Mediated Query Answering in Description Logics (Extended Abstract)[*]

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Ontology-mediated query answering (OMQA) [12, 3] emerged as a paradigm for accessing data sources through a logical theory. In this paper, we focus on description logics (DLs) [2], and study the problem of *explaining* why an ontology-mediated query (OMQ) is *entailed* from a given data source. Explainability is an essential ingredient of various application domains, and has been widely investigated in DLs under different names such as *justifications* [9, 14], *abduction* [10, 5], and *axiom pinpointing* [1, 13, 11]. There has been only a few works for deriving explanations for OMQA in DLs [4, 5]. Here we provide an abridged report of our paper on explaining OMQA in DLs that appeared at ECAI 2020 [8].

Our study is based on the framework that has been recently developed for existential rules [7]. Specifically, we view explanations as minimal sets of assertions from an ABox which satisfy the ontology-mediated query, and study a variety of problems based on such explanations. Formally, given a consistent knowledge base $\mathcal{K} = (\mathcal{T}, \mathcal{A})$ where $\mathcal{T}$ is a TBox and $\mathcal{A}$ is an ABox, and a *query* Q, we say that a subset $\mathcal{E} \subseteq \mathcal{A}$ is a *minimal explanation* (MinEX) *for the OMQ* $(Q, \mathcal{T})$ *in* $\mathcal{A}$ if $\mathcal{E} \models (Q, \mathcal{T})$, and no proper subset of $\mathcal{E}$ entails $(Q, \mathcal{T})$.

Example 1. Consider an engine that might experience a number of possible failures, each caused by a fault of one of the constituent parts, presented in Fig 1. We can model fault diagnosis as minimal ex-

Fig. 1. Possible faults in different parts of a system.

planations for OMQs. Let us define the ABox $\mathcal{A} = \{Fault(part_i) \mid 1 \le i \le 4\} \cup \mathcal{A}_{st}$, where $\mathcal{A}_{st} = \{caused(overheat, part_i) \mid i \in \{1, 2\}\} \cup \{caused(leakage, part_i) \mid i \in \{2, 3\}\}$ and the TBox $\mathcal{T} = \{\exists caused.Fault \sqsubseteq Failure\}$. The query $Q = Failure(overheat) \wedge Failure(leakage) \wedge \bigwedge_{\psi \in \mathcal{A}_{st}} \psi$ specifies the observed failures together with the structural facts of the engine. Then, any MinEX for $(Q, \mathcal{T})$

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in $\mathcal{A}$ is a minimal subset of *Fault* concept assertions, together with all assertions in $\mathcal{A}_{st}$, that lead to *overheat* and *leakage*. In particular, MinEXs for $(Q, \mathcal{T})$ in $\mathcal{A}$ correspond to minimal covers of the graph in Figure 1.   ∎

We study four decision problems related to minimal explanations: (i) given a set, decide whether it is a *minimal explanation* (Is-MinEX), (ii) given a set of sets, decide whether it is the set of *all minimal explanations* (All-MinEX), (iii) given a distinguished assertion, decide whether it is *contained in some minimal explanation* (MinEX-Rel), and (iv) given a set of forbidden sets, decide whether there is a minimal explanation *not containing any forbidden sets* (MinEX-Irrel). We illustrate these problems on our running example, and refer to the original publication, for formal definitions and details [8].

Example 2. Let us consider the following subsets of the ABox

$$\mathcal{E}_1 = \{Fault(part_2)\} \cup \mathcal{A}_{st}, \text{ and } \mathcal{E}_2 = \{Fault(part_1), Fault(part_3)\} \cup \mathcal{A}_{st},$$

on our running example and the explanation problems:

– Is-MinEX: Both $\mathcal{E}_1$ and $\mathcal{E}_2$ are MinEXs for the OMQ $(Q, \mathcal{T})$, since they are both minimal and entail the OMQ. On the other hand, neither the set $\{Fault(part_1)\} \cup \mathcal{A}_{st}$ nor the set $\{Fault(part_2), Fault(part_4)\} \cup \mathcal{A}_{st}$ are minimal explanations, as the former does not entail the OMQ and the latter is not minimal.
– All-MinEX: It is easy to see that the set $\{\mathcal{E}_1, \mathcal{E}_2\}$ is the set of all MinEXs for the OMQ in $\mathcal{A}$, i.e., there are not other minimal explanations.
– MinEX-Rel: Observe that the assertions $Fault(part_i)$, $i \in \{1, 2, 3\}$, are all relevant, as they are all contained in some MinEX.
– MinEX-Irrel: Let $\{\{Fault(part_1), Fault(part_3)\}, \{Fault(part_4)\}\}$ be forbidden sets of assertions. We need to decide whether there exists an explanation that does not contain any of these sets. The answer is yes, since $\mathcal{E}_1$ is a MinEX that does not contain any of these sets. Notice, however, $\mathcal{E}_2$ contains a forbidden set.   ∎

We conduct a thorough complexity analysis for the above-mentioned explanation problems for a large class of OMQs. In our data complexity analysis, we show that *all* these problems are *tractable* for *DL-Lite* and *DL-Lite*$_{\mathcal{R}}$. Other tractability results in the data complexity are given for Is-MinEX for $\mathcal{EL}$, $\mathcal{ELI}$, and Horn-$\mathcal{SHOIQ}$. All the other results in the data complexity confirm the *hardness* of deriving explanations, as we almost always observe an increase in the complexity in comparison to the complexity of OMQA. This is largely due to an extra complexity introduced for ensuring minimality. The hardness results for most of these problems are shown by the reductions from different satisfiability problems. In the combined complexity, we observe that the complexity is typically dominated by the complexity of OMQA.

The closest work to our study is the framework developed for existential rules [7]. Membership results, in most cases, follow from this earlier work, but hardness results are significantly different, especially for logics such as $\mathcal{ALC}$.

Explanations for OMQA in DLs have been studied earlier for *DL-Lite* [4]. Our work is complementary to explaining *negative* answers to OMQs in DLs [5], which was recently also studied in the context of existential rules [6].

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