Explanatory Diagnosis of an Ontology Stream via Reasoning About Actions

Quan Yu, Hai Wan, Jiangtao Xu, Freddy Lecue, Liang Chang

To cite this version:

Quan Yu, Hai Wan, Jiangtao Xu, Freddy Lecue, Liang Chang. Explanatory Diagnosis of an Ontology Stream via Reasoning About Actions. ECAI 2016 - 22nd European Conference on Artificial Intelligence, Sep 2016, The Hague, Netherlands. 10.3233/978-1-61499-672-9-1596 . hal-01934918

HAL Id: hal-01934918
https://hal.inria.fr/hal-01934918

Submitted on 26 Nov 2018

ECAI 2016
G.A. Kaminka et al. (Eds.)

doi:10.3233/978-1-61499-672-9-1596

Explanatory Diagnosis of an Ontology Stream via Reasoning About Actions

Quan Yu[1] and **Hai Wan**[2] and **Jiangtao Xu**[2] and **Freddy Lécué**[3] and **Liang Chang**[4]

Abstract. Explanatory diagnosis of an ontology stream aims to explain the changes hidden in the ontology stream by a sequence of actions. In this paper, we present a framework for explanatory diagnosis of an ontology stream, which allows the actions to be uncertain. In order to capture the semantics of actions, we introduce a new update operator and effect-guided bold-repair. By combining these operators with a query mechanism of description logics $\mathcal{EL}^{++}$ supporting inconsistency-tolerant semantics, we present a formal definition for the explanatory diagnosis problem of ontology streams.

1 Introduction and Related Work

The task of diagnosing streams has received particular attentions from the semantic web and diagnosis communities. Freddy Lécué proposed a framework for diagnosing anomalies in an *ontology stream* [3]. However, the task of *explanatory diagnosis* is not achieved on stream evolution and its changes. McIlraith presented a formal characterization of explanatory diagnosis in the situation calculus [5]. Yu et al. also provided a formal characterization of explanatory diagnosis in dynamic epistemic logic [7]. In this paper, we focus on the task of explanatory diagnosis of an ontology stream, which uses a sequence of actions to explain changes occurring over time.

In a road traffic context, a change is a transition from "*cleared*" to "*congested*" road in a particular time of the stream and its diagnoses can be represented as an action sequence *e.g.*, a road work, road incident. These explanations can be derived from different points of time and events between them, from which we can indirectly derive a new ontology stream of diagnoses. We introduce actions with either certain or uncertain effects. For the update of an ontology, we present a new update operator and an effect-guided bold-repair operator. Combined with (i) query mechanisms, supporting inconsistency-tolerant semantics, and (ii) both the semantics and dynamics of action sequences, we formalize the explanatory diagnosis problem in the framework of description logics (DL) $\mathcal{EL}^{++}$.

2 Background

Our approach is illustrated with DL $\mathcal{EL}^{++}$ [3], which is the basis of many more expressive DLs. As usual DLs, answers to queries are formed by constants/ terms denoting individuals explicitly mentioned in the ABox [1]. The definition of Union of Conjunctive Queries (UCQ) and Extension of UCQ (ECQ) can found in [1]. An ontology stream [2] is defined as a dynamic and evolutive version of ontologies. An ontology stream $\mathcal{O}_m^n$ from point of time m to point of time n is a sequence of ontologies $(\mathcal{O}_m^n(m), \mathcal{O}_m^n(m+1), \cdots, \mathcal{O}_m^n(n))$ where $m, n \in \mathbb{N}$ and $m < n$.

2.1 Actions and Events

We first present the definitions of certain-effect action.

Definition 1 (Certain-effect Action) *A certain action α is a pair $(pre, effs)$ where:*

- *pre is the precondition of α, which is an ECQ;*
- *$effs$ is the set of effects of α. Each effect eff has the form $Q \rightsquigarrow F$ where (i) Q is an ECQ, (ii) F is a set of facts to be added to the ABox. It is a set of non-ground ABox assertions which include constants in the initial ABox A_0 and free variables of Q.*

Our definition of certain-effect action is an adaptation of that in [1]. Then we present the uncertain effect action as follows:

Definition 2 (Uncertain-effect Action) *An uncertain-effect action α_u is a pair $(pre, Effs)$ where:*

- *pre is the precondition of α_u, which is an ECQ;*
- *$Effs = (p, effs)$ is a set of pairs. p describes the probability of $effs$ after executing action α_u, which means that each action α_u has many action effects with different probability.*

If not otherwise specified, we slightly abuse these two types of actions. We denote the precondition of α as pre_α, the effects of α as $effs_\alpha$, and each effect of α as eff_α. Note that the free variables of pre_α are the parameters of action α. We use $\alpha[\theta] = (pre_\alpha\theta, effs_\alpha\theta)$ to denote the action is substituted by partial substitution θ. We complement our framework by introducing the concept of events which decide whether an action is applicable in a current knowledge base.

Definition 3 (Event) *An event e_i, occurring in time i of ontology stream $\mathcal{O}_m^n$, is a set of non-ground ABox assertions which include constants and free variables. We use $\mathcal{E}_{m+1}^{n-1}(i)$ to denote events occurring in time $i \in (m, n)$.*

2.2 Update Operator

In the following, we introduce the definitions of (i) applicability for actions in an ABox, and (ii) update operator for describing how to update an ontology with an action.

Definition 4 (Applicable) *Given (i) a terminology T, (ii) an action $\alpha[\theta] = (pre_\alpha\theta, effs_\alpha\theta)$, (iii) the current ABox A denoted by the empty set, and (iv) an event e. $\alpha[\theta]$ is applicable in A according to e, if $A \cup e$ is consistent w.r.t. T and $\exists\sigma$ s.t.$T, A \cup e\theta\sigma \models_{BR} pre_\alpha\theta\sigma$ (The notion of $\models_{BR}$ will be introduced in the next subsection).*

---

[1] School of Mathematics and Statistics, Qiannan Normal University for Nationalities, China. email: yuquanlogic@126.com
[2] School of Data and Computer Science, Sun Yat-sen University, China. Hai Wan is the corresponding author, email: wanhai@mail.sysu.edu.cn
[3] Accenture Tech Labs, Ireland. INRIA, France.
[4] School of Computer Science and Information Security, Guilin University of Electronic Technology, China.

Definition 5 (Update with Action) *Given an action $\alpha[\theta] = (pre_\alpha\theta, effs_\alpha\theta)$, and the current $O = (T, A)$. The results of application $\alpha[\theta]$ in O is a new ontology $O' = (T, A')$, which is defined as $O' = A \circledast \alpha[\theta]$, where $A \circledast \alpha[\theta] = A \cup E_\alpha$, and $E_\alpha = \bigcup_{(Q \rightsquigarrow F) \in effs_\alpha} \bigcup_{\sigma \in ANS(Q\theta, T, A)} F\theta\sigma$.*

2.3 Repairs

Based on the defintion of Bold-repair [4], we present the definition of *effect-guided bold-repair* to fit our framework. While we use an action α to update an ABox A_0, the resulting ABox A may become inconsistent. Suppose that the effects E_α is with a higher priority, we repair the old ABox A_0 according to the fixed TBox T and E_α.

Definition 6 (Effects Guided Bold-repair) *An effects guided bold-repair (B_{rep} in short) of an ABox A and an action α, denoted as $B_{rep}(A, \alpha)$, is a subset A' of $A - E_\alpha$* s.t.*:*

- *$T \cup E_\alpha \cup A'$ has a model;*
- *there does not exists A'' such that $A' \subset A'' \subseteq A - E_\alpha$ and $T \cup E_\alpha \cup A''$ has a model.*

We use the defintion of inconsistency-tolerant semantics to decide if the precondition holds before updating the ontology by an action.

Definition 7 (Inconsistency-tolerant Semantics) *Let $KB(T, A)$ be an $\mathcal{EL}^{++}$ knowledge base, α be an action, and q be an UCQ. We say that q is BR entailed by $KB(T, A)$, written $T, A \models_{BR} q$, if $T, A' \models q$ for every B_{rep} A' of A according to action α.*

Theorem 1 *Let $KB(T, A)$ be an $\mathcal{EL}^{++}$ knowledge base, let α be an action, and let q be an UCQ. Then the complexity of deciding whether $T, A \models_{BR} q$ is in* EXPTIME.

Theorem 1 tells us that the complexity of query an UCQ over an $\mathcal{EL}^{++}$ knowledge base under the inconsistency-tolerant semantics is in EXPTIME. The complexity of ECQ will not change.

Theorem 2 *Let $KB(T, A)$ be an $\mathcal{EL}^{++}$ knowledge base, let α be an action, and let Q be an ECQ. Then the complexity of deciding whether $T, A \models_{BR} Q$ is in* EXPTIME*.*

3 Explanatory Diagnosis of an Ontology Stream

3.1 Ontology Tree

Because the evolution from $\mathcal{O}_m^n(i)$ to $\mathcal{O}_m^n(i+1)$ of an ontology stream $\mathcal{O}_m^n$ may be caused by the occurrence of one or several actions, we use *ontology tree* to capture the dynamics of semantics of an ontology stream. An ontology tree is a tree where each vertex is an ontology, each solid directed edge means an action, and each dotted directed edge indicates the effect of the action, the endpoint of which is the result of the updating the start point by an action.

3.2 Explanatory Diagnosis Problem

In our framework, fault concept is a special kinds of concept from a TBox, which is used for describing some phenomenons that we monitor from a stream perspective e.g., a congested road.

Definition 8 (Anomaly) *Given a $KB(T, A)$, suppose $\mathcal{C}$ is a set of predefined fault concepts. An assertion $C(a)$ is called as an anomaly, if $C \in \mathcal{C}$. Every concept in $\mathcal{C}$ is called a faulty concept.*

Definition 9 (Explanatory Diagnosis Problem) An explanatory diagnosis problem $\mathcal{P}$ is a tuple $\langle \mathcal{O}_m^n(m), \mathcal{O}_m^n(n), A_s, \mathcal{E}_{m+1}^{n-1}, C(a) \rangle$ which satisfies $\mathcal{O}_m^n(m) \not\models C(a)$ and $\mathcal{O}_m^n(n) \models C(a)$, where

- A_s is the set of actions, including certain effect actions and uncertain effect actions;
- $\mathcal{E}_{m+1}^{n-1}$ is the set of events which occur from time m to n;
- $C(a)$ is an anomaly, which also called as an observation.

Definition 10 (Diagnosis) *A diagnosis of a given explanatory diagnosis problem $\mathcal{P} = \langle \mathcal{O}_m^n(m), \mathcal{O}_m^n(n), A_s, \mathcal{E}_{m+1}^{n-1}, C(a) \rangle$ is a sequence of actions δ, such that $B_{rep}(\mathcal{O}_m^n(m) \circledast \delta) \models C(a)$.*

It should be noted that, for any nonempty action sequence δ and an action α, we have $B_{rep}(A_0 \circledast \alpha\delta) = B_{rep}((B_{rep}(A_0 \circledast \alpha)) \circledast \delta)$.

Theorem 3 *Explanatory diagnosis existence for $\mathcal{EL}^{++}$ with a finite individual domain is decidable in* EXPTIME *in the size of the individual domain.*

We assume familiarity with standard notions of Markov Decision Process (MDP) and value iteration [6]. A solution to a MDP is an optimal policy that maximizes value function of every state $s \in S$.

Considering that the set of action sequences is exponentially growing on a time basis, we can use MDP to compute the most likely action sequence, *i.e.*, diagnosis. Given an explanatory diagnosis problem $\mathcal{P}$, we can first generate the ontology tree, then solving problem $\mathcal{P}$ can be convert into a largest value path finding problem. It's easy to prove that there is a diagnosis δ which has the largest value function in all diagnoses as the following proposition.

Proposition 1 *Each diagnosis of an explanatory diagnosis problem $\mathcal{P}$ is an ontology stream.*

4 Conclusion and Future Work

We have developed a framework of explanatory diagnosis of an ontology stream via reasoning about actions. The semantics is captured by DL evolving over time in an ontology stream. We introduced a new update operator, modeling actions with certain and uncertain effects, and presented query mechanisms supporting inconsistency-tolerant semantics. Future work will extend our framework towards scalable explanatory diagnoses, specialty for large cities.

5 Acknowledgement

The authors is supported by NSF Grant Nos.(61463044, 61363030, and 61573386) and Grant No.LH[2014]7421 from the Joint Fund of the NSF of Guizhou province of China.

References

[1] Babak Bagheri Hariri, Diego Calvanese, Marco Montali, Giuseppe De Giacomo, Riccardo De Masellis, and Paolo Felli, 'Description logic knowledge and action bases', *JAIR*, **46**, 651–686, (2013).

[2] Zhisheng Huang and Heiner Stuckenschmidt, 'Reasoning with multi-version ontologies: A temporal logic approach', in *Proc. of ISWC*, pp. 398–412, (2005).

[3] Freddy Lécué, 'Towards scalable exploration of diagnoses in an ontology stream', in *Proc. of AAAI*, pp. 87–93, (2014).

[4] Domenico Lembo, Maurizio Lenzerini, Riccardo Rosati, Marco Ruzzi, and Domenico Fabio Savo, 'Inconsistency-tolerant semantics for description logics', in *Proc. of RR*, pp. 103–117, (2010).

[5] Sheila A. McIlraith, 'Explanatory diagnosis: Conjecturing actions to explain observations', in *Proc. of KR*, pp. 167–179, (1998).

[6] M. L Puterman, *Markov decision processes: Discrete stochastic dynamic programming*, Wiley, 1994.

[7] Quan Yu, Ximing Wen, and Yongmei Liu, 'Multi-agent epistemic explanatory diagnosis via reasoning about actions', in *Proc. of IJCAI*, pp. 1183–1190, (2013).