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Explanatory dialogues with argumentative faculties over inconsistent knowledge bases

Abdallah Arioua [a,*], Patrice Buche [a], Madalina Croitoru [b]

[a] UMR IATE. French National Institute for Agricultural Research, Place Pierre Viala, 34060 Montpellier, France
[b] University of Montpellier. LIRMM, 161 rue ADA, F34392 Montpellier Cedex 5, Montpellier, France

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ABSTRACT

We introduce a formal model of explanatory dialogue called EDS. We extend this model by including argumentation capacities to facilitate knowledge acquisition in inconsistent knowledge bases. To prove the relevance of such model we provide the DALEK (DiALectical Explanation in Knowledge-bases) framework that implements this model. We show the usefulness of the framework on a real-world application in the domain of Durum Wheat sustainability improvement within the ANR (French National Agency) funded Dur-Dur project. The preliminary pilot evaluation of the framework with agronomy experts gives a promising indication on the impact of explanation dialogues on the improvement of the knowledge's content.

1. Introduction

In the popular Ontology-based Data Access setting the domain knowledge is represented by an ontology facilitating query answering over existing data (Poggi et al., 2008). In practical OBDA systems involving large amounts of data and multiple data sources, data inconsistency might occur (Lembo, Lenzerini, Rosati, Ruzzi, & Savo, 2015). In the literature, such inconsistency is addressed by reparation techniques: the extraction of maximal consistent subsets and reasoning over them (Bienvenu, 2012; Bienvenu & Rosati, 2013; Bourgaux, 2016; Du & Qi, 2015; Lembo, Lenzerini, Rosati, Ruzzi, & Savo, 2010, 2015) (i.e. considering their intersection, the intersection of the closure, etc.). While such strategies ensure quality query answering (at a high computational cost Lukasiewicz, Martinez, Pieris, & Simari, 2015) they only keep the consistent and contradiction-free subsets of knowledge. This approach is too drastic as it **removes** a lot of expert knowledge. It would be more fertile to acquire more knowledge from experts in a *rule-governed and structured* way to potentially solve some sources of inconsistency. This paper paves the way for such solution.

The motivation of our work stems also from a practical aspect. In the Dur-Dur research project[1] we aim at restructuring the Durum Wheat agrifood chain in France by reducing pesticide and fertilizer usage while providing a protein-rich Durum Wheat. The project relies on constructing a *Datalog±* (Calì, Gottlob, & Lukasiewicz, 2012) multidisciplinary knowledge base (involving all actors in the agrofood chain) which will be used as a reference for decision making. This knowledge base is collectively built by several knowledge engineers from different sites of the project. Due to various causes (errors in the factual information due to typos, erroneous databases / Excel files, incomplete facts, unspoken obvious information "everybody knows" etc.) the collectively built knowledge base (KB) is prone to *inconsistencies*. Applying classical repairing strategies will result in a loss of considerable amount of acquired knowledge. Consequently, this would result in an inefficient exploitation of time and resources which were allocated to the knowledge engineer in the project. Therefore, more conservative repairing strategies are needed.

The main salient point of the paper is proposing a formal model of explanatory dialogue used for the acquisition of new knowledge to remove inconsistencies. We build on Preece (1993) and focus on improving a *prototypical* knowledge base. We propose the EDS formal model of explanatory dialogue that takes place between the domain expert and the system that explains *query entailment* in inconsistent knowledge bases in order to better expose its content to the expert. We demonstrate how the model's instantiation is concretely used in agronomy for improving an inconsistent knowledge base. Our hypothesis is that using a formal model of explanation

* Corresponding author.
E-mail addresses: abdallaharioua@gmail.com, arioua@lirmm.fr (A. Arioua), buche@inra.fr (P. Buche), croitoru@lirmm.fr (M. Croitoru).

[1] http://www.agence-nationale-recherche.fr/?Projet=ANR-13-ALID-0002.

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increases the acquired expert knowledge and removes inconsistencies.

The contribution of the paper is summarized hereafter:

- We propose a formal model of explanatory dialogues that integrates questions and argumentation (as opposed to Arioua and Croitoru (2015); Walton (2016)).
- We show how the model is used in the acquisition of new knowledge in inconsistent knowledge bases to remove inconsistencies.
- We provide a general schema to implement such model.

We implemented a dialogue framework called DALEK (**D**i**AL**ectical **E**xplanation in **K**nowledge-bases) and carried out a pilot evaluation with agronomy experts. The goal of this evaluation is to measure the quantity of acquired knowledge and reduced inconsistencies in the presence/absence of explanation dialogues. Our hypothesis is that using explanatory dialogues increases the acquired expert knowledge and removes inconsistencies.

To show the significance and the motivation of our work consider the following example which is an excerpt of a real dialogue within the project Dur-Dur[2].

Example 1 (Motivating Example)**.** Consider the query =" Do we perform stubble breaking?" which was asked by the `User` and to which the `Reasoner` has answered *yes*. The following is an explanatory dialogue explaining why we perform stubble breaking.

1. `User`: Why do we perform stubble breaking?
2. `Reasoner`: Stubble breaking is necessary to prepare the soil.
3. `User`: Why do we prepare the soil?
4. `Reasoner`: Because there was a cultural precedent on the soil.
5. `User`: Which cultural precedent?
6. `User`: Sunflower.
7. `User`: I still don't understand why do we need to prepare the soil.
8. `Reasoner`: The soil needs to be soften.
9. `User`: Okey , I understand.
10. `User`: But I still don't understand why do we perform stubble breaking.
11. `Reasoner`: Can you tell me what are the hazards against Durum Wheat?
12. `User`: Fungi, viruses, weed.
13. `Reasoner`: Exactly, stubble breaking is used against weed. By softening the soil, the seeds of the weed will germinate and grow. Consequently, they will be easy to eliminate in the next seeding plan.
14. `User`: Ok, I understand now why we perform stubble breaking.

The dialogue starts at stage (1) by an explanation request or a why-question about a factual statement addressed to the `Reasoner` by the `User`. At stage (2) the `Reasoner` attempts to explain why do we perform stubble breaking. This attempt has evoked another explanation request at stage (3) to which the `Reasoner` attempted to explain at stage (4). This attempt, in its turn, has evoked a follow-up question (which-question) which is asked by the `User` at stage (5). The `User` asks such question to better understand the explanation made at stage (4). Unfortunately, after having received an answer to his/her question at stage (6), the `User` at stage (7) is still unable to understand why one needs to prepare the soil. The `Reasoner` keeps trying to explain at stage (8) where it provides another attempt to explain why one needs to prepare the soil. Note that at this stage the scope is not on the first why-question, but rather on another evoked explanation request which depends on the first one. Fortunately, at stage (9) the `User` comes to understand why we need to prepare the soil. However, this does not necessarily mean that the `User` has understood why do we perform stubble breaking. That is why at stage (10) he/she disacknowledges understanding. At this moment the `Reasoner` has chosen another way to explain. It makes use of question at stage (11) where it asks the `User` for Durum Wheat hazards, then it uses the answer of the `User` to give another attempt at stage (13). Now the `User` finds this explanation intelligible. Consequently he/she acknowledges understanding and the dialogue ends.

As one should notice, this dialogue aims at making the `User` understand the entailment of a query from the `Reasoner`'s knowledge base. Thus this dialogue has a pure explanatory purpose. However, since the `Reasoner`'s knowledge base may have some inconsistencies the feedback from the `User` is very important.

Imagine another course of action of the stage (14) where the `User` opposes to the explanation at stage (13) as follows:

15. `User`: This will postpone seeding the Durum Wheat, which is against of what we want to do on this soil (early seeding).
16. `Reasoner`: I concede.

The dialogue becomes argumentative where the `User` opposes to the `Reasoner` by giving an argument that attacks its explanation. It is clear from the `Reasoner`'s position that we will do a late seeding (a consequence of stubble breaking). This position is inconsistent with the `User`'s position. Therefore, it is assumed to be wrong since the `User` is an expert. This means that the `Reasoner` should not infer such conclusion. Since the `Reasoner` could not counter-attack the `User`, although it is allowed to do so, it concedes to the `User`'s position. From this point, the dialogue can continue, either by the `Reasoner` proving another explanation, or the `Reasoner` declaring inability to explain; or by the `User` in acknowledging or disacknowledging understanding.

This type of explanatory dialogue is corrective, it in fact allows us to consider the feedback of the `User` in reducing the inference of inconsistent conclusions by exposing the content of the knowledge base in a rule-governed and goal-directed manner. It has permitted to show only the information relevant and related to the question asked in the first place and allowed to pinpoint directly the inconsistent position which will make the process of correcting the inconsistency easy and feasible.

The dialogue respects certain rules and uses predefined locutions like "why", "understand", etc. In addition, it makes use of questions and their answers to generate explanations and uses argumentation to weigh different contradicting conclusions. The dialogue also has a turn taking mechanism where the `User` and the `Reasoner` switch turns at each stage. Given this context, the aim of this paper is to propose a new formal model of explanatory dialogues called EDS which is used to explain query entailment in inconsistent knowledge bases. We implemented this formal model in a system called DALEK (DiALectical Explanation in Knowledge-bases). We showed how the use of such model can help in reducing inconsistencies and improve knowledge acquisition in the context of the ANR (French National Agency) funded Dur-Dur project on Durum Wheat sustainability.

In Section 2 we present the *Datalog*± logical language used to represent and reason with the knowledge base. Next, in Section 3 we present the extension of the logical language with questions and explanations. Then, in Section 4 we introduce the formal model of explanatory dialogues based on the language of Section 3. After that, in Sections 5 & 6 we first present the DALEK framework that implements the proposed formal model, and then the pilot evaluation on knowledge acquisition and inconsistency reduction with explanatory dialogues. Finally, in Sections 8 & 9 we discuss related work and conclude the paper.

[2] This dialogue is carried out within the pilot evaluation which will be detailed in Section 6. Note that the `Reasoner` uses the Durum Wheat knowledge base that has been constructed for the project.