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Inference using compiled min-based possibilistic causal networks in the presence of interventions

Raouia Ayachi[a,b,*], Nahla Ben Amor[a], Salem Benferhat[b]

[a] *LARODEC, Institut Supérieur de Gestion Tunis, Le Bardo 2000, Tunisia*
[b] *CRIL-CNRS, Université d'Artois, 62307, France*

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Abstract

Qualitative possibilistic causal networks are important tools for handling uncertain information in the possibility theory framework. Contrary to possibilistic networks (Ayachi et al., 2011 [2]), the compilation principle has not been exploited to ensure causal reasoning in the possibility theory framework. This paper proposes mutilated-based inference approaches and augmented-based inference approaches for qualitative possibilistic causal networks using two compilation methods. The first one is a possibilistic adaptation of the probabilistic inference approach (Darwiche, 2002 [13]) and the second is a purely possibilistic approach based on the transformation of the graphical-based representation into a logic-based one (Benferhat et al., 2002 [3]). Each of the proposed methods encodes the network or the possibilistic knowledge base into a propositional base and compiles this output in order to efficiently compute the effect of both observations and interventions. This paper also reports on a set of experimental results showing cases in which augmentation outperforms mutilation under compilation and vice versa.

Keywords: Possibilistic inference; Min-based possibilistic causal networks; Compilation techniques

1. Introduction

Knowledge compilation [8] is an important topic in many on-line applications that involve hard tasks. It transforms knowledge bases into new structures, with the intent being to improve the problem-solving efficiency. Assuming that the input knowledge base does not often change, so it can be turned into a compiled one during an off-line compilation phase which is then used to answer queries on-line. Answering such queries using the compiled base should be computationally easier than answering them from the input base. One of the most prominent successful applications of knowledge compilation is in the context of Bayesian networks [9,10,13] referring to graphical models using the probability theory. This framework is only appropriate when all numerical data are available, which is not always possible. Moreover, there are some situations, like the case of *total ignorance*, which is not well handled and can make the probabilistic reasoning unsound.

* Corresponding author at: LARODEC, Institut Supérieur de Gestion Tunis, Le Bardo 2000, Tunisia. Tel.: +216 99076003.
E-mail addresses: raouia.ayachi@gmail.com (R. Ayachi), nahla.benamor@gmx.fr (N. Ben Amor), benferhat@cril.univ-artois.fr (S. Benferhat).

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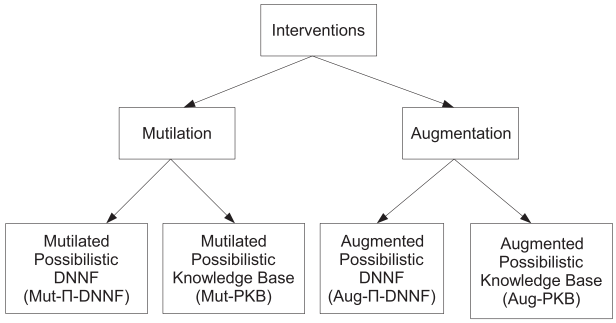

Fig. 1. Proposed methods.

Several non-classical theories of uncertainty have been proposed in order to deal with uncertain and imprecise data such as *Evidence theory* [25,27,28], *Spohn's ordinal conditional functions* [29,30] and *Possibility theory* [17,18] issued from *Fuzzy sets theory* [31]. Possibility theory offers a natural and simple model to handle uncertain information. It is considered an appropriate framework for experts to express their opinions about uncertainty either *numerically* using possibility degrees or *qualitatively* using a total pre-order on the universe of discourse.

Recently, we have proposed two compilation-based inference approaches for min-based possibilistic networks [2]. The main idea consists in compiling the *Conjunctive Normal Form* CNF encoding of the possibilistic network to have a polytime possibilistic inference in the presence of an evidence on a set of variables (i.e., observation). The first method is an adaptation of the probabilistic compilation-based inference method [13] and the second one is a purely possibilistic method based on compiling the possibilistic knowledge base associated with the possibilistic network [3]. In our recent work, we have only studied the impact of evidences under compilation using possibilistic networks. The so-called possibilistic causal networks [5], referring to possibilistic networks dealing with both *observations* which are the results of testing some variables and *interventions* corresponding to external actions forcing some variables to have some specific values, have not been explored under compilation. Interventions may have two different interpretations depending on whether we focus on the representational or on the reasoning issue. From a reasoning point of view, an intervention on a variable A is represented using the so-called *mutilation*, by ignoring relations between the intervened variable A and its direct causes. From a representational point of view, an intervention is depicted, using the so-called *augmentation*, by adding a new extra node as a parent-node to each intervened variable. Inference in causal networks, which focuses on determining the impact of either an observation or an intervention on the remaining variables, is known as a hard problem [24].

In this paper, we will generalize the approaches proposed in [2] to deal with possibilistic causal networks. Our main contributions are

- Handling interventions in min-based possibilistic causal networks using a compilation setting, which has not been explored yet in the possibility theory, neither on the probability theory (to the best of our knowledge). In fact, each method studied in [2] will be extended and will deal with interventions in twofold: *mutilation* and *augmentation* as depicted by Fig. 1. More precisely, we will propose two mutilated-based methods that require the mutilation of symbolic compiled bases. This avoids re-compiling the network each time an intervention is occurred, which is intractable. We will also suggest two augmented-based methods that do not apply this constraint due to the new extra node. After compiling the network and handling interventions either by mutilation or augmentation, an efficient computation of the effect of both observations and interventions should be ensured using compiled bases. Fig. 1 recapitulates the proposed methods in the present paper, namely two mutilated and two augmented approaches. Each of them is either based on a possibilistic adaptation *Π*-DNNF of a probabilistic method or based on a possibilistic logic counterpart of a graphical model using possibilistic knowledge bases *PKB*.
- Proposing a comparison study between mutilated-based approaches and augmented-based approaches under a compilation framework. This study points out that the choice between mutilation and augmentation relies on the number of interventions. We will show that if the number of interventions is known in an instant t, augmented-based approaches are recommended, otherwise mutilated-based approaches are preferred.