Abstraction in First-Order Probabilistic Models

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1 Proposed Research

1.1 Background

While probabilistic models are great at handling uncertainty, their simplistic representations can be hard to interpret. On the other hand, logical systems have rich representations, but cannot handle uncertainty. *First-order probabilistic models* (FOPMs) aim to unite the two into a representation capable of handling probabilities as well as first-order logic [2].

1.2 Key Idea

"To investigate all aspects of abstraction applied to FOPMs, resulting in new algorithms, faster inference, and more transferable learning from data."

The ability to form abstractions is central to human cognition and perception. Formally, abstraction is often defined as omission of (unnecessary) detail [5]. While areas such as planning and verification have benefited from this idea in various ways [6], only recently has abstraction been defined for probabilistic programming [4] and other FOPMs [1].

This is an interesting line of research because seeking simplicity is in line with philosophical principles such as Occam's razor. It is also important because of the likely improvements in inference speed. In a way, a significant line of research for faster inference focusing on *lifted inference* can be seen as a special case of abstraction.

1.3 Objectives

- To further the theoretical understanding of abstraction in FOPMs.
- To improve inference speed by investigating abstraction as a separate process as well as a component of inference.
- To make models learned from data simpler and more transferable.
- To increase the explainability of FOPMs.

2 Methodology

We will begin by writing a survey that uses a set of example problems to highlight the strengths and weaknesses of commonly-used FOPMs. This will allow us to choose a particular model on which further work will be focused.

Then, we will develop a comprehensive list of abstraction rules (transformations) and define a way to categorise all queries answerable by a FOPM such that we could answer the following set of questions for each abstraction rule:

- What types of queries can no longer be answered exactly after applying the abstraction rule?
- What is the error bound? Can it be calculated in constant time?
- What is the complexity of applying the abstraction?

Afterwards, we will develop and evaluate a set of greedy algorithms, exploring different heuristics that establish preferences over abstraction rules and termination conditions. The algorithms will take a model, a description of a set of queries that need to be supported, and an indication of how much loss in precision (if any) the user is willing to tolerate.

Lastly, we will integrate abstraction steps into both inference and learning algorithms, resulting in faster inference as well as simpler and more robust models.

2.1 Work Plan

- Comparative survey of FOPMs (WP1)
- Abstraction rules (WP2)
- Greedy algorithms (WP3)
- Abstraction during inference (WP4)
- Abstraction in learning (WP5)

3 Measurable Outcomes

- A set of problems delineating the differences amongst various FOPMs as well as guiding future research efforts (WP1).
- Demonstrated increase in exact and approximate inference speed (WP5).
- Demonstrated improvement in models learned from data in terms of simplicity and transferability without (significant) loss in precision (WP6).

4 Impact

The survey will highlight the weaknesses of current approaches and direct future research towards open problems. Furthermore, many of the basic ideas behind abstraction for a particular model are likely to be transferable to many others, perhaps even inspiring a unifying theory behind all representations. Moreover, making the models more efficient and explainable should also make them more attractive to a larger user base, both academic and industrial.

References

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