Abstraction in First-Order Probabilistic Inference

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First-Order Probabilistic Inference

Markov Logic Network

$$0.7 \quad \forall x \forall y \forall z\, \texttt{Friends(x, y)} \land \texttt{Friends(y, z)} \implies \texttt{Friends(x, z)}$$
$$2.3 \quad \forall x\, \neg \exists y\, \texttt{Friends(x, y)} \implies \texttt{Smokes(x)}$$
$$1.5 \quad \forall x\, \texttt{Smokes(x)} \implies \texttt{Cancer(x)}$$
$$1.1 \quad \forall x \forall y\, \texttt{Friends(x, y)} \implies (\texttt{Smokes(x)} \iff \texttt{Smokes(y)})$$

First-order probabilistic models are representations combining elements of first-order logic with probabilities. In a **Markov logic network** [2], each statement is accompanied by a **weight** which can be used to calculate the probability of an **event** such as `Cancer`(Cathy) or `Friends`(Ross, Joey). These models have a wide range of applications, ranging from **cancer research** to **predicting criminal behaviour**. Combining NP-complete and #P-complete problems, inference is a challenging problem.

Abstraction

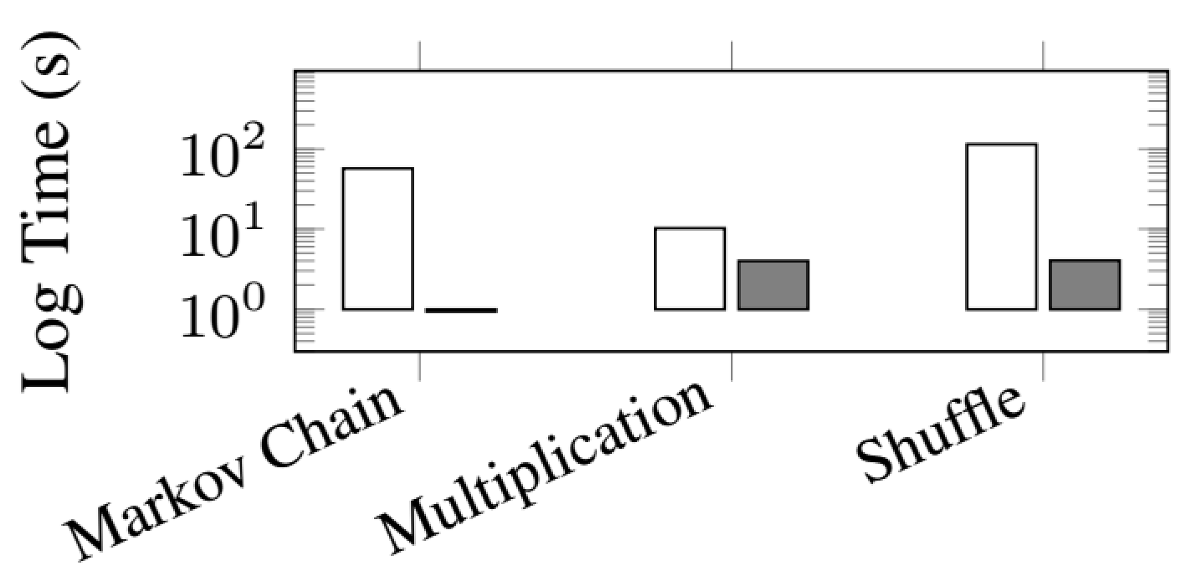
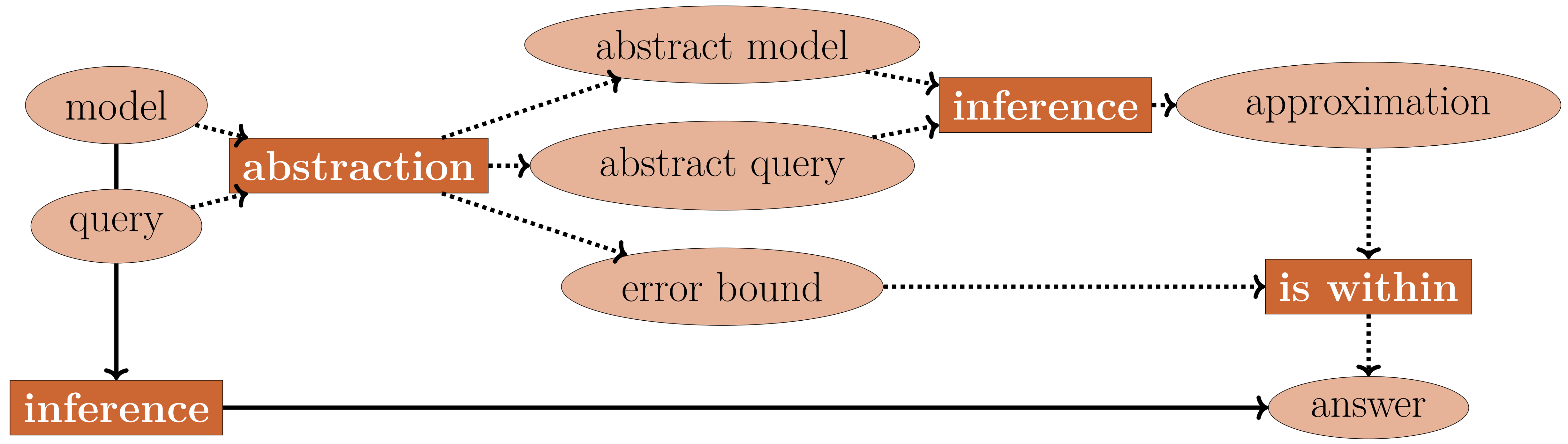


Fig. 1: Inference running time before and after abstraction for several example tasks in a probabilistic programming language Psi.

Although **abstraction** for rich probabilistic models is a new and emerging field, recent work by Holtzen et al. [1] shows **promising results** in applying **predicate abstraction** on probabilistic programs. **Our goal** is to consider a wide range of abstractions, understand their properties, and determine how to combine them in a successful manner.

Methodology



Abstraction can be used to improve inference speed by simplifying the model beforehand. We can find an abstract representation of a model specific to each query, and perform inference on the abstraction. The abstraction may be **exact** and produce the same answer as the original model, or it may produce a bounded approximation. An abstraction can be created by applying a combination of **atomic transformations** in a **greedy** manner.

Impact

This work is likely to result in significant improvements in **inference speed**, increase the **explainability** of models learned from data, and make the models more **scalable**.

References

[1] S. Holtzen, G. V. den Broeck, and T. D. Millstein. "Sound Abstraction and Decomposition of Probabilistic Programs". In: *Proceedings of the 35th International Conference on Machine Learning, ICML 2018, Stockholmsmässan, Stockholm, Sweden, July 10-15, 2018.* Ed. by J. G. Dy and A. Krause. Vol. 80. JMLR Workshop and Conference Proceedings. JMLR.org, 2018, pp. 2004–2013.

[2] M. Richardson and P. M. Domingos. "Markov logic networks". In: *Machine Learning* 62.1-2 (2006), pp. 107–136. DOI: `10.1007/s10994-006-5833-1`.