

Design and Implementation of Anglican Probabilistic Programming Language

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<https://bitbucket.org/probprog/anglican-white-paper>
<https://bitbucket.org/probprog/anglican>
<http://www.robots.ox.ac.uk/~fwood/anglican/index.html>

Outline

Motivation

Design Outline

Language

Macro-based compilation

Implementation Highlights

Managing stack size

Probabilistic forms

Memoization

Inference Algorithms

Definitions and Runtime Library

Intuition

Probabilistic program:

- ▶ A program with random computations.
- ▶ Distributions are conditioned by ‘observations’.
- ▶ Values of certain expressions are ‘predicted’ — **the output**.

Can be written in any language (extended by `sample` and `observe`).

Example: Model Selection

```
1  (let [;; Guessing a distribution
2      dist (sample (categorical
3                    [[normal 1] [gamma 1]
4                     [uniform-continuous 1]
5                     [uniform-discrete 1]]))
6      a (sample (gamma 1 1))
7      b (sample (gamma 1 1))
8      d (dist a b)]
9
10  ;; Observing samples from the distribution
11  (loop [data data]
12      (when (seq data)
13          (let [[x & data] data]
14              (observe d x))
15              (recur data)))
16
17  ;; Predicting a, b and the distribution
18  (predict :a a)
19  (predict :b b)
20  (predict :d d))
```

More examples

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- ▶ (*Due to Stuart Russell*) If you observe that a student GPA is exactly 4.0 in a model of transcripts of students from the USA (GPA's from 0.0 to 4.0) and India (GPA's from 0.0 to 10.0) what is the probability that the student is from India?

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$$\Phi = \int_{-\infty}^{\infty} \varphi(x)p(x)dx$$

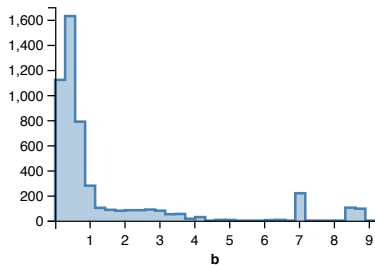
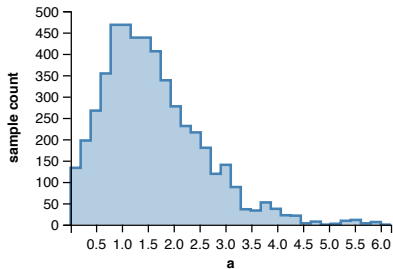
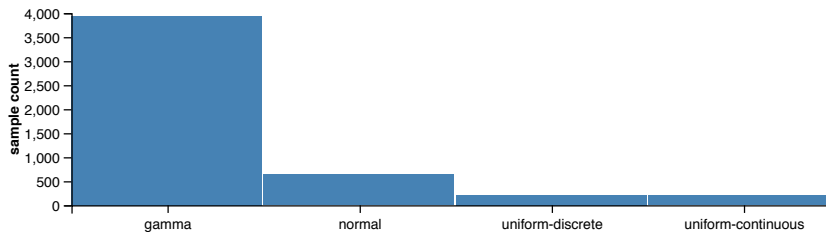
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- ▶ Continuously and **infinitely generate a sequence of samples** drawn from the distribution of the output expression — so that someone else puts it in good use (vague but common). ✓

Example: Inference Results



Importance Sampling

loop

Run program, computing weight based on observations.
Output result and weight.

end loop

- ▶ Simple — good.
- ▶ Slow convergence (unless one knows the answer) — bad.

Can we do better?

Lightweight Metropolis-Hastings (LMH)

Run program once, remembering random choices.

loop

Uniformly select one random choice.

Propose a new value for the choice.

Re-run the program.

Accept or reject with MH probability.

Output result.

end loop

Can we do better?

- ▶ Particle methods
- ▶ Variational inference
- ▶ ...

Why functional?

We want a functional language because an inference algorithm controls the execution:

- ▶ A program is run many (often many hundreds of thousands) of times (with almost any algorithm).
- ▶ A program must be partially re-executed multiple times from different positions (particle methods).
- ▶ We want to reason about the distribution defined by the program.

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- ▶ Scala — Figaro.
- ▶ Haskell — Hakaru, Model-Bayes.
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As well as Python, C#, and other languages.

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Thank you!
Questions?