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

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    ;; Observing samples from the distribution
10   (loop [data data]
11     (when (seq data)
12       (let [[x & data] data]
13         (observe d x))
14       (recur data)))
15   ;; Predicting a, b and the distribution
16   (predict :a a)
17   (predict :b b)
18   (predict :d d))
```

More examples

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- *Counterfactual reasoning* — There are **two routes** from Jerusalem to Tel Aviv: 1 and 443. Based on traffic reports, I chose route 1 and was late. Would I arrive on time If I chose 443 instead?
- *(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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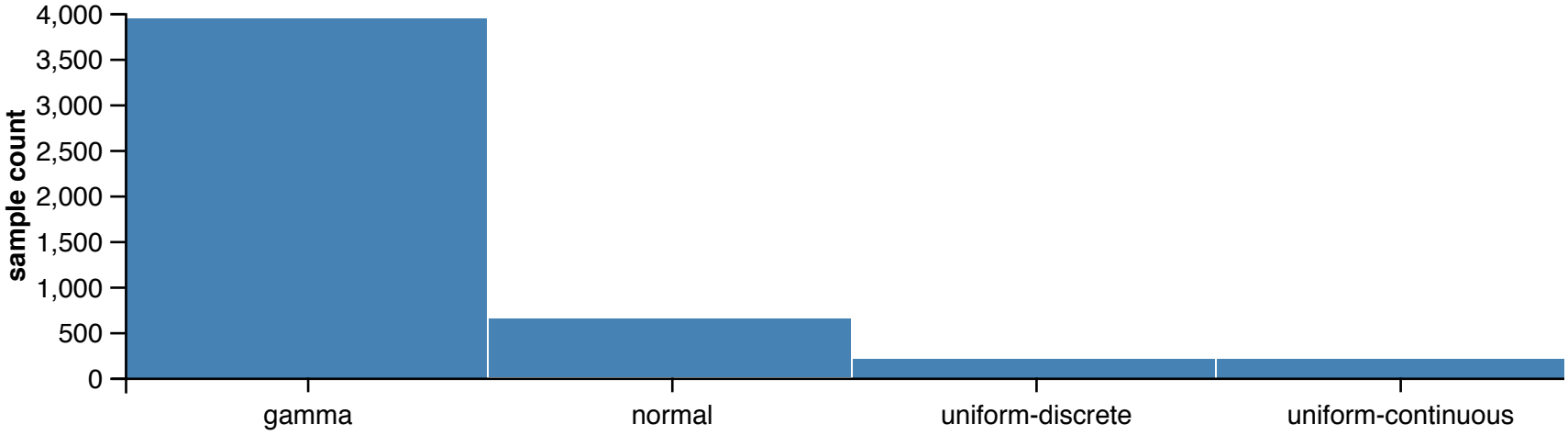
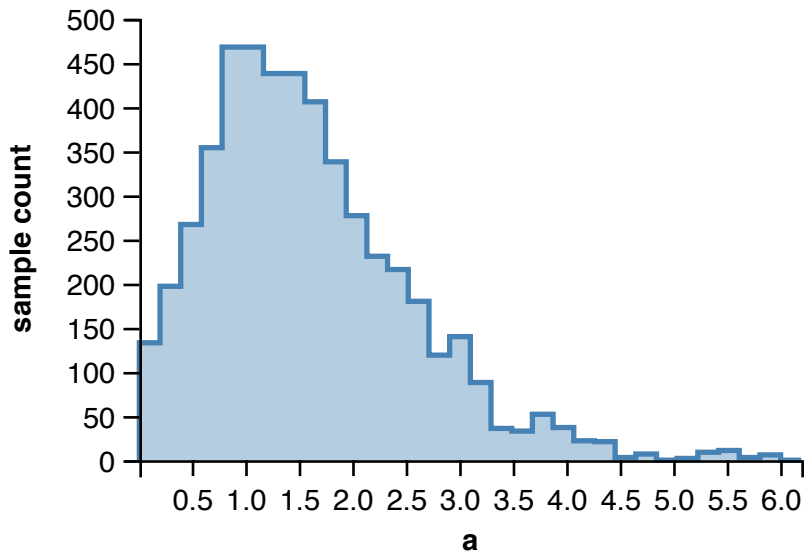
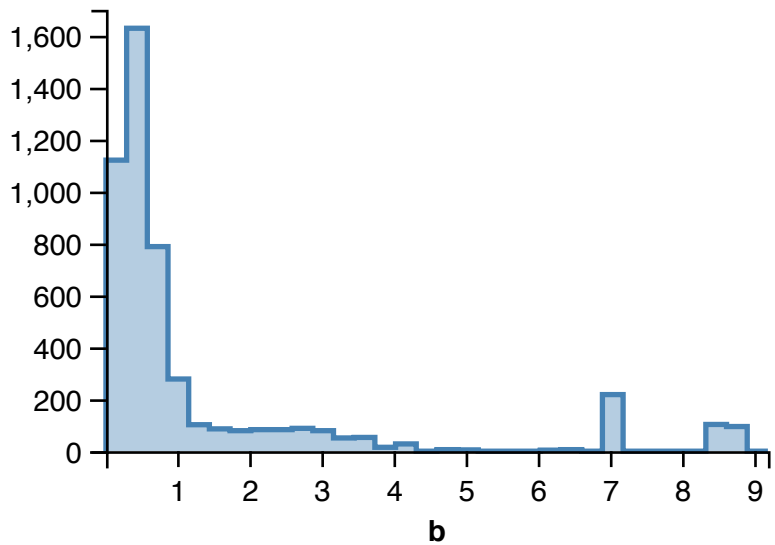
- Continuously and **infinitely generate a sequence of samples** drawn from the distribution of the output expression — so that someone else puts it in good use (vague but common). ✓

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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- Scheme — (Church, Venture).
- Scala — Figaro.
- Haskell — Hakaru, Model-Bayes.
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As well as Python, C#, and other languages.

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Anglican and Clojure

On language on top of (or besides) another:

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- Integrated language. ✓

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Anglican is

- Integrated with Clojure.
- Shares syntax.
- Alters operational semantics.

Anglican

A subset of Clojure, wrapped inside `defquery`:

- `if`, `when`, `cond`, `case`, `let`, `and`, `or`, `fn`.
- Vector destructuring in bindings of `let` and `fn`.
- Compound literals for vectors, hash maps, and sets.
- `loop`/`recur` — a convenience.

Core library:

- All of Clojure core library, except for higher-order functions.
- `map`, `reduce`, `filter`, `some`, `repeatedly`, `comp`, `partial`.

Any Clojure function can be called from Anglican.

Macro-based compilation

Anglican code macro-compiled into Clojure:

```
1   (loop [data data]
2     (if (seq data)
3       (let [[x & data] data]
4         (observe (gamma a b) x)
5         (recur data))
6       (predict :a a)))
```

```
1   (fn loop [C23151 state data]
2     (if (seq data)
3       (let [[x & data] data]
4         (->observe 'O23153 (gamma a b) x
5           (fn do23152 [_ state]
6             (loop C23151 state data))
7           state))
8       (fn []
9         (C23151
10          nil
11          (add-predict state :a a)))))
```

Outline

Managing stack size

Probabilistic forms

Memoization

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Thank you!
Questions?