

Implementing Inference Methods in Anglican

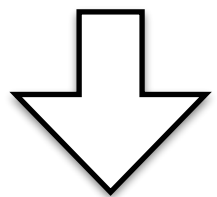
Jan-Willem van de Meent

Interface for Inference

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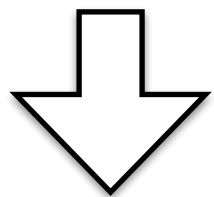


Likelihood Weighting
(implemented by hand)

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(defn importance-one-flip
  [outcome]
  (let [theta (sample* (beta 1 1))
        lp (observe* (flip theta) outcome)]
    {:log-weight lp
     :result theta
     :predicts []}))
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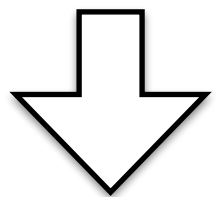


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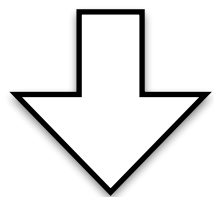


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- *Language Runtime*
All deterministic operations
- *Inference Back End*
Implements **sample** and **observe**

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Anglican Backend Implementation

- Repeat until finished:
 - Call **exec** to run program until next **sample** or **observe**
 - Perform algorithm-specific actions and continue

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```
(use '[anglican emit runtime inference state])
(exec :importance one-flip [true] initial-state)
```

Interface for Inference

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Algorithm

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Query

Interface for Inference

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Argument values

Interface for Inference

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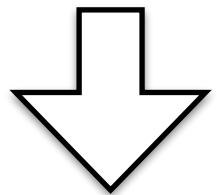
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Execution state

Interface for Inference

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Program Execution

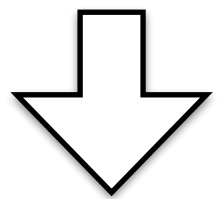
```
#anglican.trap.sample{:id S23882,  
  :dist (anglican.runtime/beta 1 1),  
  :cont #function[...],  
  :state {:log-weight 0.0,  
    :predicts [],  
    :result nil,  
    :anglican.state/mem {},  
    :anglican.state/store nil}}
```

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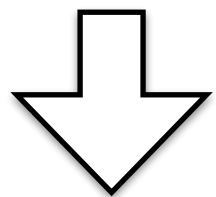


Continuation Passing Style

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(fn [outcome $state]
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    (beta 1 1)
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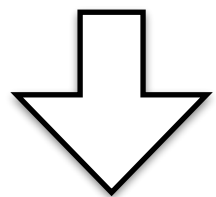


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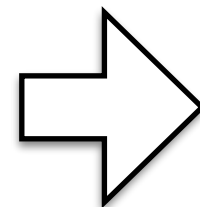
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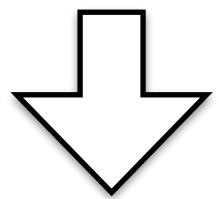


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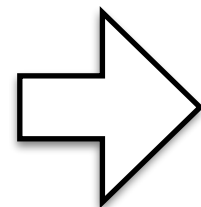
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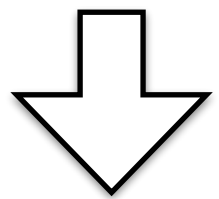


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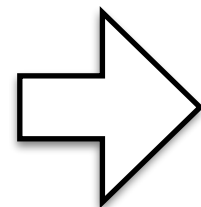
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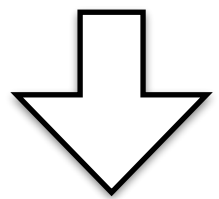


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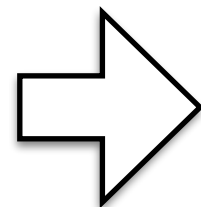
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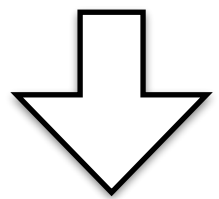


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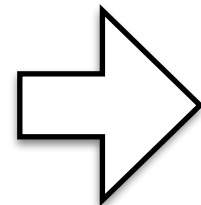
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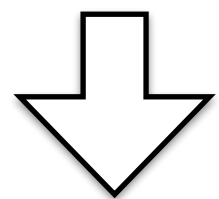


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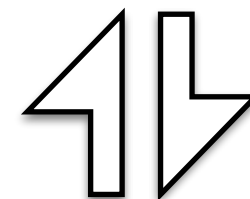
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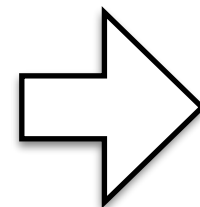
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```
(let [x (sample* dist)]
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Inference Backend

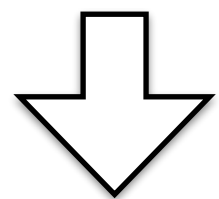


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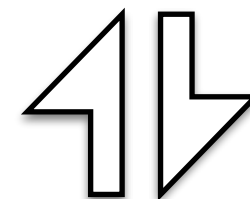
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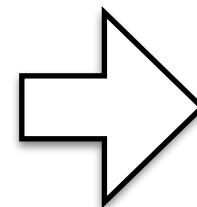
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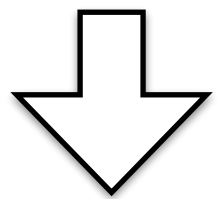


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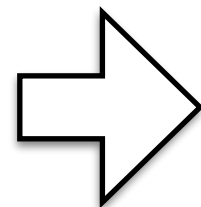

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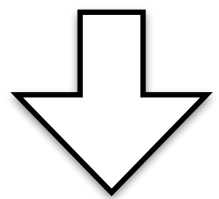


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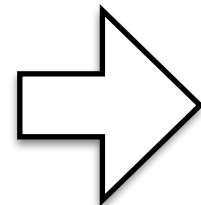
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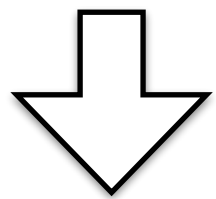


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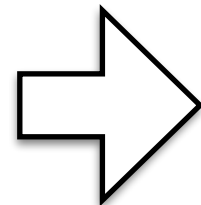
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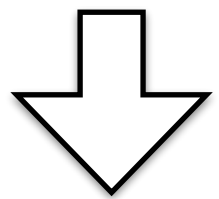


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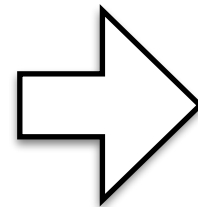
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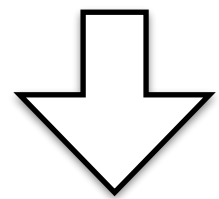


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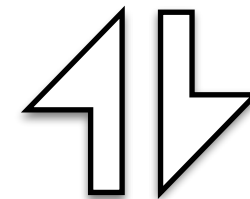
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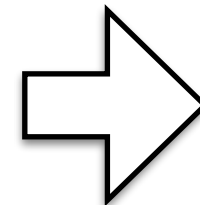
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  (cont nil (add-log-weight
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Inference Backend

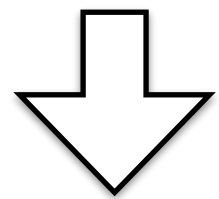


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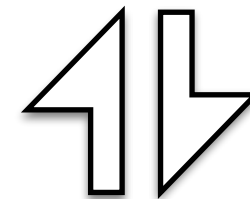
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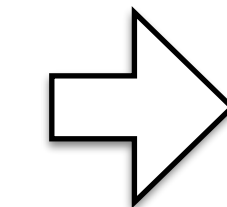
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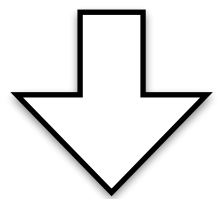


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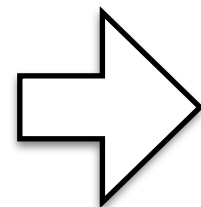
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          (->result theta $state))
          $state))
    $state)))
```



Returns

```
{:result theta
 :log-weight
   (:log-weight $state)
 :predicts
   (:predicts $state)}
```

Likelihood Weighting

Implementation for **sample**

```
(let [x (sample* dist)]  
  (cont x $state))
```

Implementation for **observe**

```
(let [lp (observe* dist value)]  
  (cont nil (add-log-weight  
              $state lp)))
```


Likelihood Weighting

```
(derive ::algorithm :anglican.inference/algorithm)
```

```
(defmulti checkpoint  
  (fn [alg cpt] [alg (type cpt)]))
```

```
(defmethod checkpoint  
  [::algorithm anglican.trap.sample] [alg smp]  
  (let [cont (:cont smp)  
        x (sample* (:dist smp))  
        state (:state smp)]  
    (fn [] (cont x state))))
```

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(defmethod checkpoint  
  [::algorithm anglican.trap.observe] [alg obs]  
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Likelihood Weighting

```
(derive ::algorithm :anglican.inference/algorithm)
```

```
(defmulti checkpoint  
  (fn [alg cpt] [alg (type cpt)]))
```

(->sample ...)

```
(defmethod checkpoint  
  [::algorithm anglican.trap.sample] [alg smp]  
  (let [cont (:cont smp)  
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Likelihood Weighting

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(derive ::algorithm :anglican.inference/algorithm)
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  (let [cont (:cont smp)  
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        state (:state smp)]  
    (fn [] (cont x state))))
```

(->observe ...)

```
(defmethod checkpoint  
  [::algorithm anglican.trap.observe] [alg obs]  
  (let [cont (:cont obs)  
        lp (observe* (:dist obs) (:value obs))  
        state (:state obs)]  
    (fn [] (cont nil (add-log-weight state lp))))
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Likelihood Weighting

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Likelihood Weighting

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  (let [cont (:cont obs)  
        lp (observe* (:dist obs) (:value obs))  
        state (:state obs)]  
    (fn [] (cont nil (add-log-weight state lp)))))
```


Likelihood Weighting

```
(defmulti infer
  (fn [alg prog value & _] alg))

(defmethod infer :importance
  [alg prog value & opts]
  (letfn [(sample-seq []
            (let [result (exec ::algorithm
                                prog
                                value
                                initial-state)]
              (cons (:state result)
                    (sample-seq))))])
  (sample-seq)))
```


Likelihood Weighting

```
(defmulti infer
  (fn [alg prog value & _] alg))

(defmethod infer :importance
  [alg prog value & {}]
  (letfn [(sample-seq []
            (let [result (exec ::algorithm
                               prog
                               value
                               initial-state)]
              (lazy-seq
               (cons (:state result)
                     (sample-seq)))))]
    (sample-seq)))
```

`(->result`
`(set-result $state ...))`

Algorithm Implementations

15+ algorithms, ~180 lines of code per algorithm on average

Algorithm	Type	Lines	Citation	Description
smc	IS	127	Wood et al. AISTATS, 2014	Sequential Monte Carlo
importance	IS	21		Likelihood weighting
pcascade	IS	176	Paige et al., NIPS, 2014	Particle cascade
bbvb	IS	480	van de Meent et al., AISTATS, 2016	Black Box Variational Inference
ipmcmc	PMCMC	198	Rainforth et al., ICML, 2016	Interacting Particle Markov Chain Monte Carlo
pgibbs	PMCMC	121	Wood et al. AISTATS, 2014	Particle Gibbs (iterated conditional SMC)
pimh	PMCMC	68	Wood et al. AISTATS, 2014	Particle independent Metropolis-Hastings
pgas	PMCMC	179	van de Meent et al., AISTATS, 2015	Particle Gibbs with ancestor sampling
lmh	MCMC	177	Wingate et al., AISTATS, 2011	Lightweight Metropolis-Hastings
almh	MCMC	320	Tolpin et al., ECML PKDD, 2015	Adaptive scheduling lightweight Metropolis-Hastings
rmh	MCMC	377	-	Random-walk Metropolis-Hastings
palmh	MCMC	66	-	Parallelised adaptive scheduling lightweight MH
plmh	MCMC	62	-	Parallelised lightweight Metropolis-Hastings
bamc	MAP	318	Tolpin et al., SoCS, 2015	Bayesian Ascent Monte Carlo
siman	MAP	193	Tolpin et al., SoCS, 2015	MAP estimation via simulated annealing