Implementing Inference Methods in Anglican

Jan-Willem van de Meent

Interface for Inference

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(defquery one-flip [outcome]
 (let [theta (sample (beta 1 1))]
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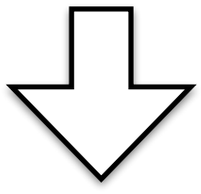

Likelihood Weighting
(*implemented by hand*)

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(defn importance-one-flip
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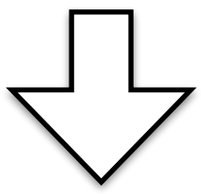

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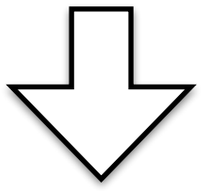

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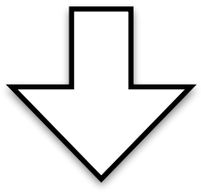

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- *Language Runtime*
  All deterministic operations
- *Inference Back End*
  Implements sample and observe

Interface for Inference

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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)
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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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Execution state

Interface for Inference

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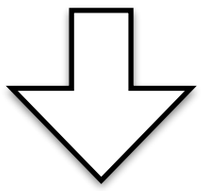

Program Execution

```
#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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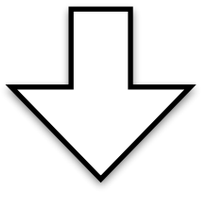

Continuation Passing Style

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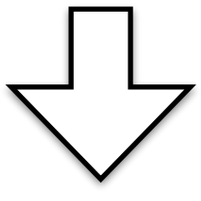

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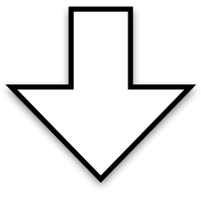

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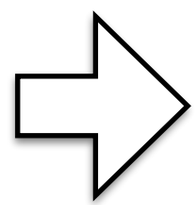

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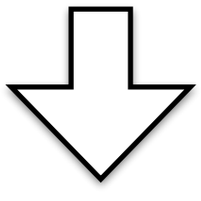

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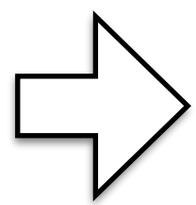

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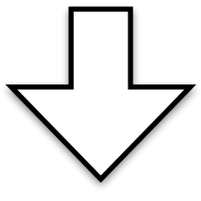

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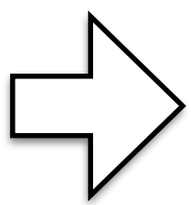

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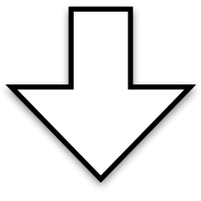

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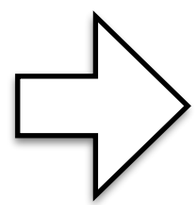

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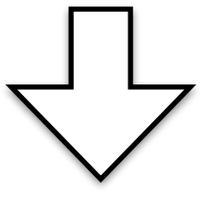

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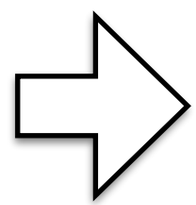

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(let [x (sample* dist)]
  (cont x $state))
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Inference Backend

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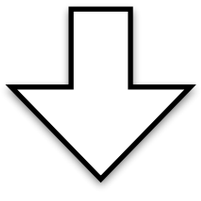

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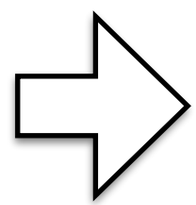

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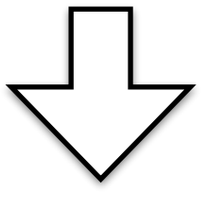

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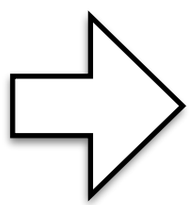

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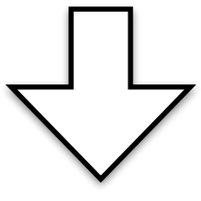

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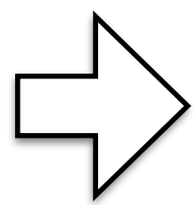

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Returns

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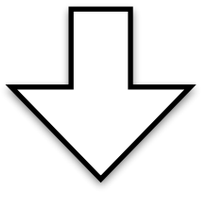

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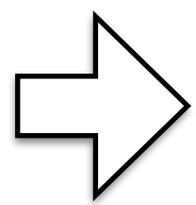
   (->observe 'O24724
    (flip theta)
    outcome
    (fn [_ $state]
      (->result theta $state))
    $state))
  $state))
```



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)))
```

Implementation of infer

infer: *calls* exec *to construct sample sequence*

```
(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)
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    (sample-seq)))
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```

doquery: *wrapper around* infer

Implementation of exec

exec: *calls* checkpoint *to handle interrupts*

```
(defn exec
  "executes the program, calling checkpoint handlers
  at the checkpoints and stopping when the handler
  returns a non-callable value"
  [algorithm prog value state]
  (loop [step (trampoline prog value state)]
    (let [next (checkpoint algorithm step)]
      (if (fn? next)
        (recur (trampoline next))
        next))))
```

Implementation of checkpoint

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

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

(defmethod checkpoint
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  (let [cont (:cont obs)
        lp (observe* (:dist obs) (:value obs))
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    (fn [] (cont nil (add-log-weight state lp)))))
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(->sample …)

Implementation of checkpoint

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(->observe …)

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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