# Building blocks for exact and approximate inference

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## Motivation

We address the need for *modular inference methods* that can be reused over models and composed to build more methods. We present a collection of black-box methods implemented as probabilistic-program transformations. Modular building-blocks such as algebraic simplification can be reused to mechanically derive an *efficient program* from the original one. This collection creates a search space of inference strategies that combines exact and approximate techniques.

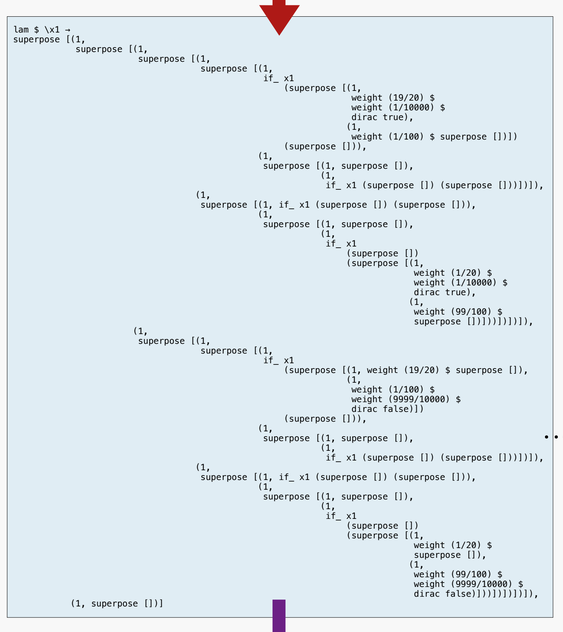
## Workflow examples using Hakaru

**Model**

Burglary-alarm model (Pearl 1988)

```
burg :: (Mochastic repr) ⇒ repr (HMeasure (HPair HBool HBool))
burg = bern 0.0001 `bind` \burglary →
       bern (if_ burglary 0.95 0.01) `bind` \alarm →
       dirac (pair alarm burglary)
```

disintegrate



simplify

```
lam $ \x1 →
if_ x1
    (superpose [(19/200000, dirac true), (9999/1000000, dirac false)])
    (superpose [(1/200000, dirac true), (989901/1000000, dirac false)])
```

Linear sequential model for device calibration

```
thermometer :: (Mochastic repr)
            ⇒ repr (HMeasure (HPair (HPair HReal HReal)
                                    (HPair HProb HProb)))
thermometer =
    liftM unsafeProb (uniform 3 8) `bind` \noiseT →
    liftM unsafeProb (uniform 1 4) `bind` \noiseM →
    normal 21 noiseT `bind` \t1 →
    normal t1 noiseM `bind` \m1 →
    normal t1 noiseT `bind` \t2 →
    normal t2 noiseM `bind` \m2 →
    dirac (pair (pair m1 m2) (pair noiseT noiseM))
```

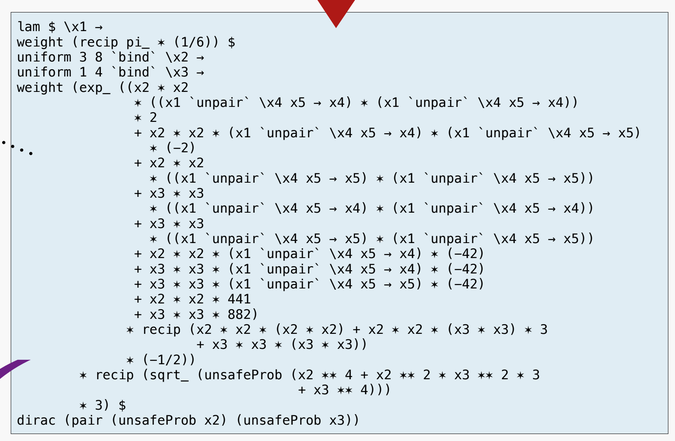
disintegrate

```
lam $ \x1 →
x1 `unpair` \x2 x3 →
uniform 3 8 `bind` \x4 →
normal 21 (unsafeProb x4) `bind` \x5 →
uniform 1 4 `bind` \x6 →
normal x5 (unsafeProb x4) `bind` \x7 →
weight (exp_ (−(x3 − x7) ∗ (x3 − x7)
                / fromProb (2 ∗ pow_ (unsafeProb x6) 2))
        / unsafeProb x6
        / sqrt_ (2 ∗ pi_)) $
weight (exp_ (−(x2 − x5) ∗ (x2 − x5)
                / fromProb (2 ∗ pow_ (unsafeProb x6) 2))
        / unsafeProb x6
        / sqrt_ (2 ∗ pi_)) $
dirac (pair (unsafeProb x4) (unsafeProb x6))
```

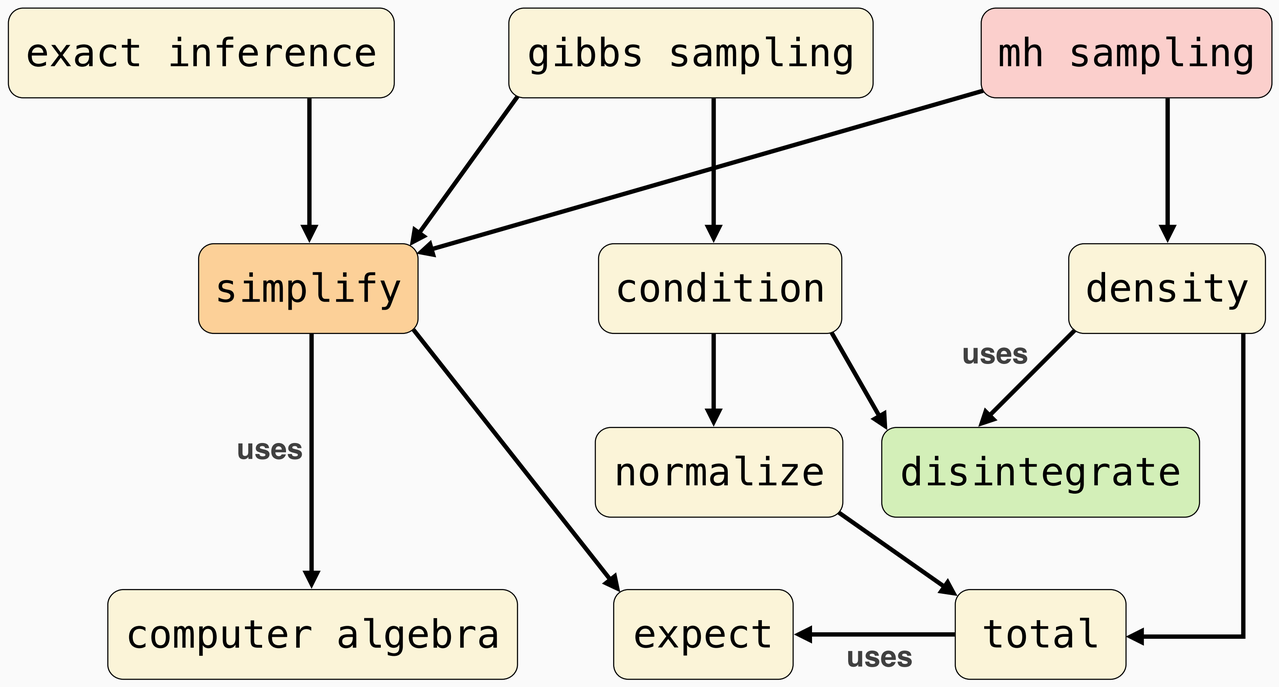
**Posterior**

**Simplified posterior**

simplify

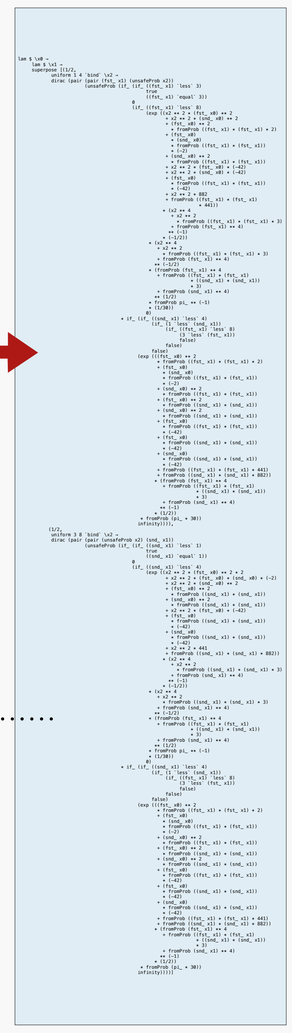


**Dependencies among building blocks**




mh sampling

simplify



**MH transition kernel**

**Simplified transition kernel**

| Source of code | Average run time (ms) |
|---|---|
| Generated by disintegrator | 2015 ± 4 |
| Generated, then automatically simplified | 569 ± 4 |
| Written by hand | 529 ± 10 |
| Expressed in WebPPL | 948 ± 8 |

## Related work

We share the modularity concerns of Venture (Mansinghka et al. 2014) and WebPPL (Goodman and Stuhlmüller 2014). Ścibior et al. (2015) use a monadic probabilistic language to describe and compose sophisticated models and inference methods. We describe in detail the techniques of disintegration (Shan and Ramsey 2015) and simplification (Carette and Shan 2015).

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