Expressing and Verifying Probabilistic Assertions

A new way to check properties of programs that behave statistically.

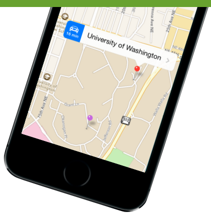
Artifact * AEC * Consistent * Complete * Well Documented * Easy to Reuse * Evaluated * PLDI *

≈ Approximate Computing

Compute: Allow random errors in operations to improve hardware efficiency.
Check: Output is likely to be high-quality even in the face of error.

Data Obfuscation for Privacy

Compute: Add random noise to private data to avoid divulging exact information.
Check: Obfuscated data is still useful in aggregate.



Mobile and Sensing

Compute: Draw conclusions from noisy sensor data.
Check: Conclusions are still useful to the user.

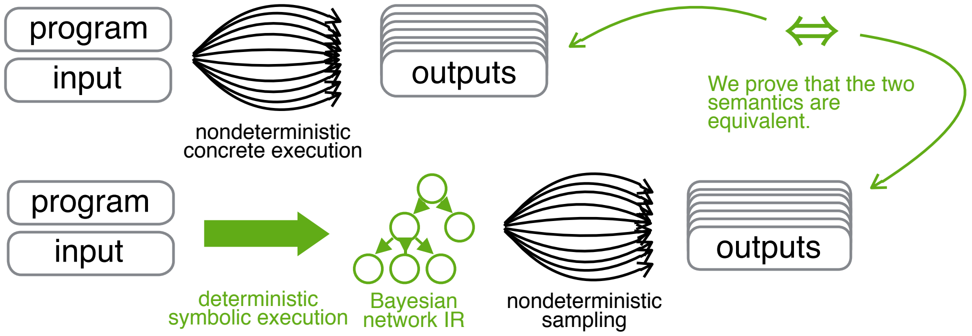
Probabilistic programs need **probabilistic assertions.**

`passert e, p, c`: Expression *e* is true with at least probability *p* at confidence level *c*.

distribution extraction

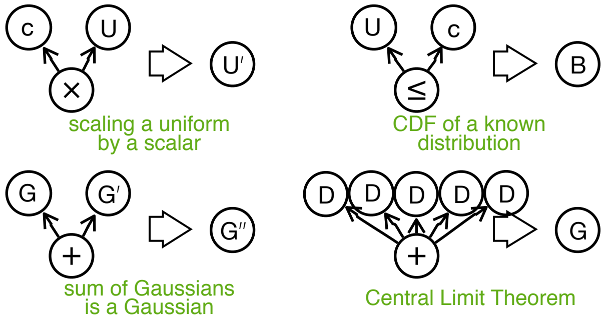
The concrete (ordinary) semantics are nondeterministic.

A symbolic semantics captures a program's probabilistic behavior.


program
input
nondeterministic concrete execution
outputs
⇔
We prove that the two semantics are equivalent.
program
input
deterministic symbolic execution
Bayesian network IR
nondeterministic sampling
outputs

statistical optimizations

The expression dag output from distribution extraction is a Bayesian network, a representation of probability distributions that lets statistical properties act as optimizations.


c
U
×
U′
scaling a uniform by a scalar
U
c
≤
B
CDF of a known distribution
G
G′
+
G″
sum of Gaussians is a Gaussian
D
D
D
D
D
+
G
Central Limit Theorem

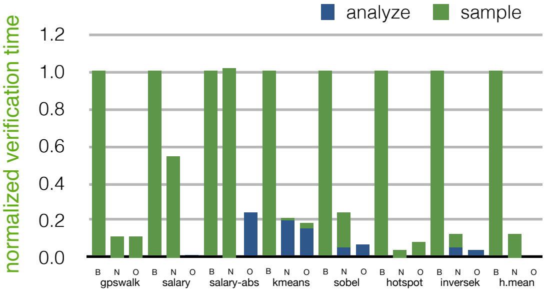
Simpler networks mean faster sampling.

verification

Optimizations collapse the network to a Bernoulli and we verify the `passert` exactly.

OR

Sample the network and perform a hypothesis test to get a statistical guarantee.



for each benchmark: baseline, no optimization, optimized

Our verifier checks `passerts` 24× faster than a naive checker on average.

sampa

Microsoft® Research

Adrian Sampson
Pavel Panchekha
Todd Mytkowicz

Kathryn S. McKinley
Dan Grossman
Luis Ceze

contact:
asampson@cs.washington.edu
http://homes.cs.washington.edu/~asampson