

fn sample_bernoulli_rational

Michael Shoemate

April 7, 2025

This proof resides in “**contrib**” because it has not completed the vetting process.

Warning 1 (Code is not constant-time). `sample_bernoulli_rational` takes in an optional `trials` parameter to denote the number of trials to run. The current implementation does not guard against other types of timing side-channels that can break differential privacy, e.g., non-constant time code execution due to branching.

PR History

- [Pull Request #473](#)

This document proves that the implementations of `sample_bernoulli_rational` in `mod.rs` at commit [f5bb719](#) (outdated¹) satisfies its proof definition.

At a high level, `sample_bernoulli` considers the binary expansion of `prob` into an infinite sequence `a_i`, like so: $\text{prob} = \sum_{i=0}^{\infty} \frac{a_i}{2^{i+1}}$. The algorithm samples $I \sim \text{Geom}(0.5)$ using an internal function `sample_geometric_buffer`, then returns `a_I`.

0.1 Hoare Triple

Preconditions

- User-specified types:
 - Variable `prob` must be of type `T`
 - Variable `constant_time` must be of type `bool`
 - Type `T` has trait `Float`. `Float` implies there exists an associated type `T::Bits` (defined in `FloatBits`) that captures the underlying bit representation of `T`.
 - Type `T::Bits` has traits `PartialOrd` and `ExactIntCast<usize>`
 - Type `usize` has trait `ExactIntCast<T::Bits>`

Pseudocode

```
1 # returns a single bit with some probability of success
2 def sample_bernoulli_rational(prob: RBig, trials: Optional[int]) -> bool:
3     number, denom = prob.into_parts()
4     return number > UBig.sample_uniform_int_below(denom, trials)
```

¹See new changes with `git diff f5bb719..2c73f8c rust/src/traits/samplers/bernoulli/mod.rs`

Postcondition

Definition 0.1. For any setting of the input parameters `prob` of type `T` restricted to $[0, 1]$, and optionally `trials` of type `usize`, `sample_bernoulli_rational` either

- raises an exception if there is a lack of system entropy or if `trials` is set and it runs more than `trials` times, or
- returns `out` where `out` is \top with probability `prob`, otherwise \perp .

If `trials` is set, the implementation's runtime is constant.

Proof. An integer sample is taken uniformly at random from $[0, \text{denom})$, where `denom` is the denominator of `prob`. The implementation then returns \top if the sample is less than the numerator of `prob`, and \perp otherwise. Since only at most `numer` outcomes of \top are possible, out of `denom` possible outcomes, the implementation returns \top with probability `prob`.

The implementation runs in constant-time if `trials` is set. □