

MakeNoise<VectorDomain<AtomDomain<IBig>>, MI, MO> for RV

Michael Shoemate

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

Proves soundness of the implementation of **MakeNoise** for RV over vectors of big integers in **mod.rs** at **commit f5bb719** (outdated¹).

This is the core implementation of all variations of the gaussian or laplace mechanism.

1 Hoare Triple

Precondition

Compiler-Verified

MakeNoise is parameterized as follows:

- MI implements trait **Metric**
- MO implements trait **Measure**
- RV implements trait **Sample**

The following trait bounds are also required:

- (VectorDomain<AtomDomain<IBig>>, MI) implements trait MetricSpace
- RV implements **NoisePrivacyMap**<MI, MO>

User-Verified

None

Pseudocode

```
1 # analogous to impl MakeNoise<VectorDomain<AtomDomain<IBig>>, MI, MO> for RV in Rust
2 class RV:
3     def make_noise(self, input_space) -> Measurement[VectorDomain[AtomDomain[IBig]], Vec[
        IBig], MI, MO]:
4         input_domain, input_metric = input_space
5         return Measurement.new(
6             input_domain,
7             Function.new_fallible(
8                 lambda x: [self.sample(x_i) for x_i in x]), #
9             input_metric,
```

¹See new changes with `git diff f5bb719..a7353b4 rust/src/measurements/noise/mod.rs`

```

10         MO.default(),
11         self.noise_privacy_map(), #
12     )

```

Postcondition

Theorem 1.1. For every setting of the input parameters (`self`, `input_space`, `MI`, `MO`, `RV`) to `make_noise` such that the given preconditions hold, `make_noise` raises an error (at compile time or run time) or returns a valid measurement. A valid measurement has the following properties:

1. (Data-independent runtime errors). For every pair of members x and x' in `input_domain`, `invoke(x)` and `invoke(x')` either both return the same error or neither return an error.
2. (Privacy guarantee). For every pair of members x and x' in `input_domain` and for every pair (d_in, d_out) , where `d_in` has the associated type for `input_metric` and `d_out` has the associated type for `output_measure`, if x, x' are `d_in`-close under `input_metric`, `privacy_map(d_in)` does not raise an error, and `privacy_map(d_in) = d_out`, then `function(x), function(x')` are `d_out`-close under `output_measure`.

Proof of data-independent errors. The precondition of `Sample.sample` requires that `self` is a valid distribution. This is satisfied by the postcondition of `NoisePrivacyMap<MI, MO>` on line 11. The postcondition of `Sample.sample` guarantees that the function only ever returns an error independently of the data. \square

For the proof of the privacy guarantee, start by reviewing the postcondition of `NoisePrivacyMap<MI, MO>`, which has an associated function `noise_privacy_map` to be called on line 11.

Lemma 1.2 (Postcondition of `NoisePrivacyMap`). Given a distribution `self`, returns `Err(e)` if `self` is not a valid distribution. Otherwise the output is `Ok(privacy_map)` where `privacy_map` observes the following:

Define `function(x) = x + Z` where `Z` is a vector of iid samples from `self`.

For every pair of elements x, x' in `VectorDomain<AtomDomain<IBig>>`, and for every pair (d_in, d_out) , where `d_in` has the associated type for `input_metric` and `d_out` has the associated type for `output_measure`, if x, x' are `d_in`-close under `input_metric`, `privacy_map(d_in)` does not raise an exception, and `privacy_map(d_in) ≤ d_out`, then `function(x), function(x')` are `d_out`-close under `output_measure`.

Proof of privacy guarantee. Assuming line 11 does not fail, then the returned privacy map is subject to Theorem 1.2. The privacy guarantee applies when `function(x) = x + Z`, where `Z` is a vector of iid samples from `self`. In this case `self` describes the noise distribution.

We argue that `function` is consistent with the function described in Lemma 1.2. Line 8 calls `self.sample(x_i)` on each element in the input vector. The precondition that `self` represents a valid distribution is satisfied by the postcondition of Lemma 1.2; the distribution is valid when the construction of the privacy map does not raise an exception. Since the preconditions for `Sample.sample` are satisfied, the postcondition claims that either an error is returned independently of the input `shift`, or `shift + Z` where `Z` is a sample from the distribution defined by `self`. This is consistent with the definition of `function(x)` in the privacy map.

Therefore, the privacy guarantee from Lemma 1.2 applies to the returned measurement. \square