

MakeNoise<MapDomain<AtomDomain<TK>, AtomDomain<TV>»,
LOPInfDistance<P, AbsoluteDistance<QI>», MO> for
IntExpFamily<P>

Michael Shoemate

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

Proves soundness of the implementation of `MakeNoiseThreshold` over hashmaps for `IntExpFamily` in `mod.rs` at commit `f5bb719` (outdated¹).

This mechanism samples from the `IntExpFamily` distribution, where the tails are clipped to the smallest and largest representable integers in the native integer type. This is done by first sampling from the `ZExpFamily`, the equivalent distribution supported on all integers, and then clipping the tails by clamping. The clamping is done by saturating the cast of the sampled value to the native integer type.

1 Hoare Triple

Precondition

Compiler-Verified

- Generic `T` implements trait `Integer` and `SaturatingCast<IBig>` The saturating cast is for infallible postprocessing of big ints back to type `T`.
- Const-generic `P` is of type `usize`
- Generic `QI` implements trait `Integer`
- Generic `MO` implements trait `Measure`
- Type `IBig` implements trait `From<T>`. This infallible exact cast is for converting integers to big ints in the preprocessing transformation.
- Type `RBig` implements trait `TryFrom<QI>`. This is for fallible casting from input sensitivity of type `QI` to a rational in the privacy map.
- Type `ZExpFamily<P>` implements trait `NoisePrivacyMap<LpDistance<P, RBig>, MO>`. This bound requires that it must be possible to construct a privacy map for this combination of noise distribution, distance type and privacy measure.

User-Verified

None

¹See new changes with `git diff f5bb719..7e67449 rust/src/measurements/noise_threshold/nature/integer/mod.rs`

Pseudocode

```
1 class IntExpFamily:
2     def make_noise_threshold(
3         self,
4         input_space: tuple[
5             MapDomain[AtomDomain[TK], AtomDomain[TV]], LOPInfDistance[P, AbsoluteDistance[QI]
6         ],
7         threshold: TV,
8     ) -> Measurement[
9         MapDomain[AtomDomain[TK], AtomDomain[TV]],
10        HashMap[TK, TV],
11        LOPInfDistance[P, AbsoluteDistance[QI]],
12        MO,
13    ]:
14        distribution = ZExpFamily(
15            scale=integerize_scale(self.scale, 0)
16        ) #
17
18        threshold = UBig.try_from(threshold)
19
20        t_int = make_int_to_bigint_threshold(input_space)
21        m_noise = distribution.make_noise_threshold(t_int.output_space())
22        f_native_int = then_saturating_cast_hashmap()
23
24        return t_int >> m_noise >> f_native_int
```

Postcondition

Theorem 1.1. For every setting of the input parameters (`self`, `input_space`, `threshold`, `MO`, `TK`, `TV`, `P`, `QI`) to `make_noise_threshold` such that the given preconditions hold, `make_noise_threshold` raises an exception (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 elements x, x' in `input_domain`, `function(x)` returns an error if and only if `function(x')` returns an error.
2. (Privacy guarantee). For every pair of elements x, 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 exception, and $\text{privacy_map}(d_{in}) \leq d_{out}$, then `function(x), function(x')` are d_{out} -close under `output_measure`.

Proof. Line 16 constructs a new random variable following a distribution equivalent to `IntExpFamily`, but without clipped tails.

Neither constructor `make_int_to_bigint_threshold` nor `MakeNoiseThreshold.make_noise_threshold` have manual preconditions, and the postconditions guarantee a valid transformation and valid measurement, respectively. `then_saturating_cast_hashmap` also does not have preconditions, and its postcondition guarantees that it returns a valid postprocessor.

The chain of a valid transformation, valid measurement and valid postprocessor is a valid measurement. \square