fn counting_query_stability_map

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This document proves that the implementation of `counting_query_stability_map` in `mod.rs` at commit f5bb719 (outdated[1]) satisfies its proof definition.

1 Hoare Triple

Preconditions

Compiler-verified

- Argument `public_info` must be Keys, Lengths or None
- Generic `M` must implement `UnboundedMetric`
- Const generic `P` must be of type `usize`

User-verified

None

Pseudocode

```
def counting_query_stability_map(
    public_info: Literal["Keys"] | Literal["Lengths"] | None,
) -> StabilityMap[PartitionDistance[M], LpDistance[P, f64]]:

    if public_info == "Lengths":  #
        return StabilityMap.new(lambda _: 0.)

    def norm_map(d_in: f64) -> f64:  #
        if P == 1:
            return d_in
        if P == 2:
            return d_in.inf_sqrt()
        raise ValueError("unsupported Lp norm. Must be an L1 or L2 norm.")

    def stability_map(d_in: tuple[u32, u32, u32]) -> f64:
        l0, l1, l_inf = d_in  #
        l0_p = norm_map(f64.from_(l0))  #
        l1_p = f64.from_(l1)
        l_inf_p = f64.from_(l_inf)
        return l1_p.total_min(l0_p.inf_mul(l_inf_p))  #

    return StabilityMap.new_fallible(stability_map)  #
```

[1] See new changes with `git diff f5bb719..619a00f rust/src/transformations/make_stable_expr/expr_count/mod.rs`

Postcondition

Definition 1.1. For any setting of the input parameters `public_info`, `M` and `P`, returns a `StabilityMap` where for any predicate $p(\cdot)$ and $f(x) = [\sum_i \mathbb{1}_{p(x_{1i})}, \sum_i \mathbb{1}_{p(x_{2i})}, \ldots]$, if $d_{\text{PartitionDistance<M>}}(x, x') \leq d_{in}$, then $d_{LP}(f(x), f(x')) \leq d_{out}$, where $d_{out} = \texttt{StabilityMap.eval}(d_{in})$.

Proof. Since the input metric is PartitionDistance<M>, and M is an unbounded dataset distance metric (with associated distance type `u32`), the distance type is a tuple of the L_0, L_1 and L_∞ distances between the per-partition distances with respect to the input metric `M`, as shown on 16.

$$
\begin{aligned}
&d_{LP}(f(x), f(x')) \tag{1}\\
&= d_{LP}\left(\left[\sum_j^{\text{len}(x_1)} \mathbb{1}_{p(x_{1j})}, \sum_j^{\text{len}(x_2)} \mathbb{1}_{p(x_{2j})}, \ldots\right], \left[\sum_j^{\text{len}(x_1)} \mathbb{1}_{p(x'_{1j})}, \sum_j^{\text{len}(x_2)} \mathbb{1}_{p(x'_{2j})}, \ldots\right]\right) \tag{2}\\
&= \left(\sum_i^{\text{len}(x)} \left(\sum_j^{\text{len}(x_i)} \mathbb{1}_{p(x_{ij})} - \mathbb{1}_{p(x'_{ij})}\right)^P\right)^{1/P} \tag{3}
\end{aligned}
$$

Consider two cases. First, when substituting the Δ_0 and Δ_∞ bounds:

$$
\begin{aligned}
&= \left(\sum_i^{\text{len}(x)} \left(\sum_j^{\text{len}(x_i)} \mathbb{1}_{p(x_{ij})} - \mathbb{1}_{p(x'_{ij})}\right)^P\right)^{1/P} \tag{4}\\
&\leq \left(\sum_i^{\Delta_0} (\Delta_\infty)^P\right)^{1/P} \tag{5}\\
&= \Delta_0^{1/P} \Delta_\infty \tag{6}
\end{aligned}
$$

Alternatively, apply the Δ_1 bound, considering that distance is maximized when all Δ_1 contributions are made to the same partition:

$$
\begin{aligned}
&= \left(\sum_i^{\text{len}(x)} \left(\sum_j^{\text{len}(x_i)} \mathbb{1}_{p(x_{ij})} - \mathbb{1}_{p(x'_{ij})}\right)^P\right)^{1/P} \tag{7}\\
&\leq (\Delta_1^P)^{1/P} \tag{8}\\
&= \Delta_1 \tag{9}
\end{aligned}
$$

The sensitivity is no greater than the smaller of these two bounds:

$$
d_{LP}(f(x), f(x')) \leq \min(\Delta_1, \Delta_0^{1/P} \Delta_\infty) \tag{10}
$$

We now switch to the pseudocode. If partition length is invariant (via `public_info`), then $\Delta_1 = \Delta_\infty = 0$, making the query insensitive. This invariant is reflected in 5, where an insensitive stability map is returned, satisfying the postcondition.

`norm_map` on line 8 computes $x^{1/P}$, and is used on line 17 to compute $\Delta^{1/P}$. Line 20 then returns the bound from equation 10. Therefore, the stability map returned on line 22 also satisfies the postcondition.

□