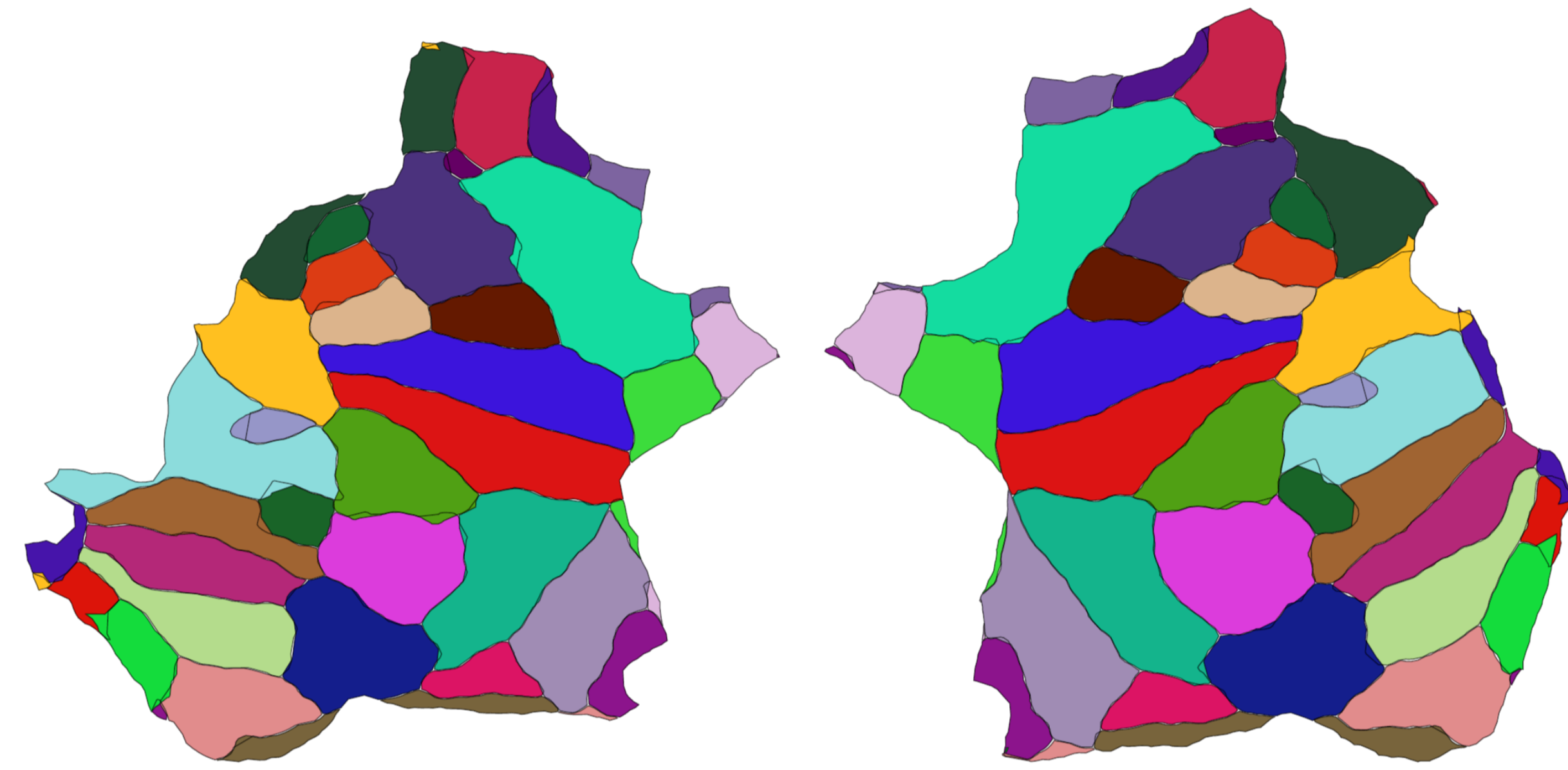


Topological Consistency, Not Fidelity, Bounds the Cost Relief of Simplified EEG Brain Maps

Simplifying cortical parcellation boundaries for the NBT brain-map viewer: what topological guarantees actually buy, and what they spend

1 The NBT brain-map viewer

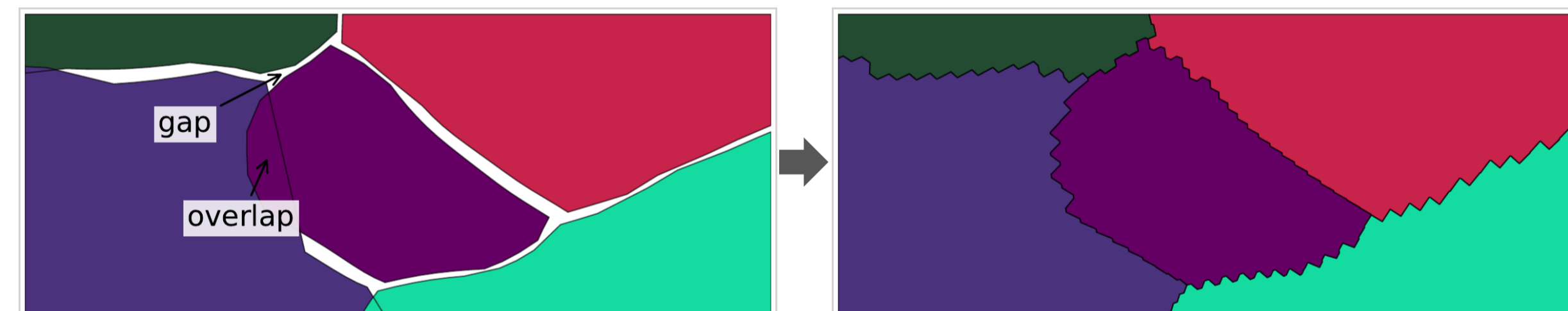
NBT paints EEG statistics onto a 2-D map of cortical regions called a **parcellation**. At clinical scale it must render both fast and correctly.



Invalid regions, redrawn for every interaction.

2 The problem

NBT fits each region's boundary on its own, so they leave **gaps** and **overlaps**.



current: gaps & overlaps

a shared boundary: clean

To render faster boundaries must be simplified (fewer vertices, less to draw)
Simplifying broken boundaries exacerbates topological errors.
These topological failures can be prevented through a different representation.

3 What we built

A **shared-arc model**: each boundary is stored once, shared by both regions. One edit moves both sides at once, so gaps and overlaps are now **impossible by construction**.

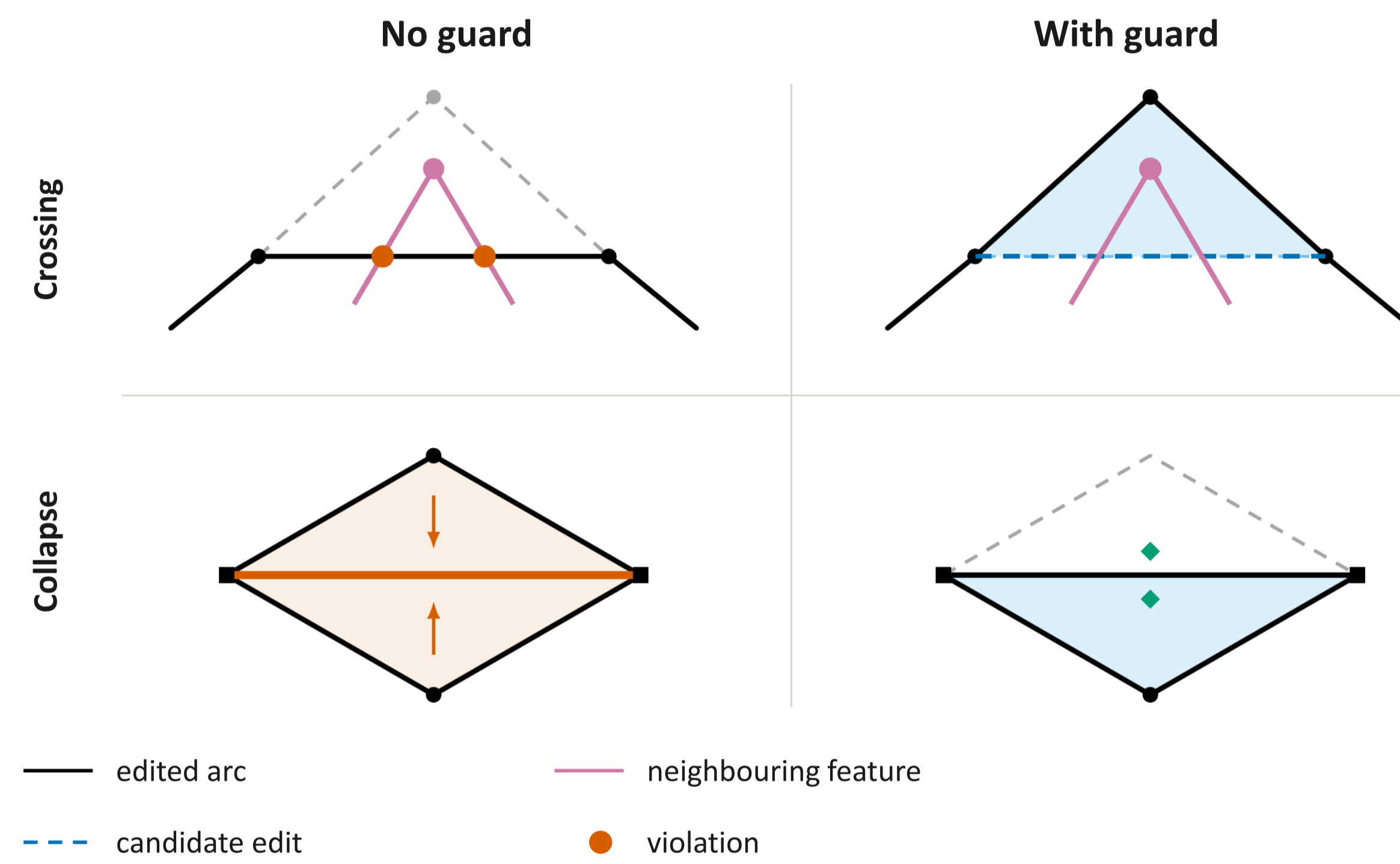
Two failure modes still survive, set by how each arc is simplified: a **crossing** (an arc cuts across a neighbour) and a **collapse** (a region shrinks to zero area).

Shared-arc model · RDP, VW, Saalfeld, de Berg, TopoVW · 6 cortical atlases

4 Five simplification algorithms

All five simplify a boundary by removing vertices. A guard tests each edit first:

- the **sidedness test** rejects edits that push a neighbour to the wrong side → catches **crossings**.
- a **collapse** moves no neighbour, so the test is blind to it, TopoVW adds dummy **control points** the test can catch.



Crossings: stopped by 3 of 5. Collapse: by 1 (TopoVW).

5 What the evaluation found

Q Does the algorithm change fidelity?

A Barely, 4 of 5 agree within 0.01 IoU; what matters is how hard you push.

Q What topological errors remain?

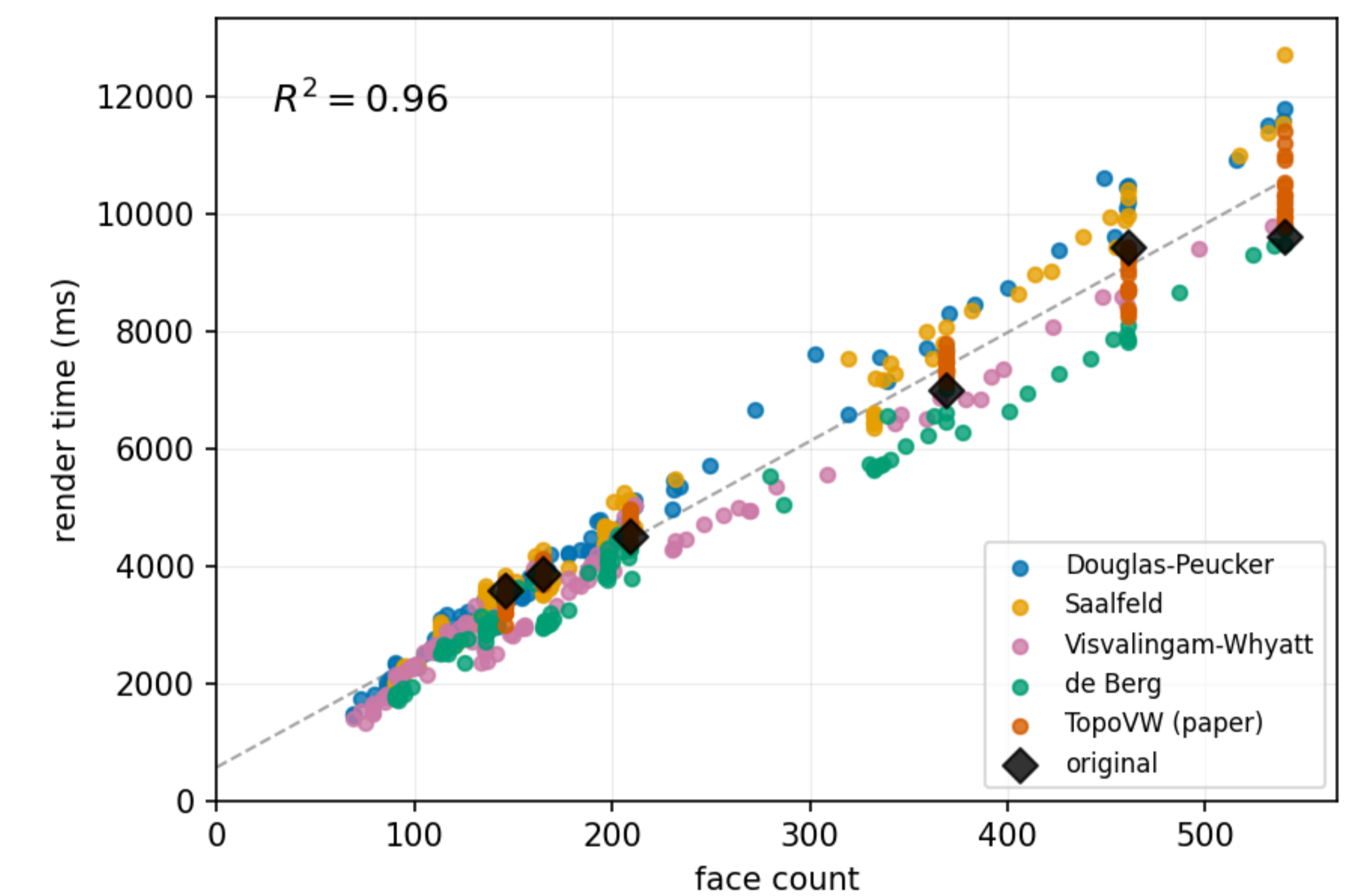
A Both small: crossings (2 baselines) + collapse (all but TopoVW), <3% area.

Q What drives render time?

A **Faces, not vertices**, face count explains ≥95% of render cost.

6 The result

Topological guarantees prevent face collapse, but allow the **least cost relief**.



Render time is near-linear in **face count** ($R^2 = 0.96$, above).

Algorithms shed faces only through **collapse**, and the guards that make an algorithm safe are exactly the ones that prevent it.

So the safest algorithm, TopoVW, frees **zero** faces, and the least cost.

7 A more direct lever

Simplification sheds faces by accident. **Filtering** small components prevents them from ever entering the parcellation.

At matched face count it is at least as faithful as simplification where our data resolves it (4 of 6 atlases).
Two atlases unresolved; never tested in combination.

A full evaluation of this approach is left to future work.