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CIENCIAS DE LA COMPUTACIÓN
UNIVERSIDAD DE CHILE

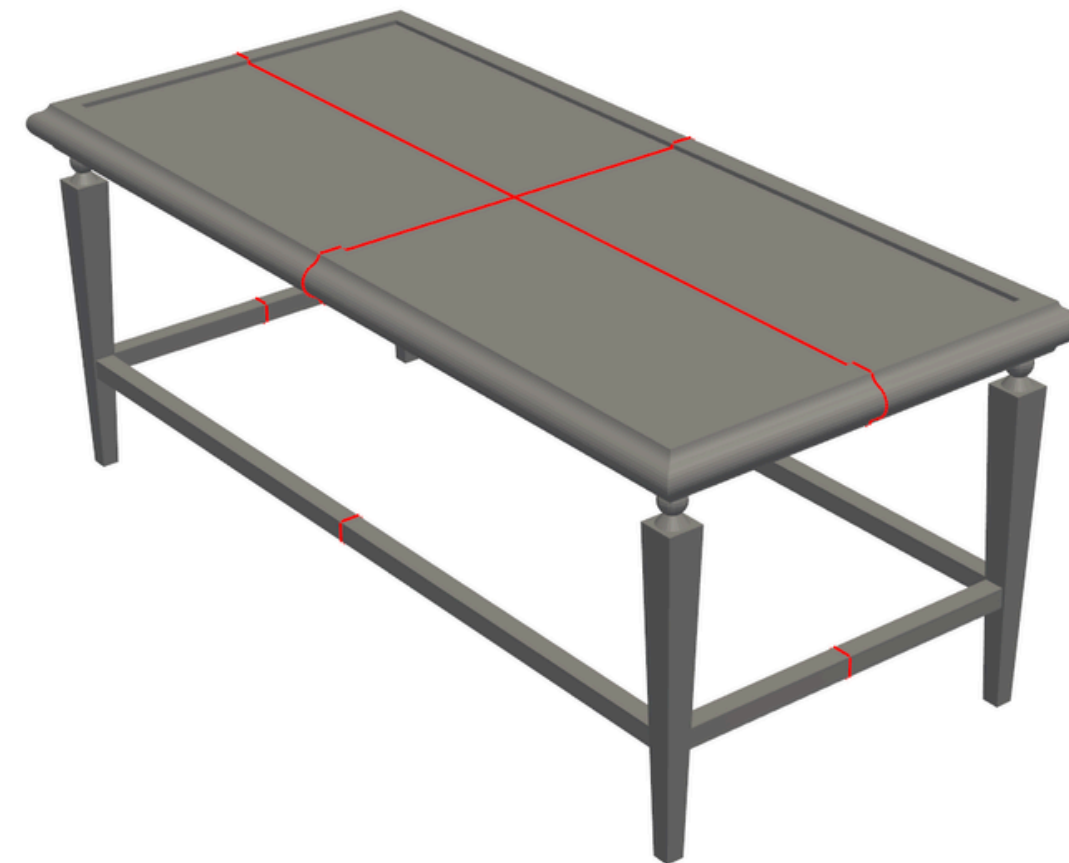


Enhanced Back-Projection of Vision Features for 3D Symmetry Detection

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Motivation

- Symmetry is fundamental for understanding 3D shape.
- 3D symmetry detection requires reliable features.
- Traditional geometric features/descriptors:
 - Often noisy or unstable
- Deep learning approaches:
 - Dataset dependent
 - High computational cost



Core idea

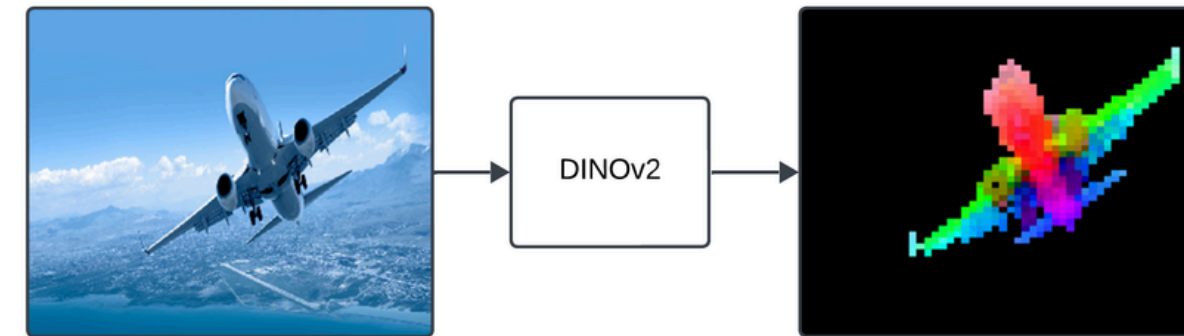
- **Feature Back-Projection** produces features for 3D meshes.
- We **improve** feature back-projection:
 - Better viewpoint sampling
 - Image rotations
- **More consistent features** → **Better Symmetry Detection.**



Feature Back-Projection

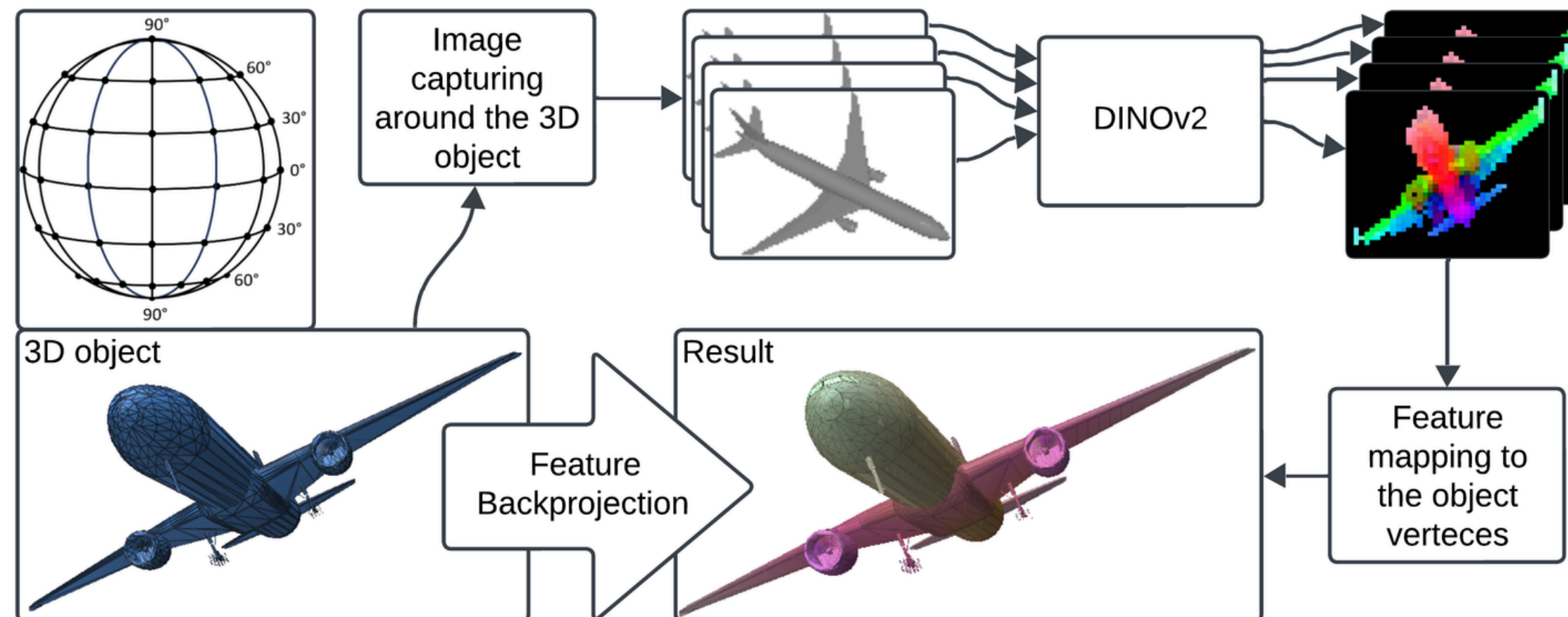
Feature extraction of 2D images:

- Using vision models: *DINOv2*, *CLIP*, etc.
- Each Pixel in the image has a feature.



Feature extraction of 3D objects:

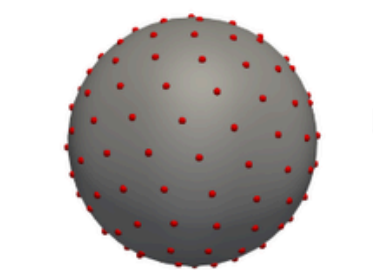
- Each vertex/point has its own feature!
- Methods: BT3D, COPS



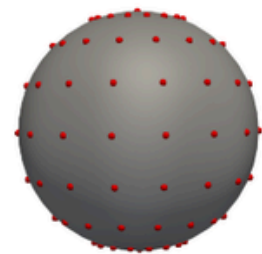
Improvements

Better viewpoint sampling:

- Fibonacci Sampling (FI) instead of standard latitude-longitude sampling (RE)



*Fibonacci

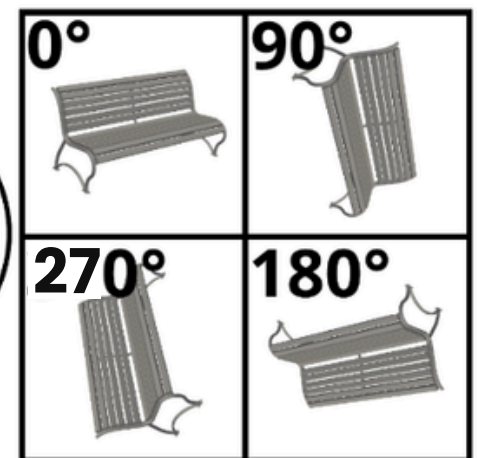


*Standard



Viewpoint
sampling

Image
capturing



• Four images for
each viewpoint

Frozen
DINOv2

Feature
back-projection



Image rotations:

- Instead of a single image, use rotations of the image: 0°, 90°, 180, 270°. (1R - 4R)

Feature Representations



Original Mesh

**Feature
Back-Projection**



Raw-Mesh (RM)

**Sampling of mesh
and features**



Feature-Mesh Sampling (FM)

- Sampling and interpolation after performing RM



Sampled Mesh

**Feature
Back-Projection**



Point Cloud (PC)

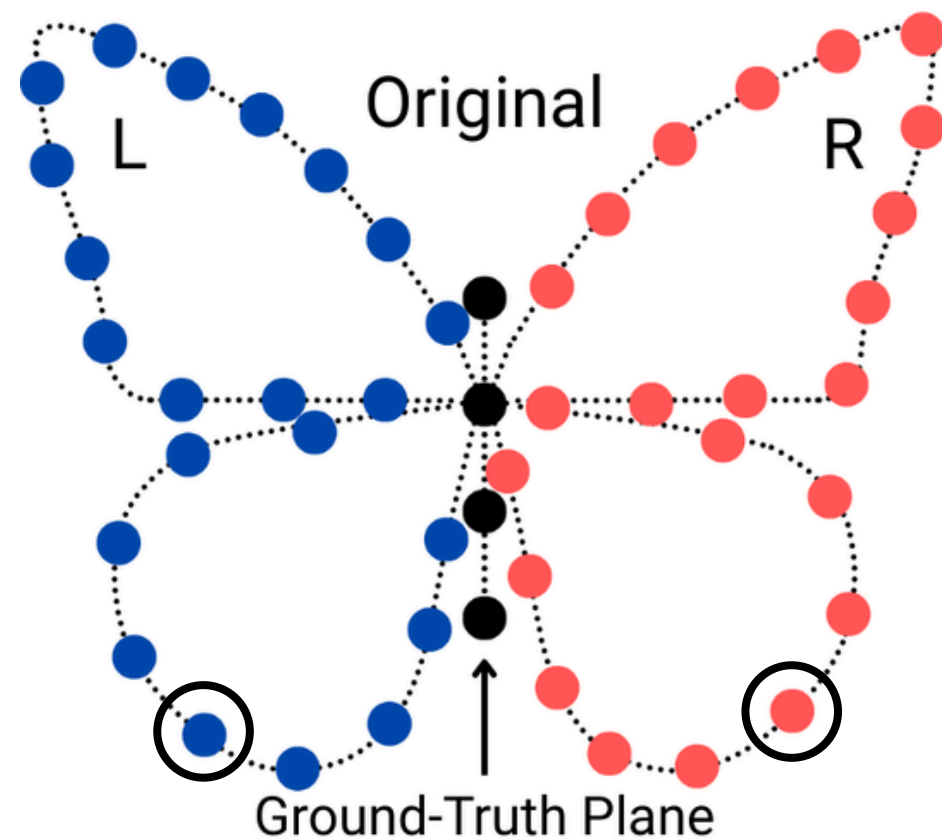
Feature invariance

Hypothesis:

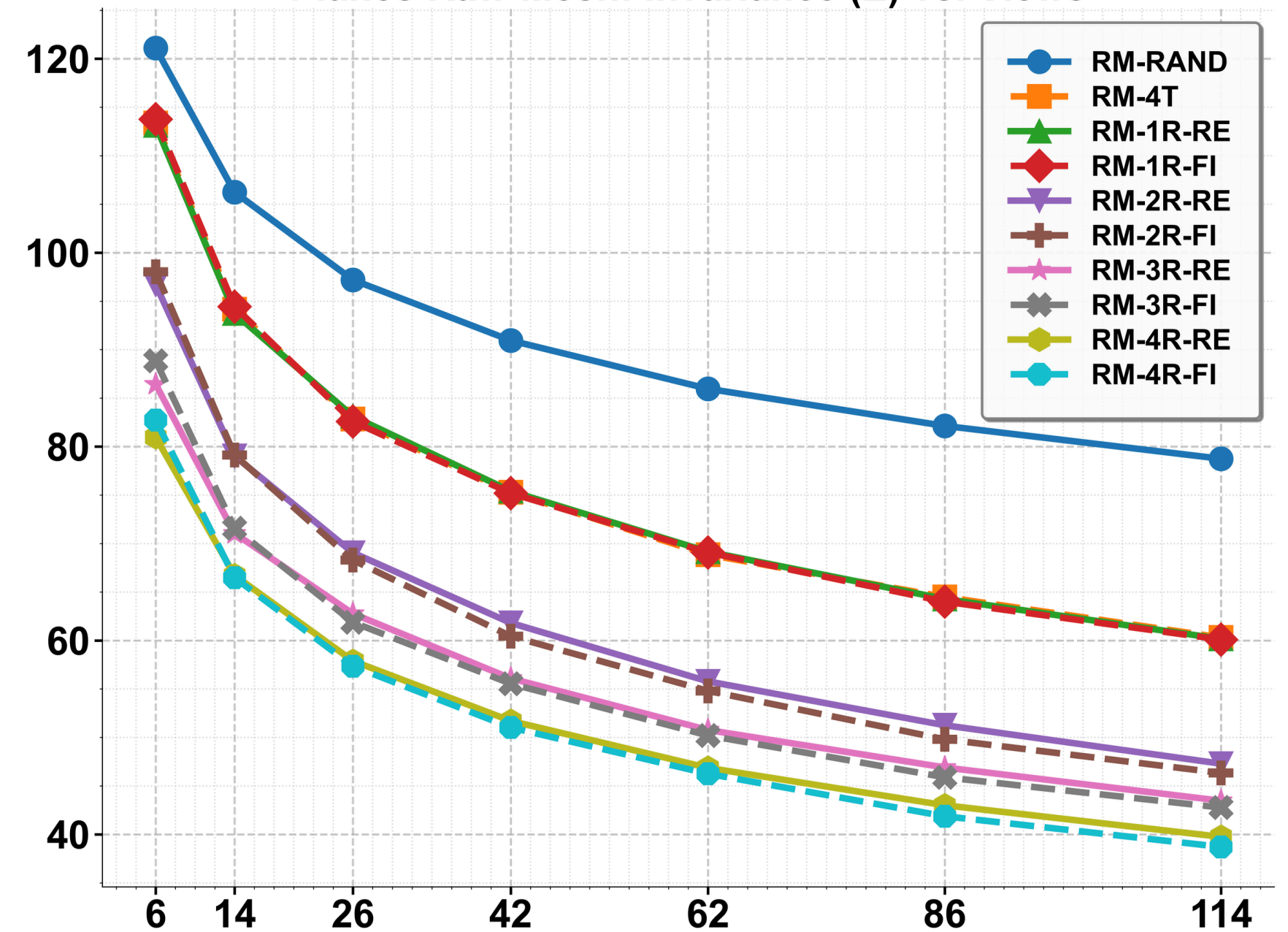
- Symmetric points should have similar features

Evaluation:

- Feature distance between symmetric points

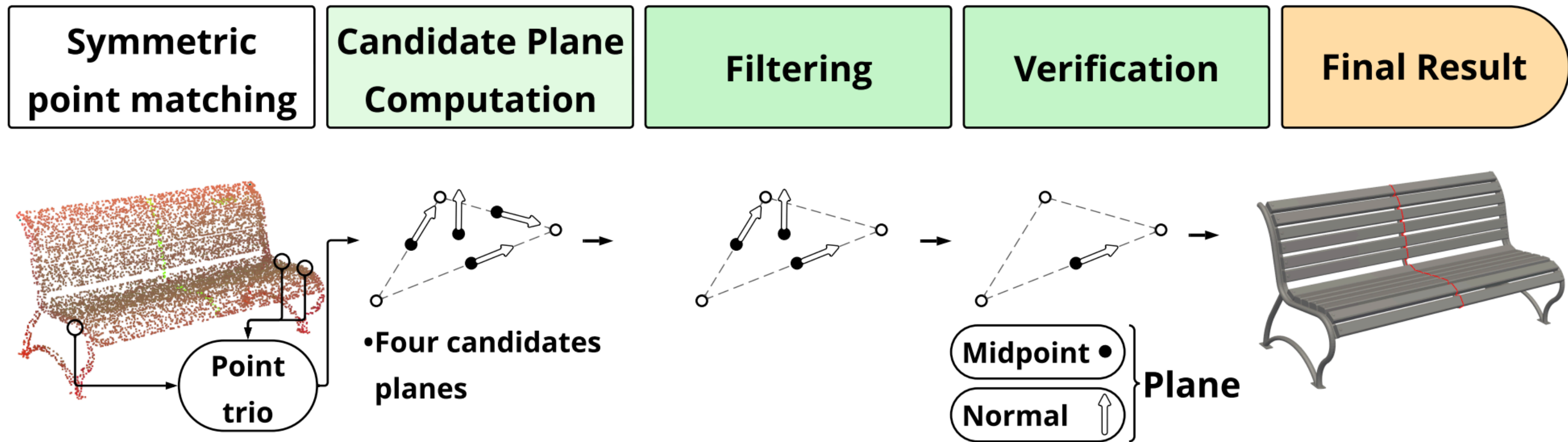


Planes Raw-Mesh: Invariance (E) vs. Views



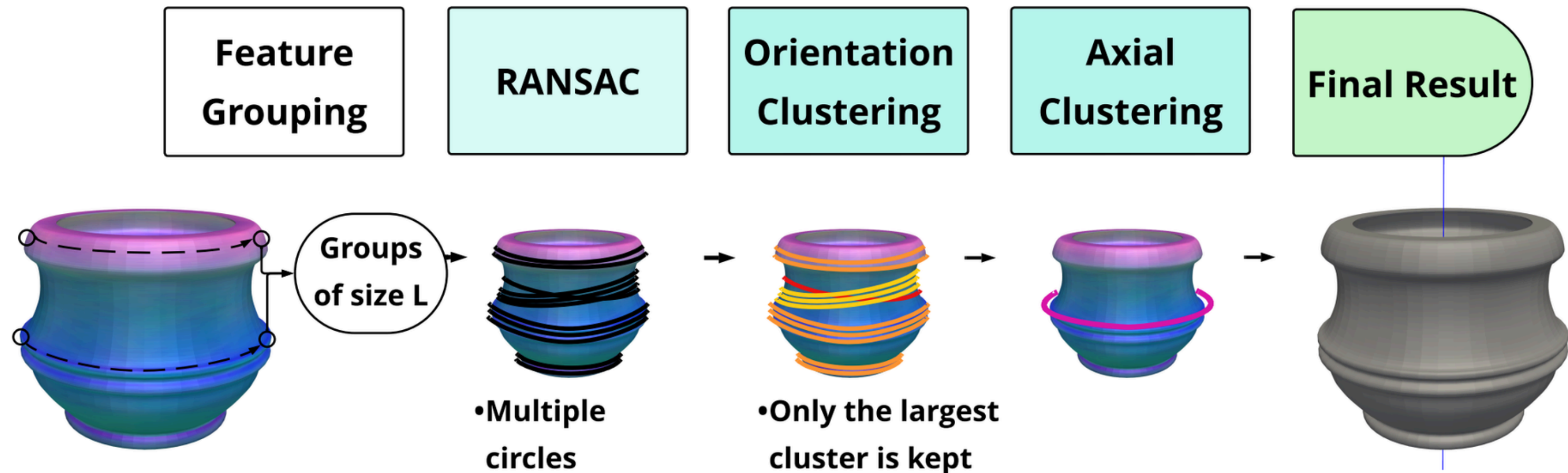
Planar Symmetry Detection

- Assumes that symmetric points have similar features.



Axial Symmetry Detection

- Assumes that symmetric points have similar features.

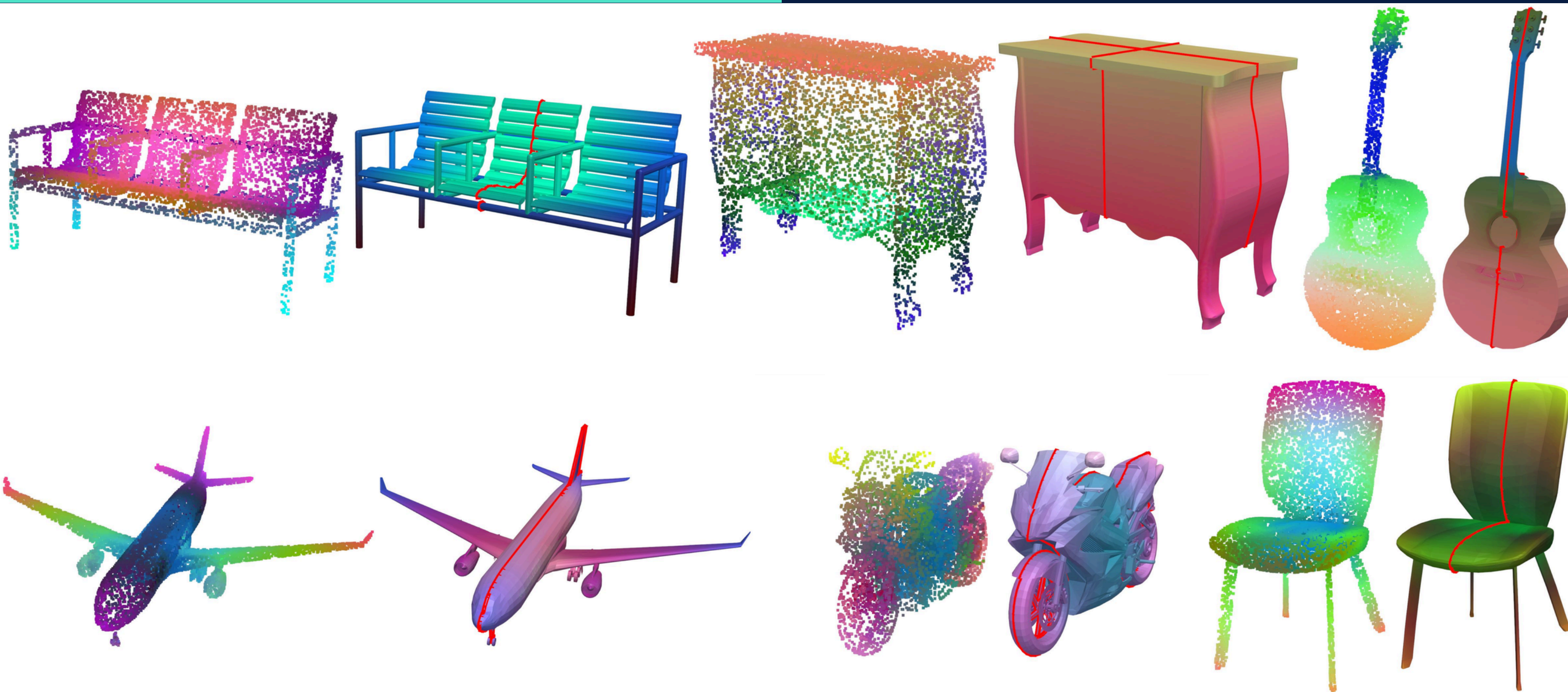


Experiments and Results

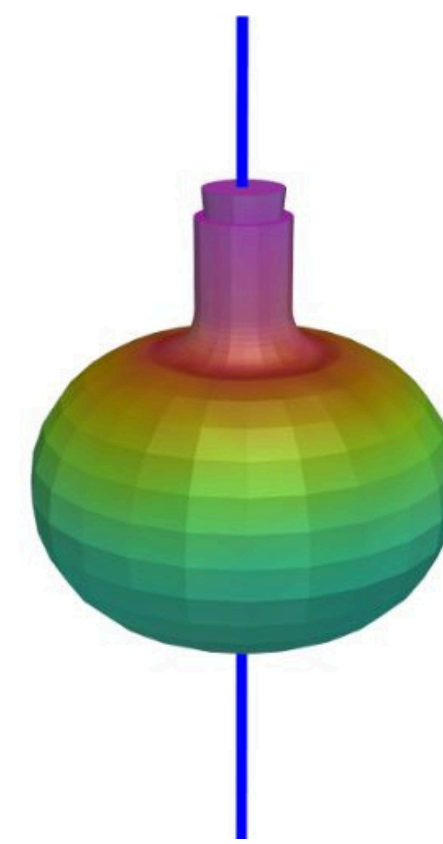
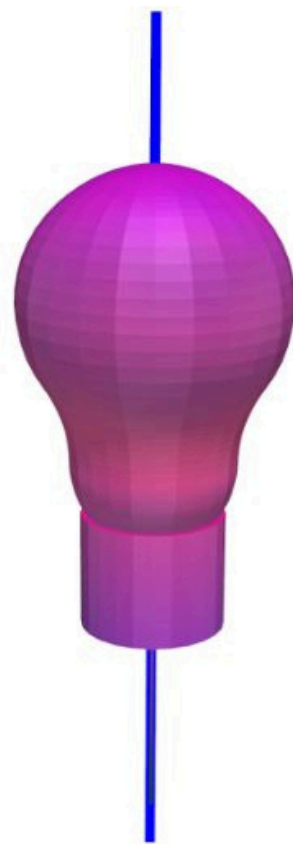
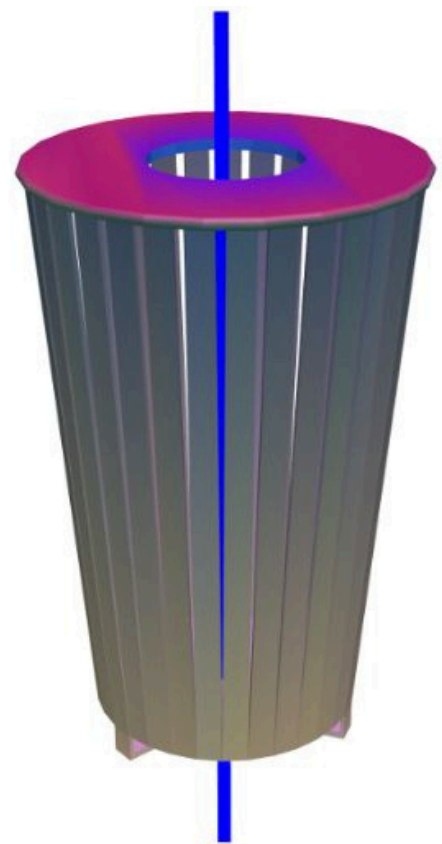
- **Two Datasets**, with **arbitrary** rotated objects from *ShapeNet*.
- A single GPU (RTX 3060 Ti 8 GB)
- *DINOv2* small (84 MB)
- Metrics:
 - **Symmetry Distance Error** (SDE)
 - **F-score**
- Best for Planes: Feature-Mesh Sampling.
- Best for Axes: Raw Mesh.
- Planes: 6 to 20 s.
- Axes: 40 to 80 s.

Method	F-score	SDE($\times 10^{-4}$)
PCA	0.692	3.32
OBB [6]	0.74	1.25
RSD [28]	0.684	0.9
ADS [43]	0.694	3.95
PASD [46]	0.322	14.2
PRST [57]	0.619	1.78
PRST+GEDT [57]	0.646	1.6
PAS [29]	0.678	1.75
PRS-Net [15]	0.712	0.86
E3Sym [36]	0.753	0.46
Diffusion [67]	0.46	7.1
Ours (FM10K-4R-FI)	0.912	0.282

Results - Planes

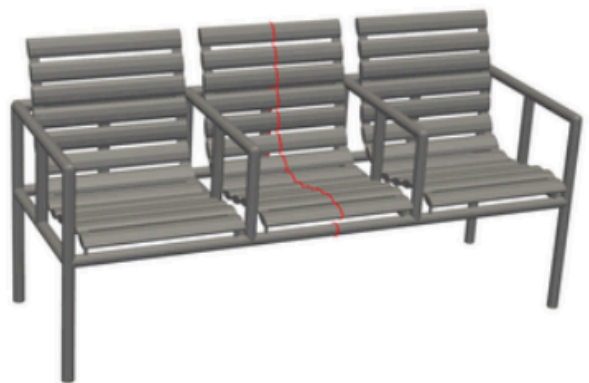


Results - Axes

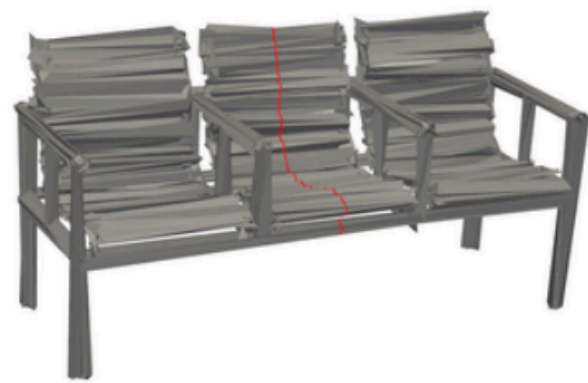


Results – Robustness

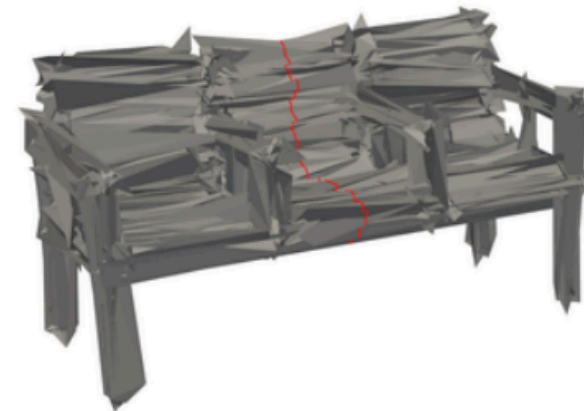
- **Noise perturbations:** Gaussian noise applied to vertices at three levels of intensity (1%, 3%, and 5%)
- **Part removal:** All points within a spherical region around a randomly selected point are removed.



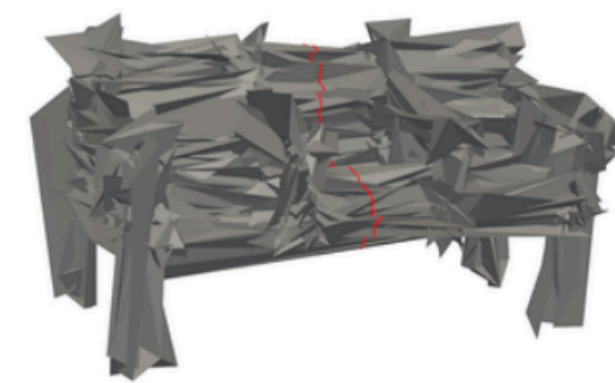
(a)



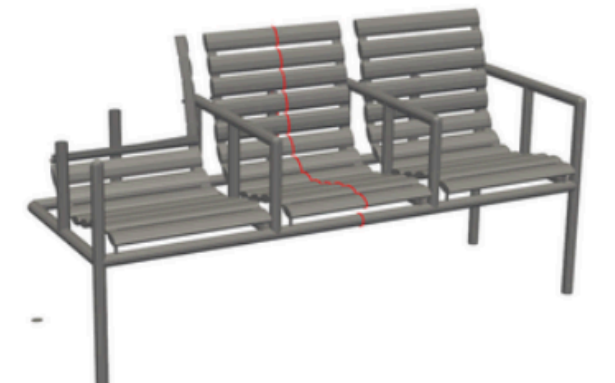
(b)



(c)



(d)



(e)

Conclusion

- **Enhanced Feature Backprojection**
 - Fibonacci viewpoint sampling
 - Image rotations
 - Feature invariance evaluation
- **Efficient symmetry detection**
 - Planar and axial symmetries
 - Single GPU
 - Seconds of runtime
- **Future work:**
 - More efficient implementations.
 - Extending beyond global symmetries.

Thanks!

