Reassembling Broken Objects using Breaking Curves

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CVPR 2023 Workshop on 3D Vision and Robotics

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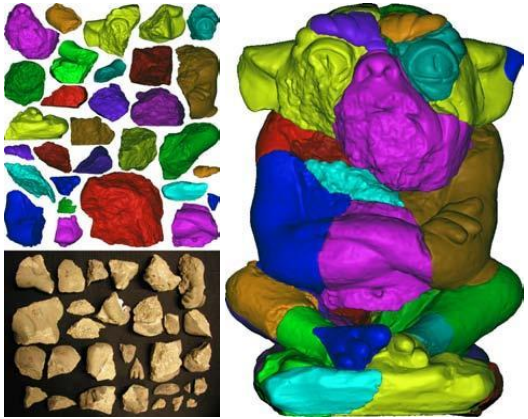
Università
Ca'Foscari
Venezia

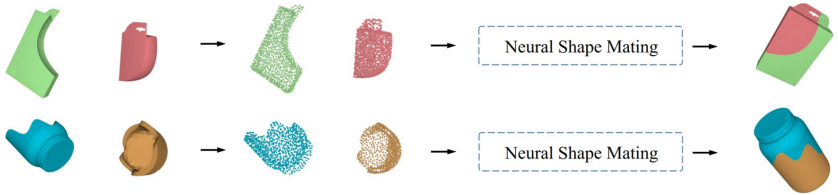
Related Work and SOTA

Geometric Methods



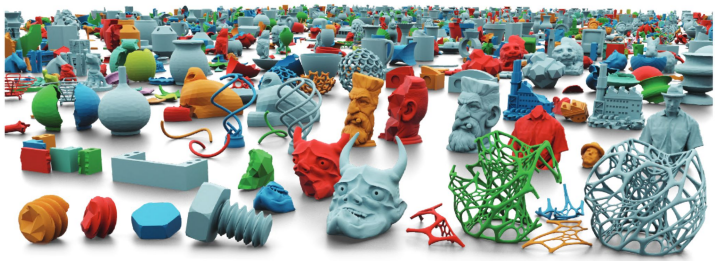
Reassembling Fractured Objects by Geometric Matching, Huang et al. SIGGRAPH 2006

Pairwise Assembly



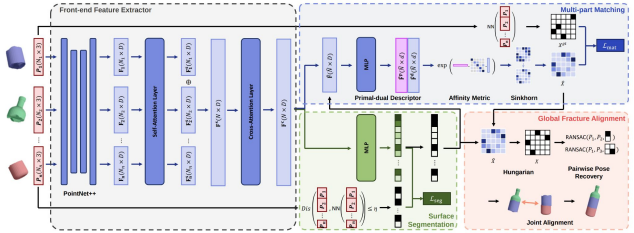
Neural Shape Mating: Self-Supervised Object Assembly with Adversarial Shape Priors, Chen et al, CVPR 2022

Benchmarking and Dataset



Breaking Bad: A Dataset for Geometric Fracture and Reassembly, Sellan, Chen, Wu et al., NeurIPS 2022 (Datasets and Benchmarks Track)

Assembling Objects Broken in Multiple Parts



Jigsaw: Learning to Assemble Multiple Fractured Objects, Lu, Sun and Quang,
Under Review 2023

Main Goal & Contributions

We aim at reassembling two parts of a broken object using point clouds:

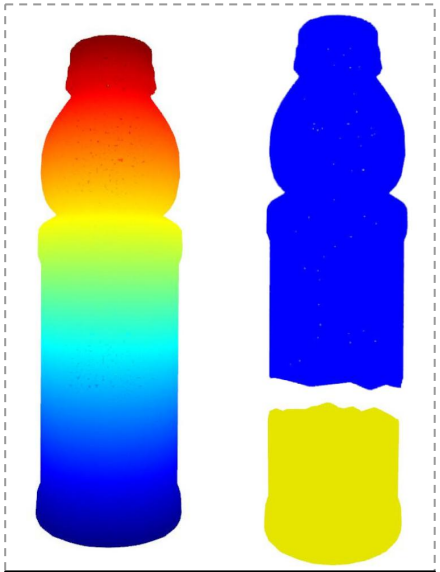
- assuming no prior information on the geometry of the broken objects
- without the need of surface reconstruction

Contributions:

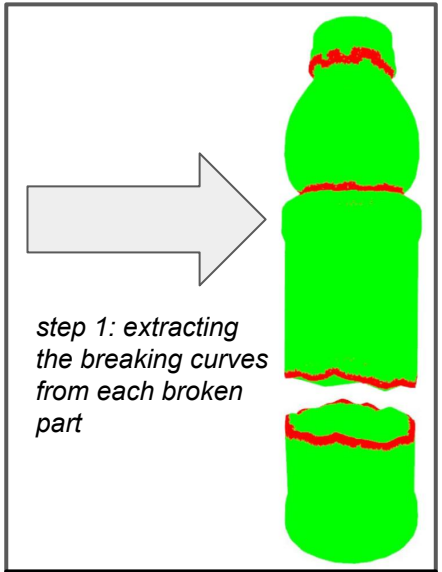
- Creation of a flexible and modular framework for assembling broken objects
- The graph-based breaking curve extraction generalizes well to different shapes, allowing to use the same approach on real and synthetic objects without prior geometric assumptions

Pipeline

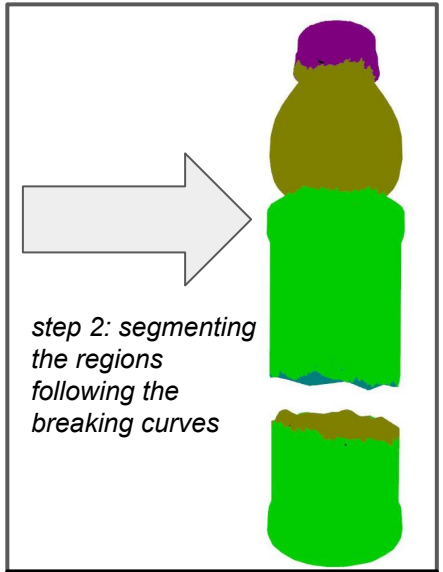
The pipeline is divided into 3 main steps



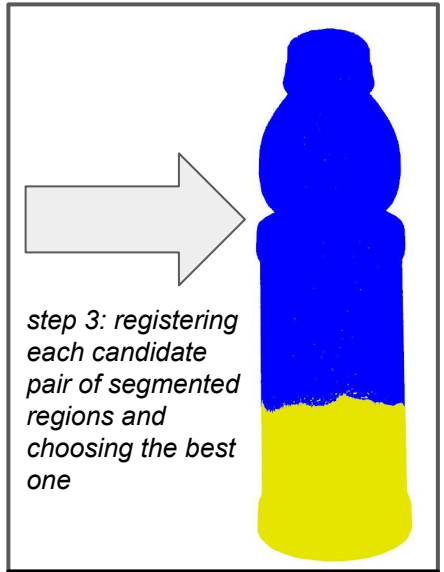
Input (original and broken)



1. Breaking curves



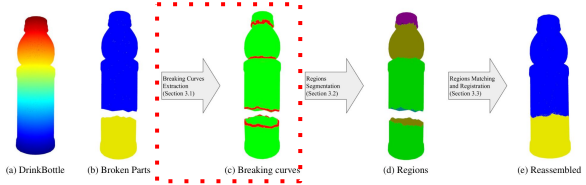
2. Segmented regions



3. Reassembled object

Extracting breaking curves, segmenting and registering segmented regions

Breaking Curves Extraction



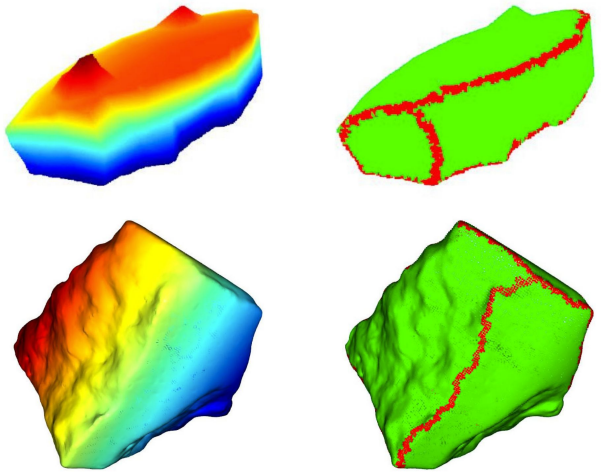
Breaking curves characterize object's fractures:

1. Represent a point cloud as an ε-graph
2. Compute for each vertex *p* a corner penalty [1]

$$\omega_{co}(p) = \frac{\lambda_2(p) - \lambda_0(p)}{\lambda_2(p)}$$

3. Select *p* nodes where $\omega_{co}(p) < \theta$

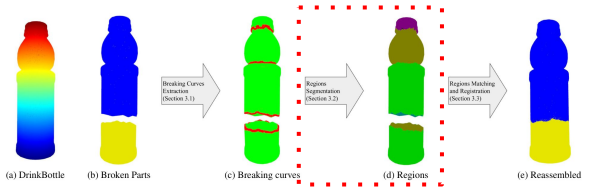
4. Pruning + Dilation to promote the creation of closed breaking curves



(a) Original (b) Breaking Curves

[1] Gumhold et.al. Feature extraction from point clouds. Proceedings of 10th international meshing roundtable, 2001, 11 2001

Region Segmentation



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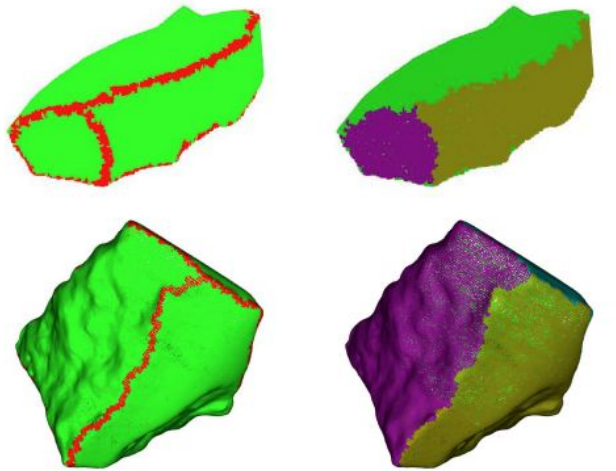


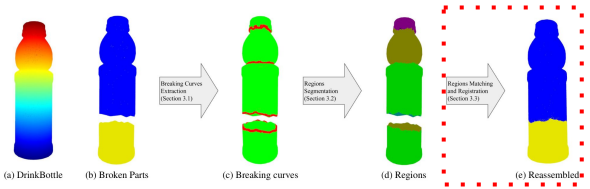
(b) Breaking Curves (c) Segmented Regions

Regions are part of the point cloud enclosed by a breaking curves

5. A B.C.-constrained region-growing technique extracts the regions.

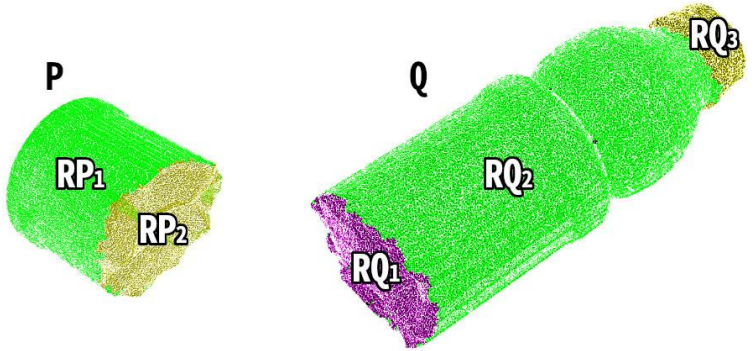
[1] Gumhold et.al. Feature extraction from point clouds. Proceedings of 10th international meshing roundtable, 2001, 11 2001

Regions Registration

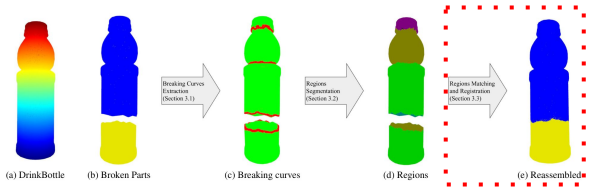


Given two segmented point clouds *P* and *Q* with regions $\mathcal{RP}$ and $\mathcal{RQ}$ the registration works by:

1. Discarding smaller regions
2. Perform ICP over all possible pair of regions
3. Assess alignment quality of each pair with the Chamfer distance
4. Select the registration with the best score and use it to align the two point clouds.



Regions Registration



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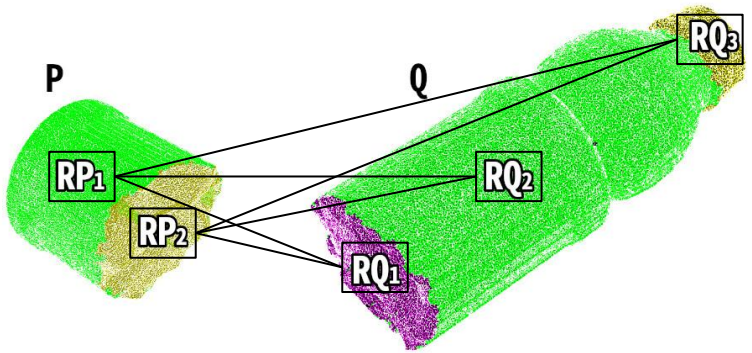

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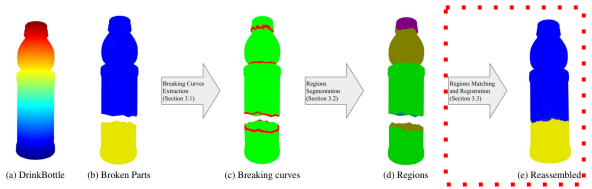

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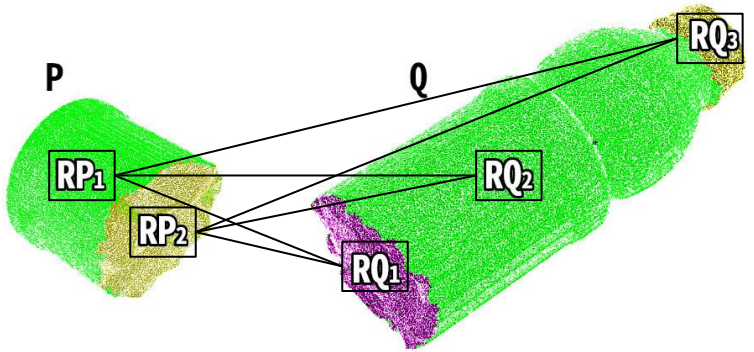
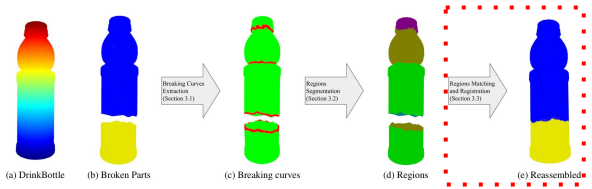


CD	RQ1	RQ2	RQ3
RP1	0.91	0.98	0.97
RP2	0.1	0.9	0.7

Regions Registration



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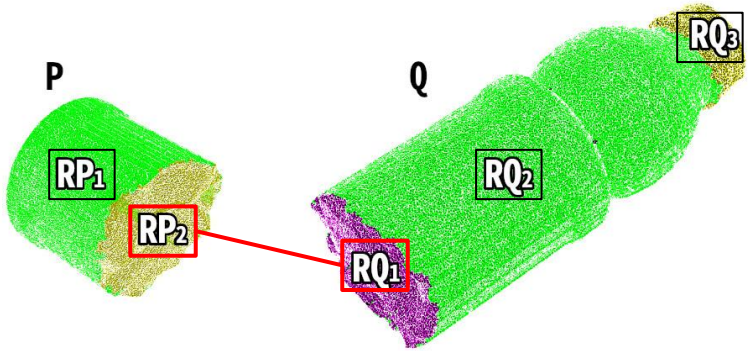

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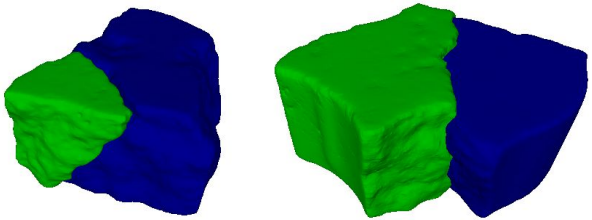
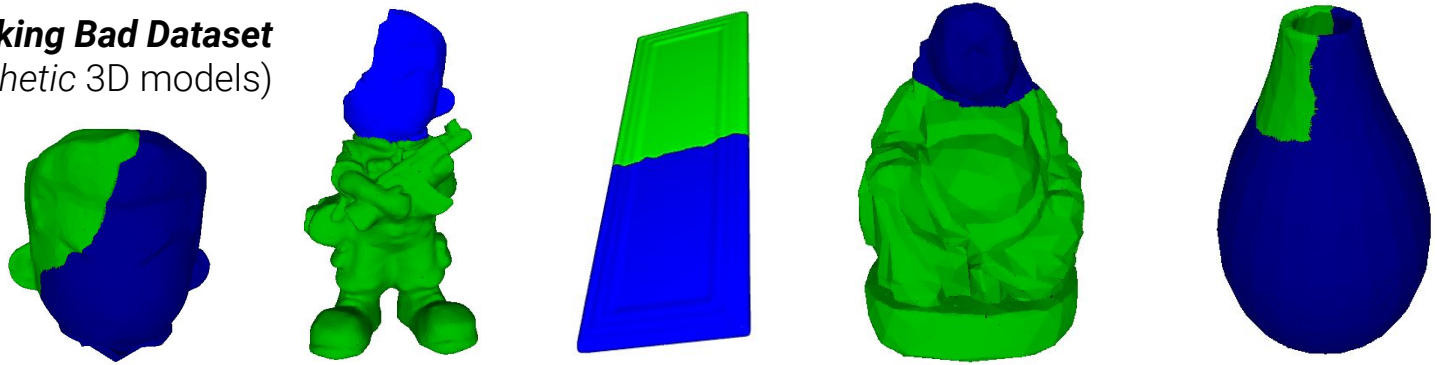
Qualitative Results

Broken Fresco from Pompeii National Park
(3D scan, *real* data, RePAIR Project)

Brick
(3D scan, *real* data, TUWien University)



Breaking Bad Dataset
(*synthetic* 3D models)



Quantitative Results

The proposed model reaches:

- Smaller RMSE in terms of rotation
- Smaller RMSE in terms of translation

Category	Relative RMSE (R)			RMSE (T)		
	ICP [2]	DGL♠ [7]	ours	ICP [2]	DGL♠ [7]	ours
BeerBottle	57.028	78.933	**1.62**	1.104	0.073	**0.02**
WineBottle	54.262	84.699	**1.58**	0.743	0.024	**0.02**
DrinkBottle	60.253	70.014	**1.89**	1.288	**0.008**	0.033
Bottle	68.125	76.802	**1.983**	1.198	0.078	**0.077**
Mug	5.041	86.221	**1.12**	0.364	0.164	**0.025**
Cookie	12.594	85.707	**1.96**	0.632	0.159	**0.043**
Mirror	0.593	81.454	**0.111**	0.503	0.125	**0.001**
ToyFigure	208.333	87.972	**1.98**	4.123	0.159	**0.079**
Statue	105.582	89.605	**0.66**	2.159	0.149	**0.003**
Vase	30.756	82.218	**0.592**	1.496	0.109	**0.002**
Brick♣ [8]	11.577	62.820	**3.064**	2.356	1.684	**0.626**
Repair♣2	7.911	87.491	**3.466**	2.525	**0.076**	0.695

No need for learning

(a) Original (b) Input (c) Proposed (d) DGL [7] (e) ICP [2]

Conclusions

- Best results overall (both R and T)
- Generalization to different categories or model types (agnostic)

https://repairproject.github.io/AAFR/

Future work:

1. Multi-part assembly
2. Enhancing breaking curve extraction methodology to make it more parameter-free

This work is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.964854.