Point MixSwap: Attentional Point Cloud Mixing via Swapping Matched Structural Division

Ardian Umam[1] Cheng-Kun Yang[2] Yung-Yu Chuang[2] Jen-Hui Chuang[1] Yen-Yu Lin[1,3]
[1]National Yang Ming Chiao Tung University [2]National Taiwan University [3]Academia Sinica

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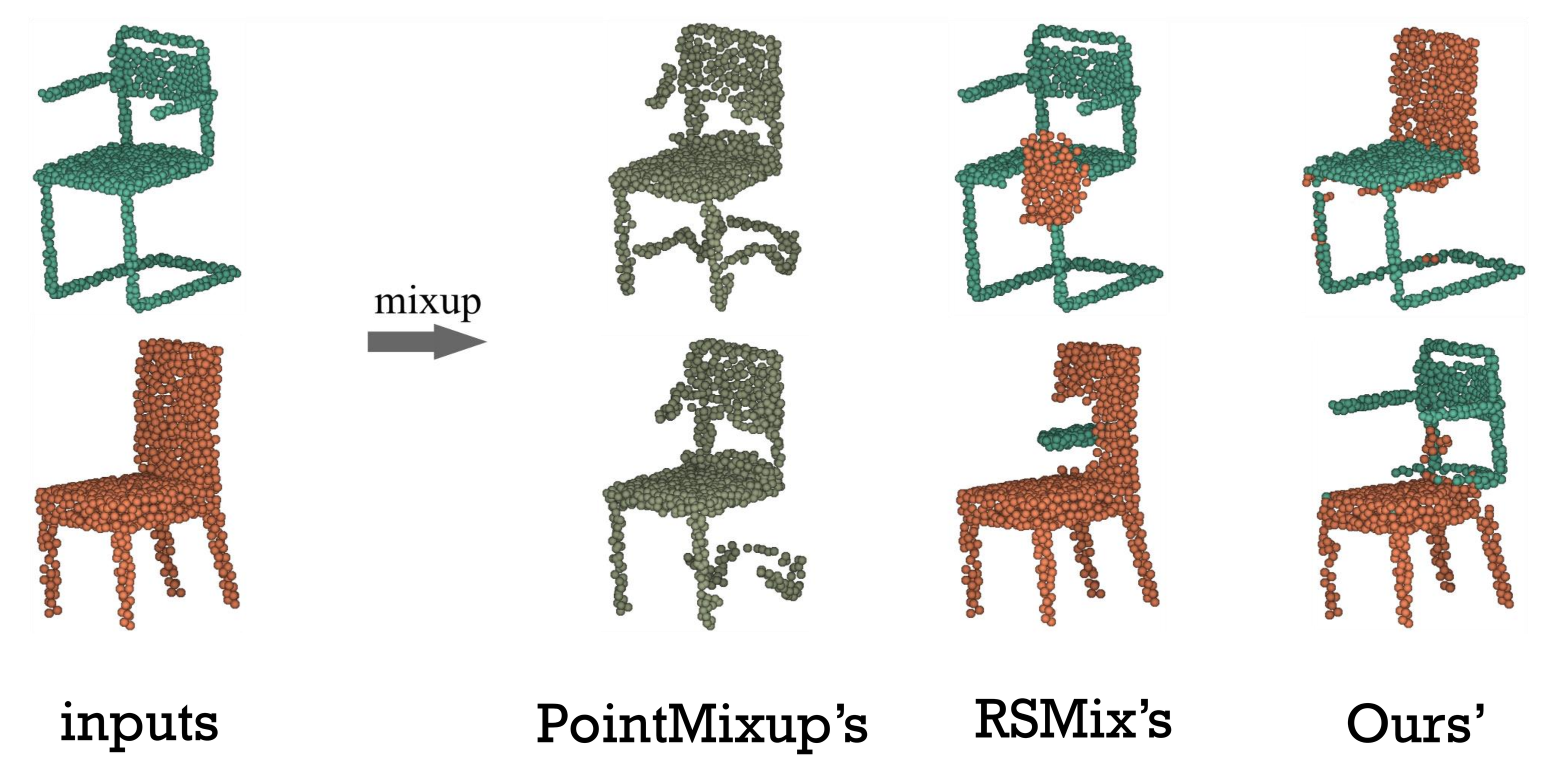
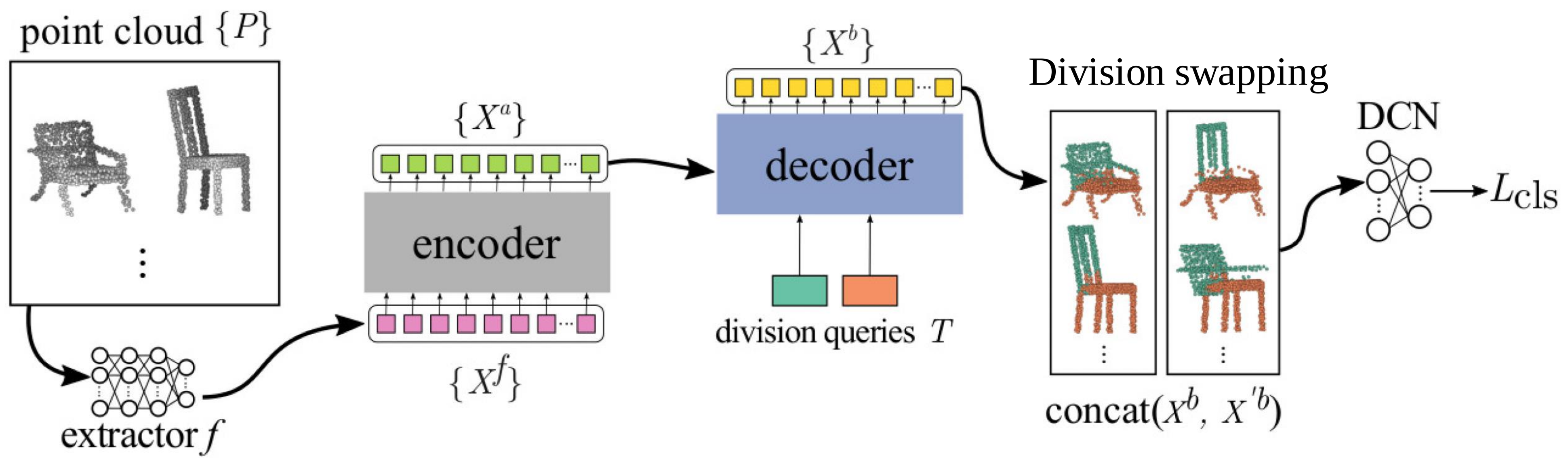
Contributions:

- Introduce an effective technique for synthesizing diverse and realistic point clouds by swapping matched structural divisions, without any part-segmentation labels
  - Develop a novel encoder-decoder structure to decompose point clouds with cross-cloud correspondences
- Mix point clouds to generate augmented data utilizing division queries, leading to significant improvement on point cloud classification
  - Augment point clouds by swapping matched divisions cross different clouds
- Evaluated on both synthetic and real-world datasets
  - ModelNet10, ModelNet40, ScanObjectNN
  - Experiment with all data (100%) and reduced data (20% & 50%)

Observations:

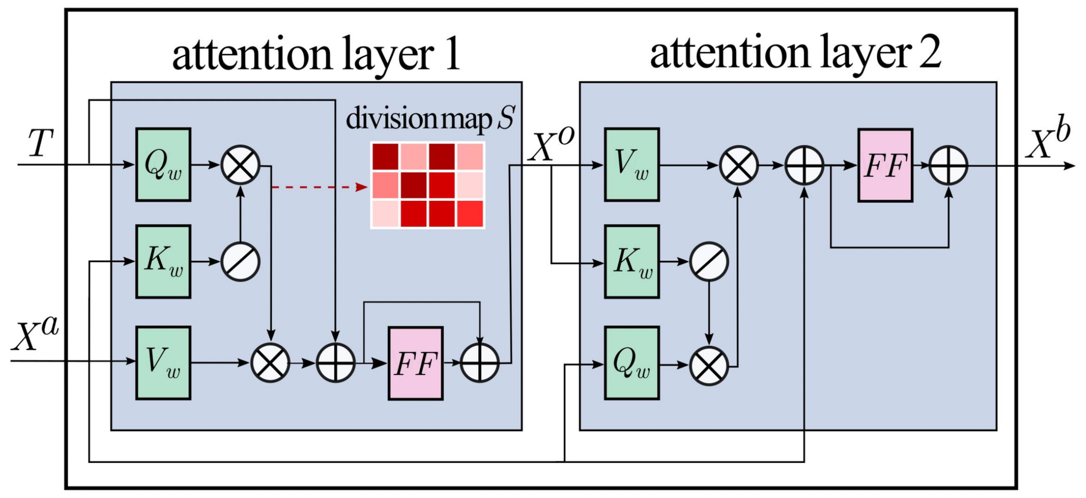
- Existing point cloud mixup methods do not consider the structural information while performing mixup:
  - We generalize the encoder-decoder model to explores inter-cloud division correspondence for division swapping
  - Through the learned division queries, we can divide the point cloud into divisions and synthesize the new point clouds





Designed encoder-decoder architecture:

- The learnable division queries jointly decompose a point cloud into R disjoint subsets, for division swapping
- The query and key-value pairs are switched in the second layer and produce point-specific features



Quantitative results:

- Accuracy scores on ModelNet40 (M40) and ModelNet10 (M10)

Method	Rate 20%		Rate 50%		Rate 100%	
	M40	M10	M40	M10	M40	M10
PointNet	82.1	89.4	85.9	92.7	88.6	93.2
PointNet + Ours	**86.3** (4.2↑)	**91.3** (1.9↑)	**88.7** (2.8↑)	**93.6** (0.9↑)	**90.2** (1.6↑)	**93.9** (0.7↑)
DGCNN	87.5	93.2	91.5	94.3	92.7	94.8
DGCNN + Ours	**91.3** (3.8↑)	**94.6** (1.4↑)	**92.8** (1.3↑)	**94.9** (0.6↑)	**93.5** (0.8↑)	**96.0** (1.2↑)

- Accuracy scores on rotated M40 (RM40) and ScanObjectNN (SON)

Method	Rate 20%		Rate 50%		Rate 100%	
	RM40	SON	RM40	SON	RM40	SON
DGCNN	87.0	73.7	90.3	81.6	91.5	86.2
DGCNN + Ours	89.3 (2.3↑)	76.3 (2.6↑)	91.1 (0.8↑)	84.1 (2.5↑)	**92.3** (0.8↑)	88.6 (2.4↑)
DGCNN + Ours + PAA	**90.1** (3.1↑)	**76.8** (3.1↑)	**91.3** (1.0↑)	**84.8** (3.2↑)	**92.3** (0.8↑)	**89.0** (2.8↑)

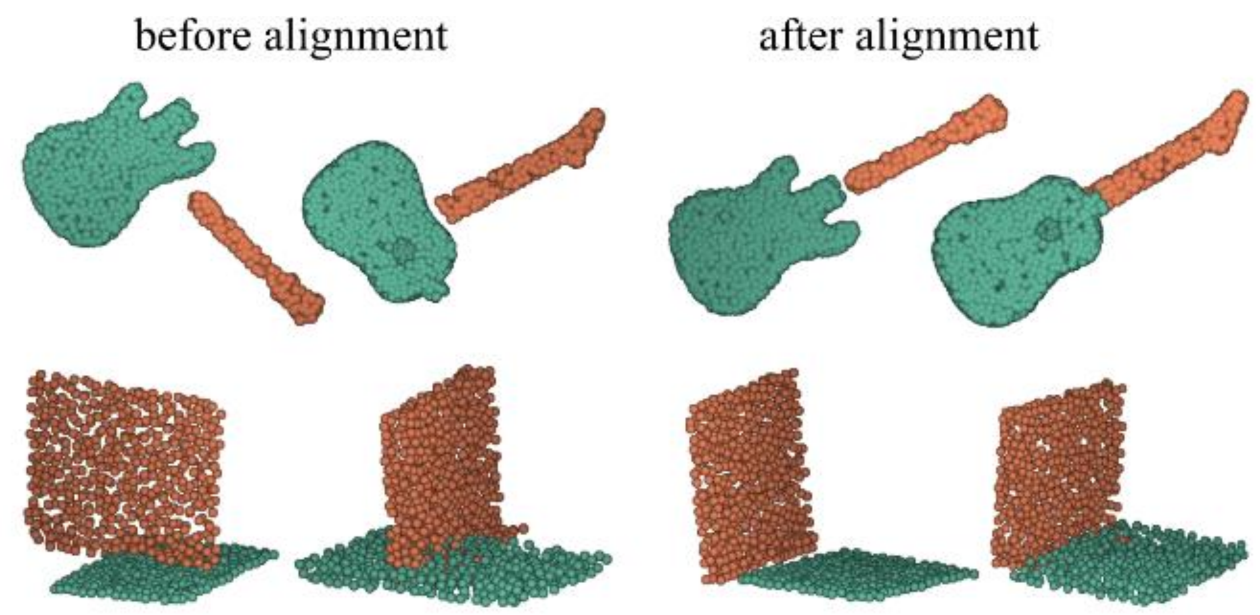
- Comparison with SoTAs (left) and hyper params. analysis (right)

Method	Rate 20%		Rate 100%	
	M40	M10	M40	M10
DGCNN	87.5	93.2	92.6	94.8
DGCNN + PointMixup [3]	89.0	93.8	93.1	95.1
DGCNN + PointAugment [12]	88.6	92.8	93.4	95.2
DGCNN + RSMix [11]	90.1	93.7	**93.5**	95.9
DGCNN + PointWOLF [9]	89.3	93.5	93.2	95.1
DGCNN + Ours	**91.3**	**94.6**	**93.5**	**96.0**

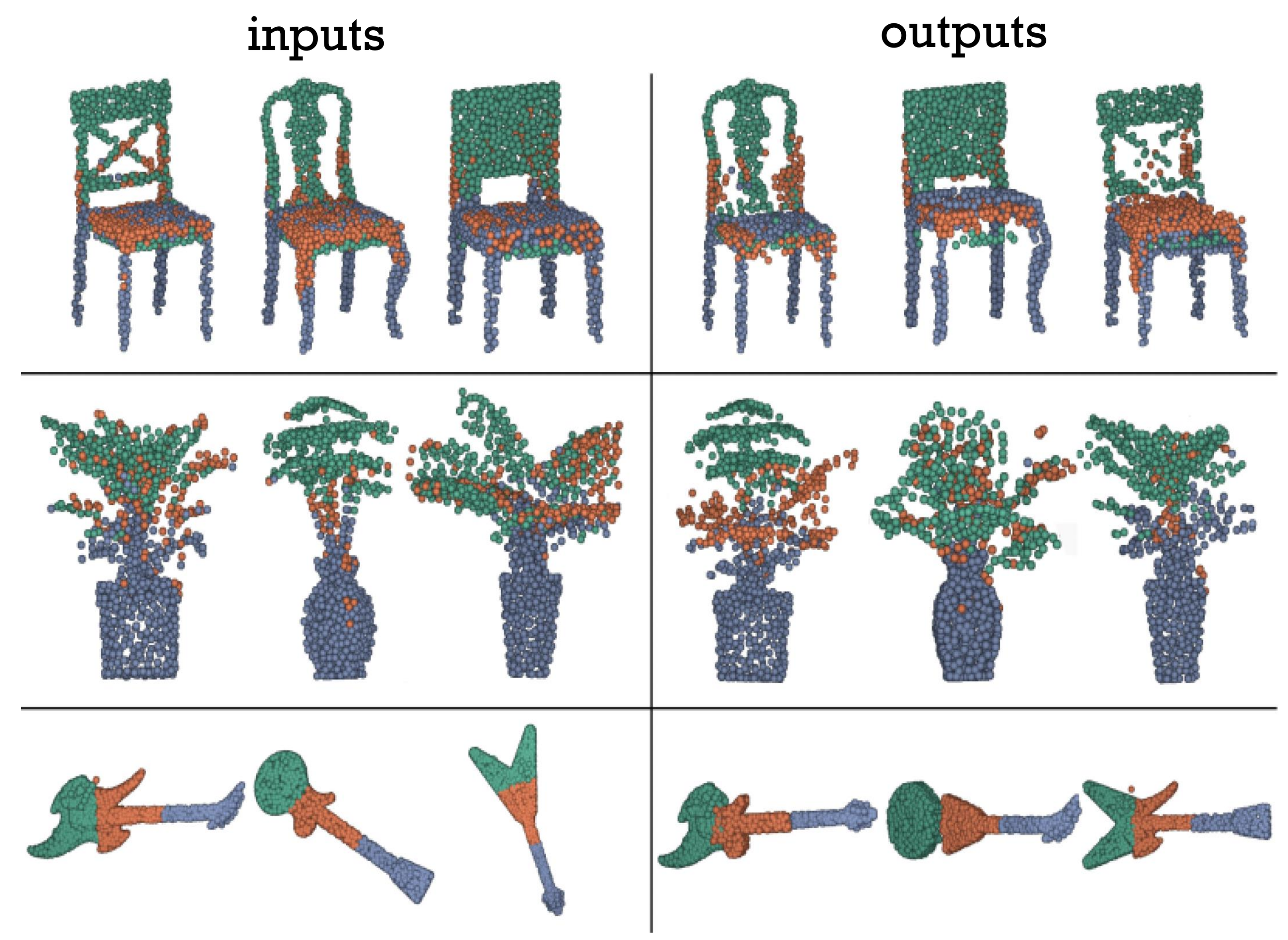
Divisions	Level	M40	M10	SON
2	Input	91.0	94.6	75.9
	Feature	91.1	**94.7**	76.2
3	Input	91.2	94.5	76.1
	Feature	**91.3**	94.6	**76.3**
4	Input	91.0	94.4	75.7
	Feature	91.2	94.6	76.1
5	Input	91.0	94.3	75.5
	Feature	91.2	94.6	76.0

Visualizations:

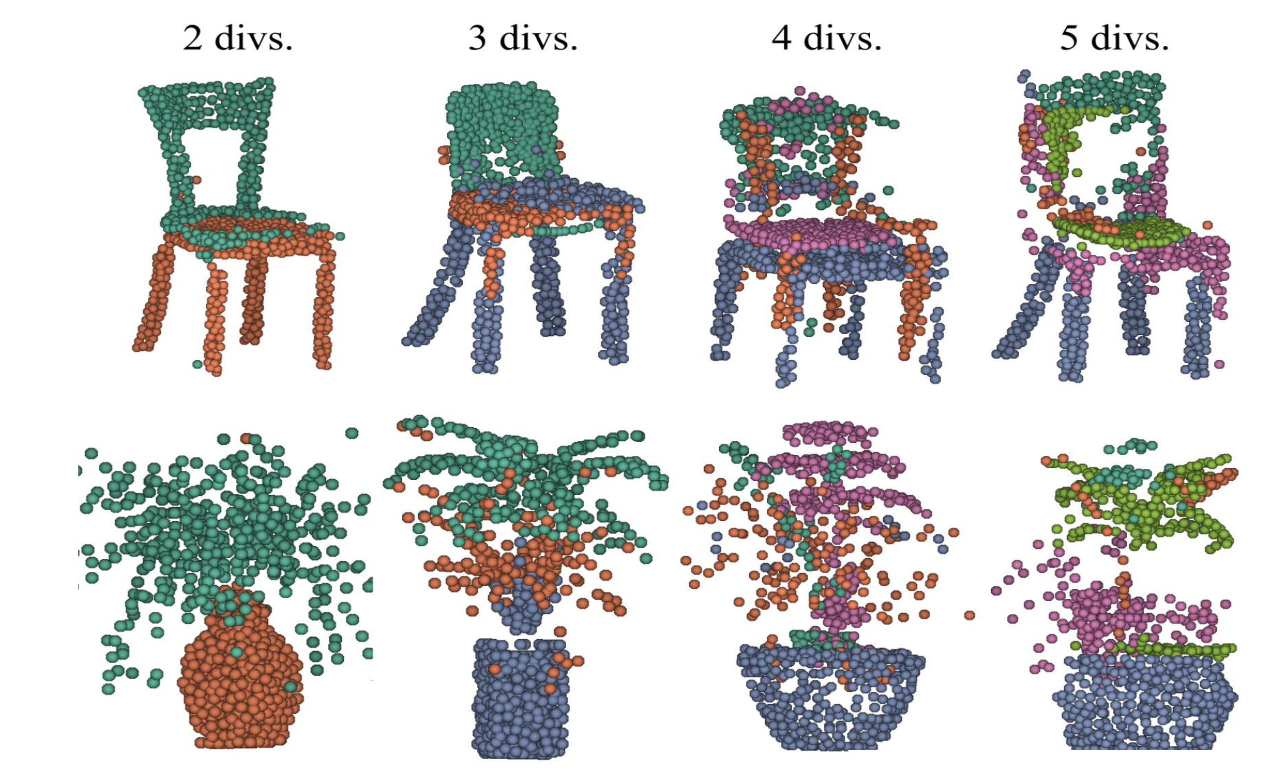
- Mixup samples before-after alignment (PAA)



- Mixup samples input-output using 3 divisions



- Mixup samples on different division numbers



Source code available: