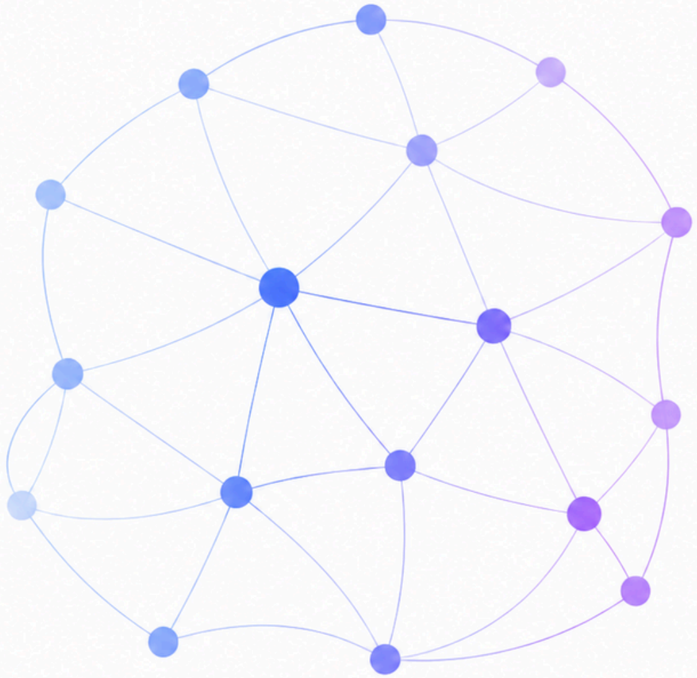
GNNs FOR 3D MODELS GENERATION AND CLASSIFICATION

Applied Machine Learning 2026

Lydia Sakellaridi
Martina Rossi
Tommaso Guarniera



PyG

Can a GNN learn to classify and generate 3D objects?

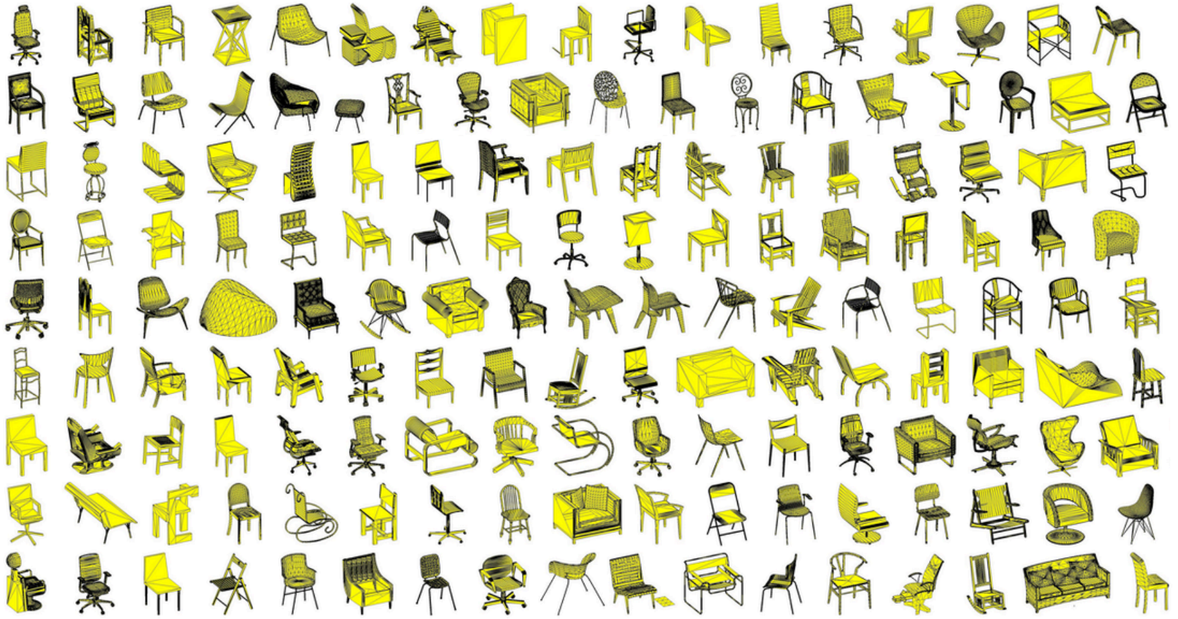
In this project, we present:

1. **Dataset**: ModelNet40 3D objects represented as point clouds
2. **Methodology**: GNN-based classification and generative modeling pipeline
3. **Classification results**: comparison of baseline, AE-pretrained, and SO(3)-invariant models
4. **Generation results**: reconstruction and generation of 3D point-cloud objects - Conditional Variational Graph Autoencoder
5. **Real-world testing**: object scanning experiments and model performance on scanned data

Why do we need models able to classify and generate 3D objects?

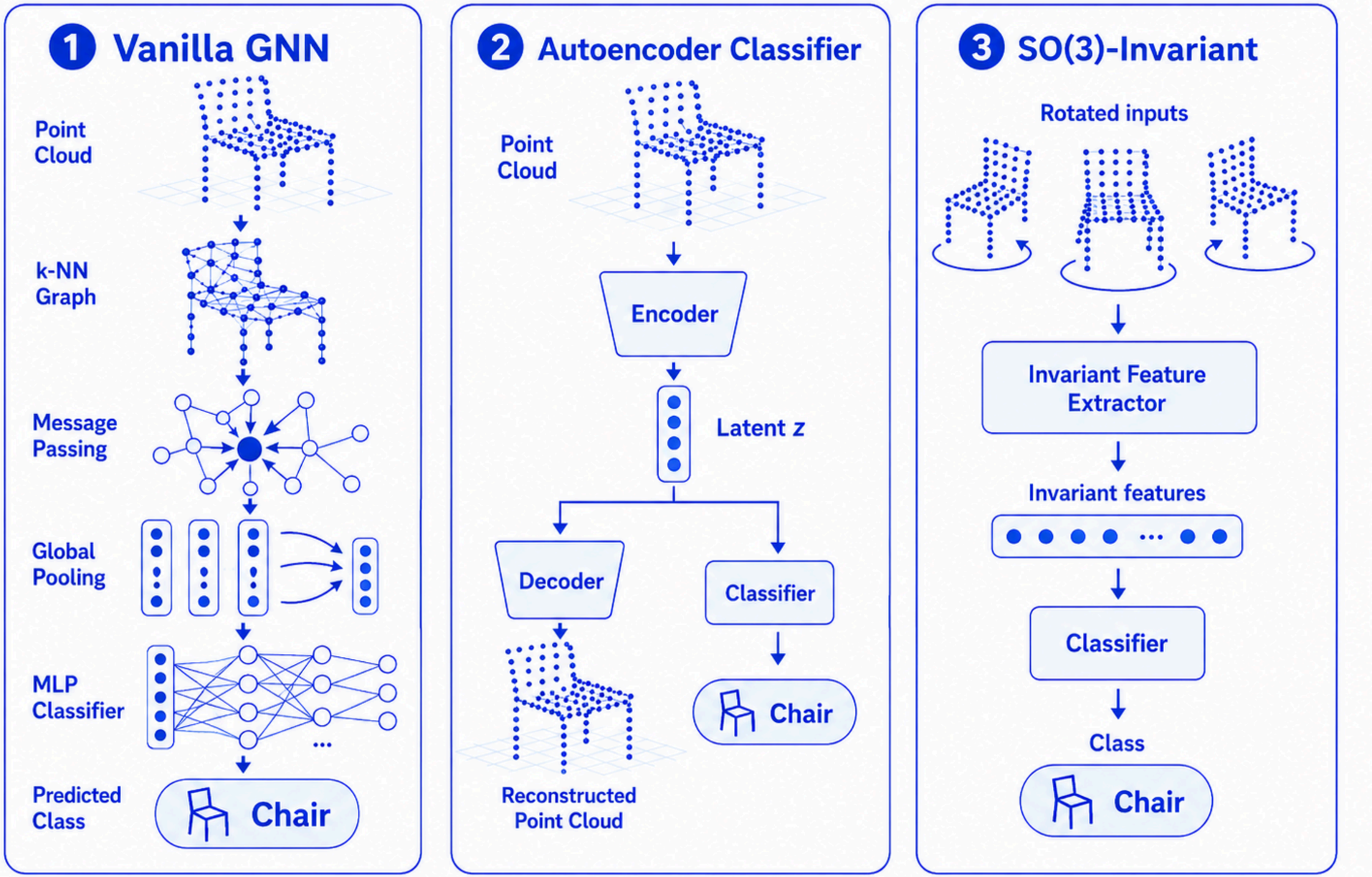
- **Navigation and mobility** - Spatial guidance and obstacle avoidance
- **Robotics** - object recognition and manipulation
- **Healthcare** - Medical imaging analysis
- **Industry & Manufacturin** - Industrial inspection
- **Entertainment & Content Creation** - gaming and virtual word

Dataset: ModelNet40 Point Clouds



- 12,311 graphs
- 2,048 sampled nodes
- KNN edges

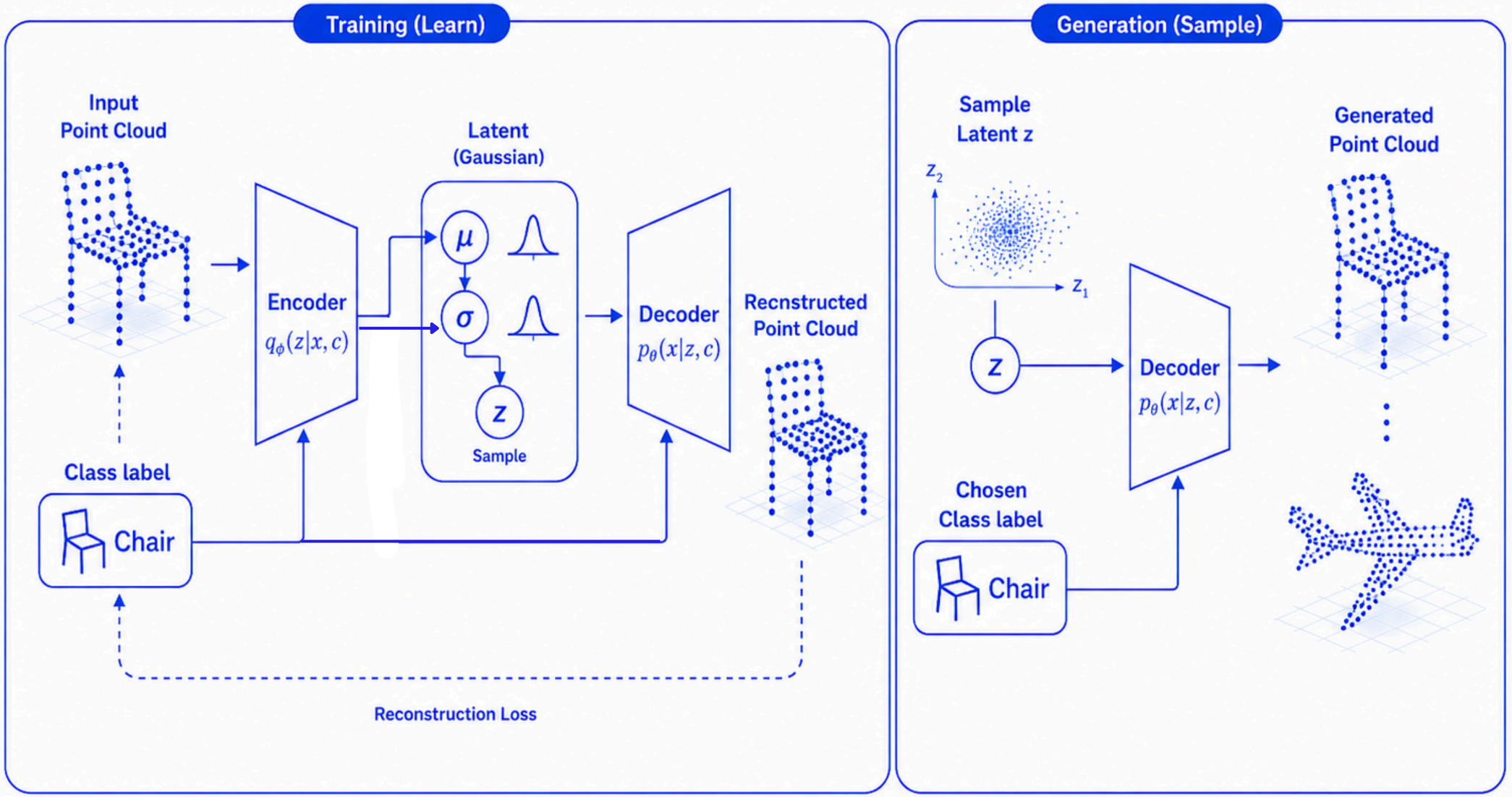
Dataset: ModelNet40 Point Clouds



# params:	851,624	2,034,232	853,288

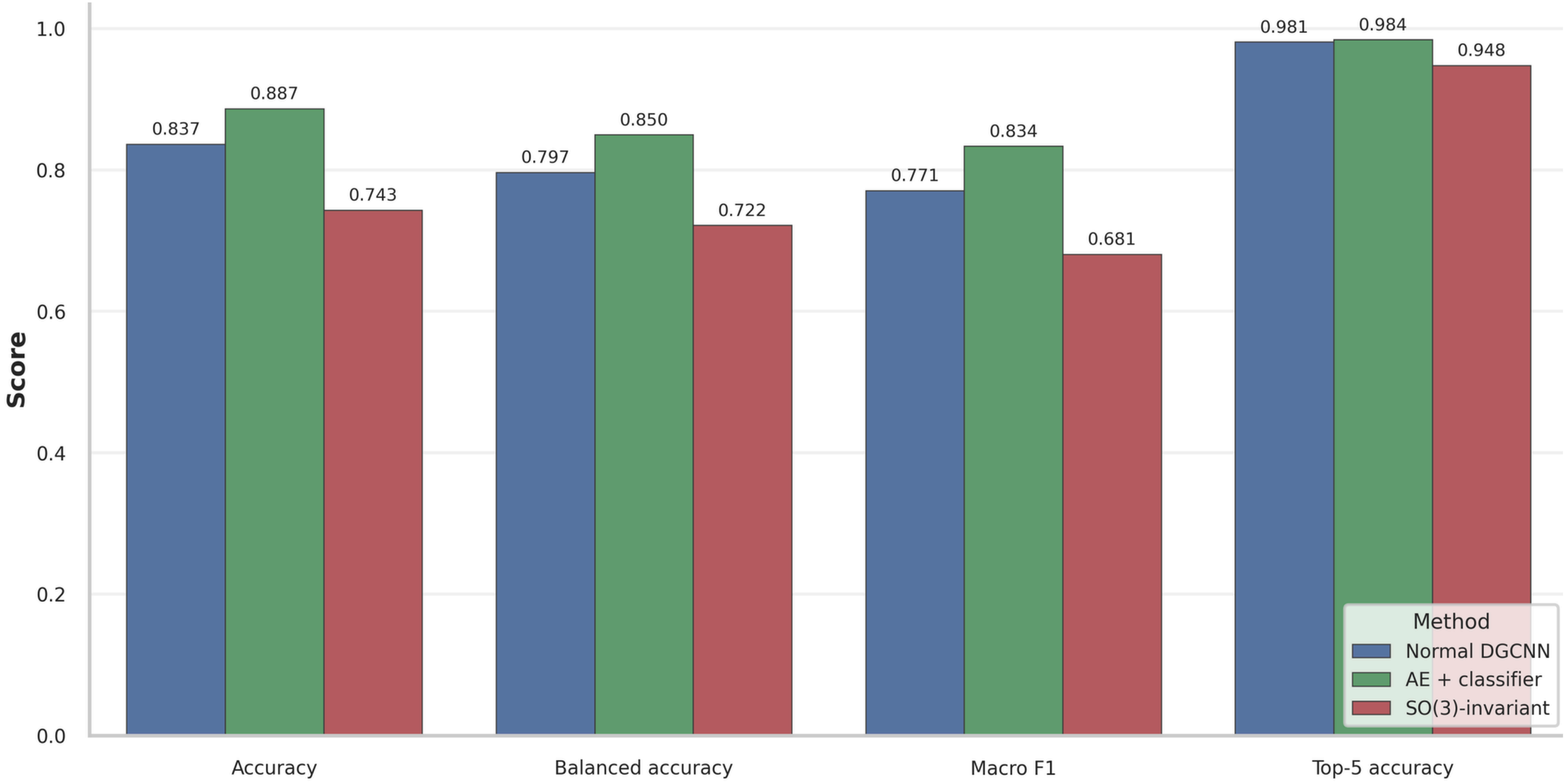
Generation Method

Conditional VAE (CVAE) # params: 2,572,295



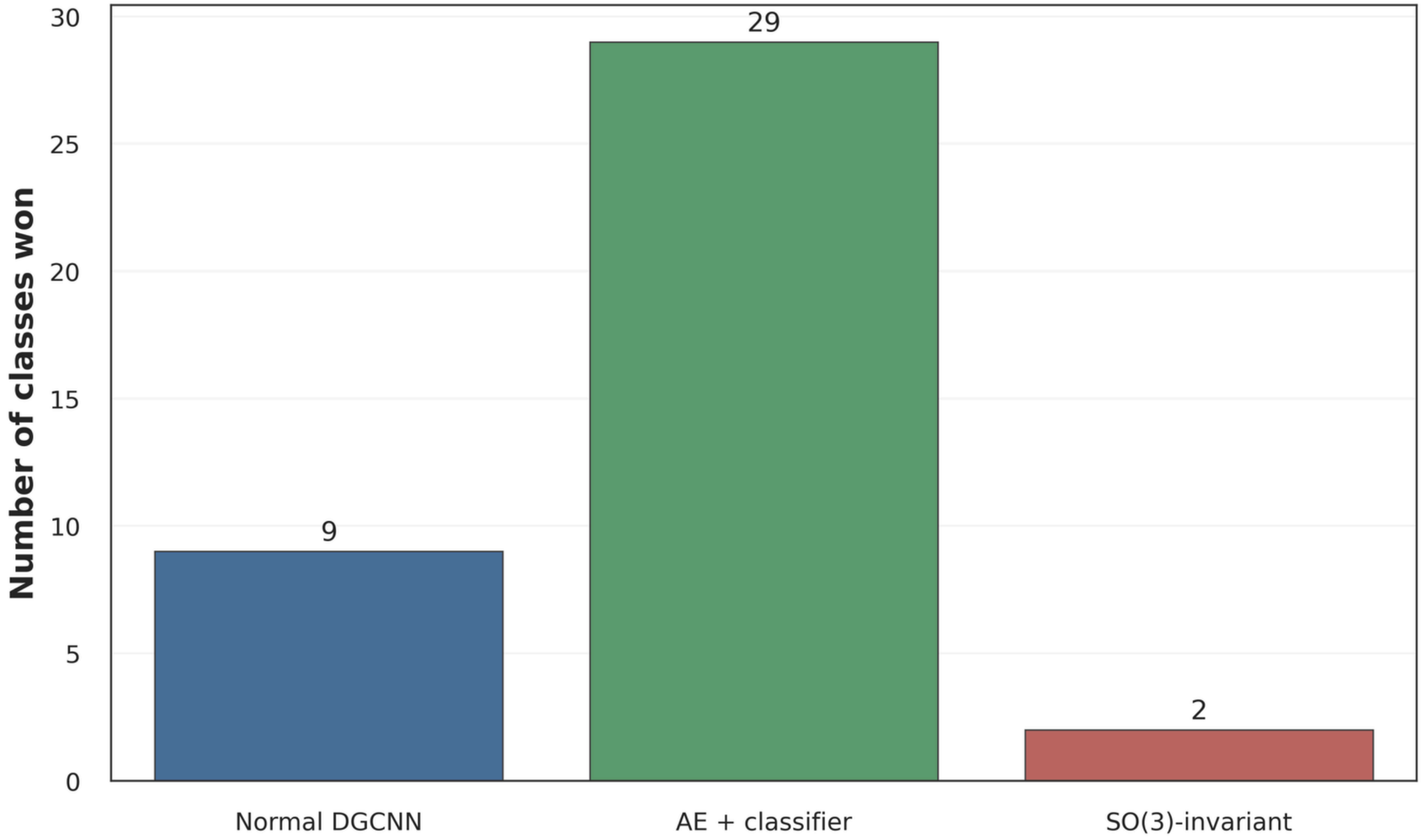
Results: Classification

Classification performance comparison



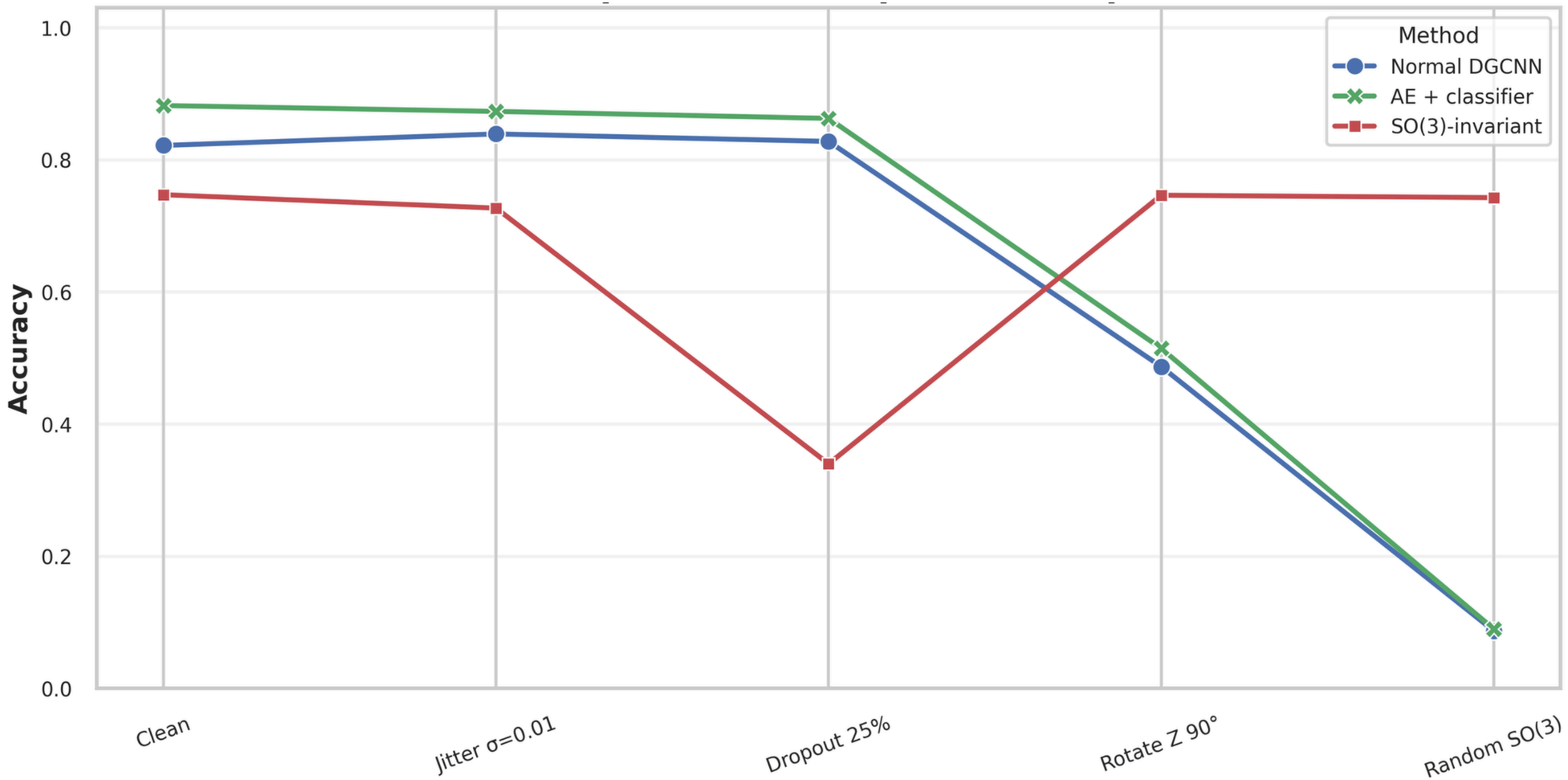
Results: Classification

How many classes each method wins (per-class F1)



Results: Classification

Robustness comparison under point-cloud pertubations

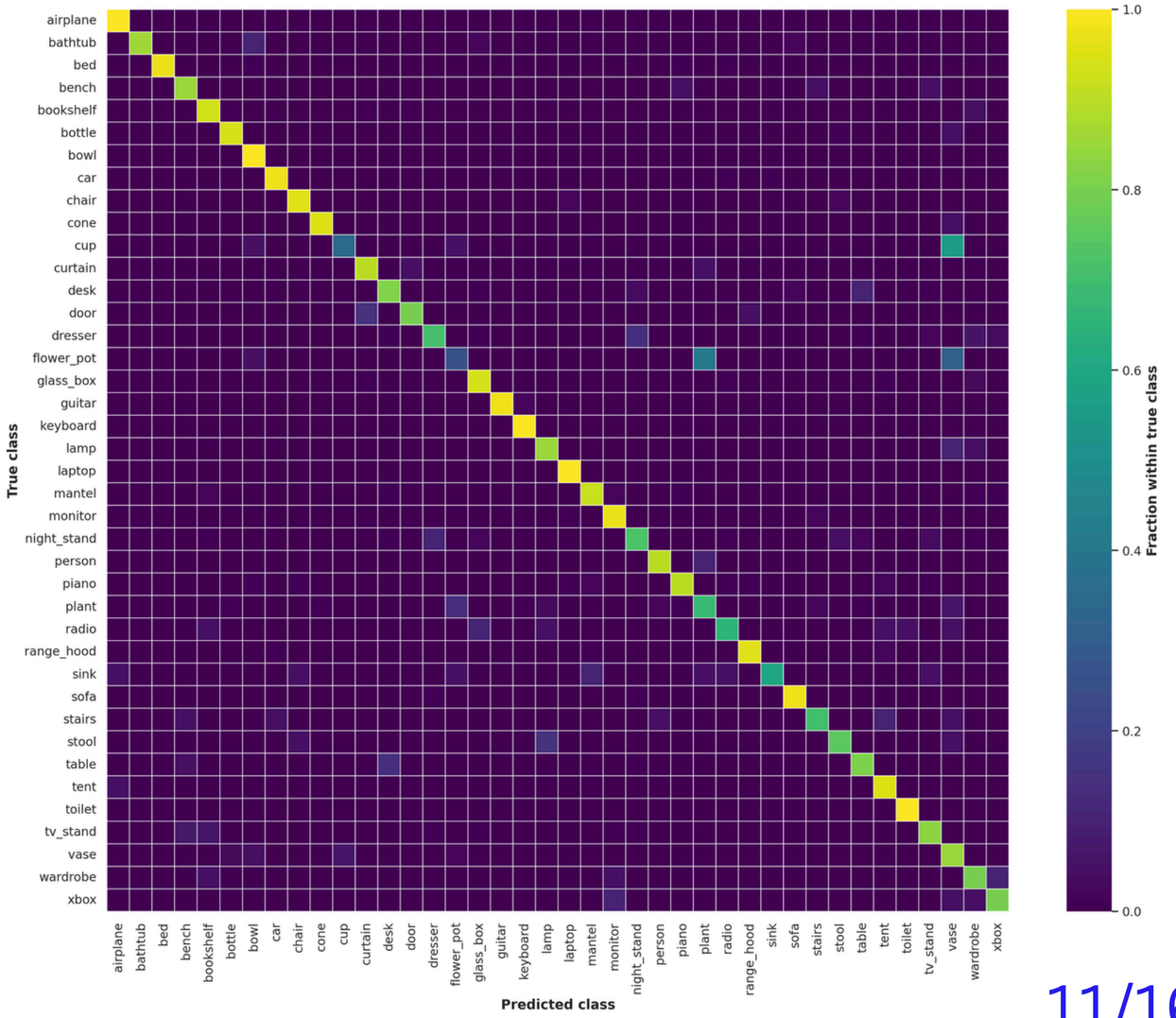


Results: Classification

Normalized confusion matrix - AE classifier

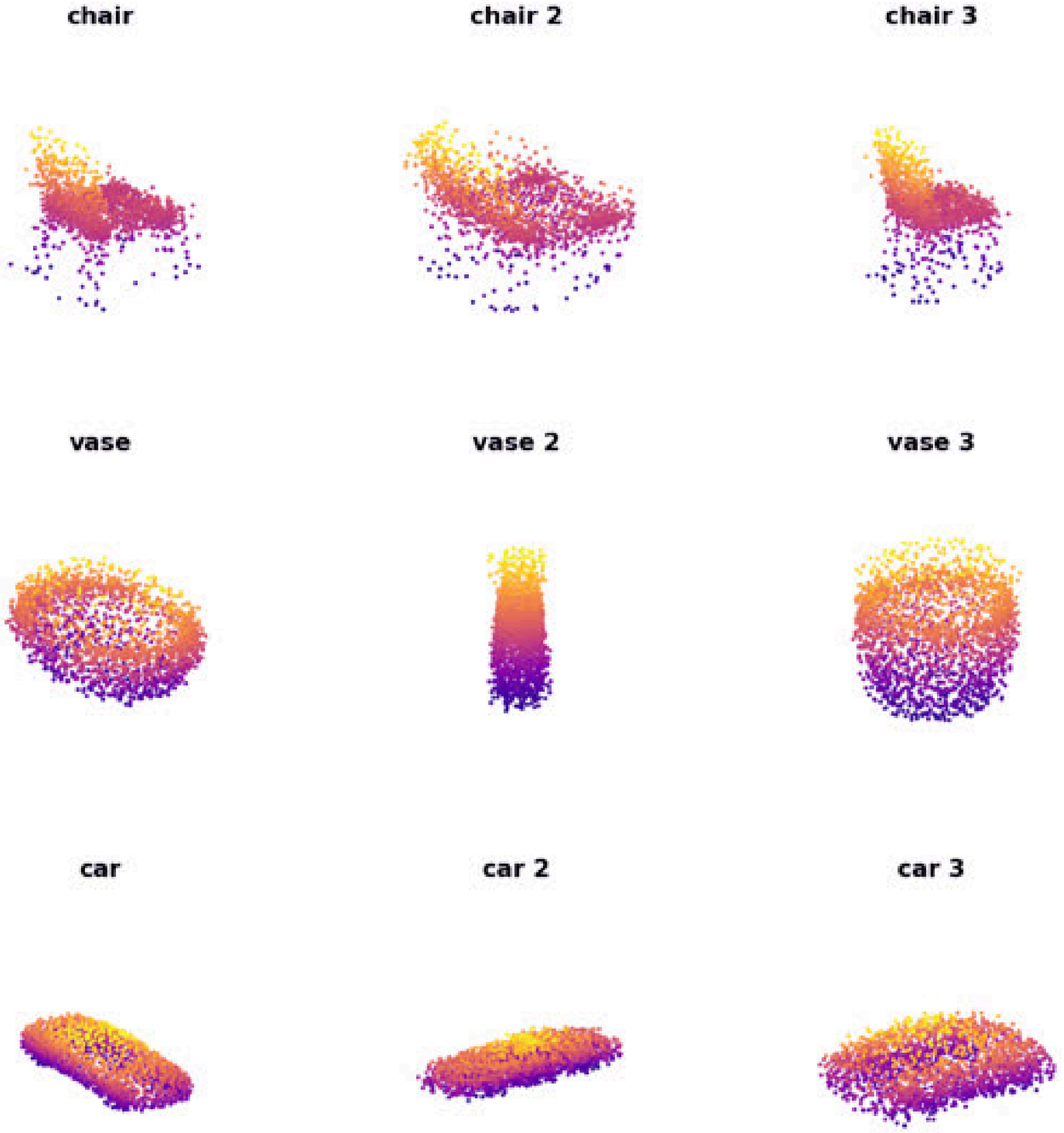
Top 5 misclassification pairs:

1. plant → flower_pot
2. table → desk
3. dresser → night_stand
4. cup → vase
5. night_stand → dresser

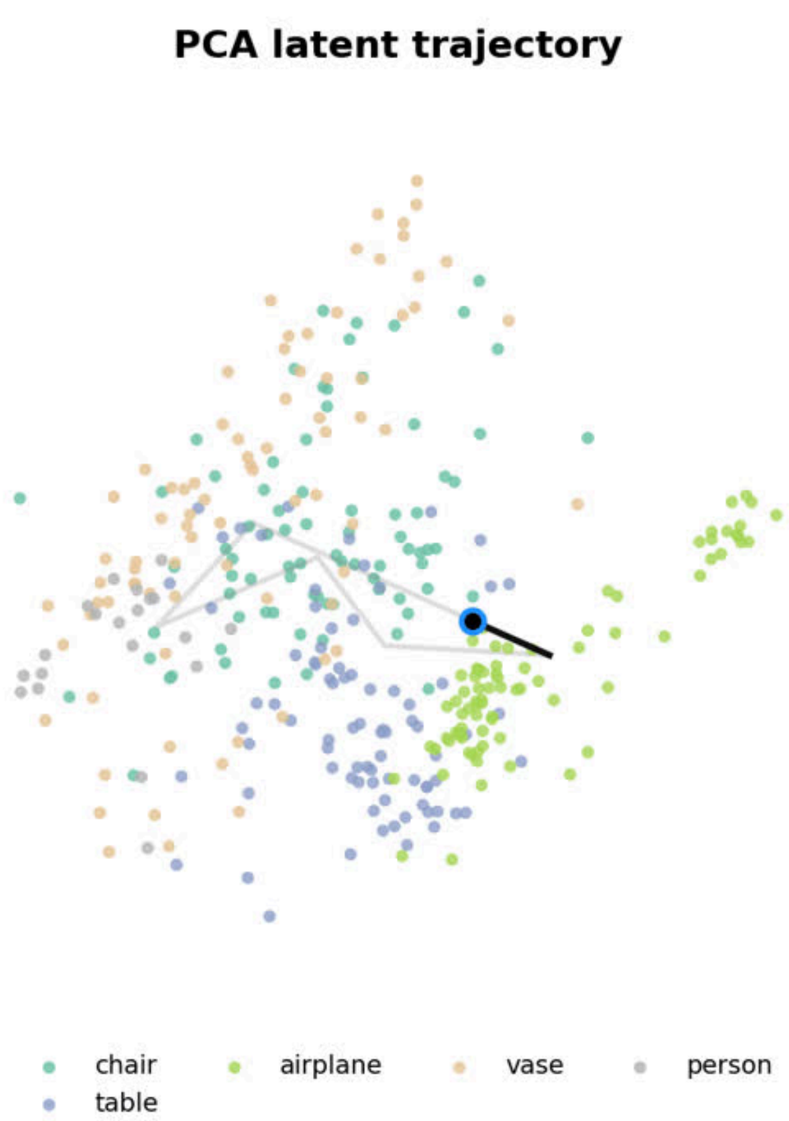


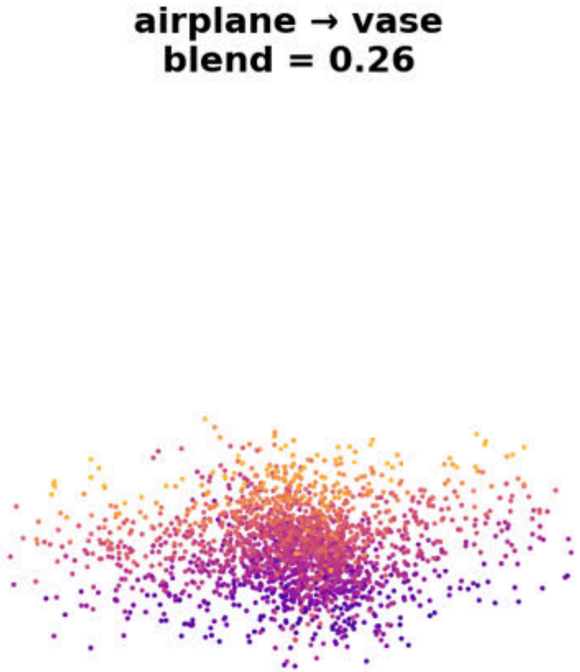
Results: Generation

Gallery of generated samples using CVAE

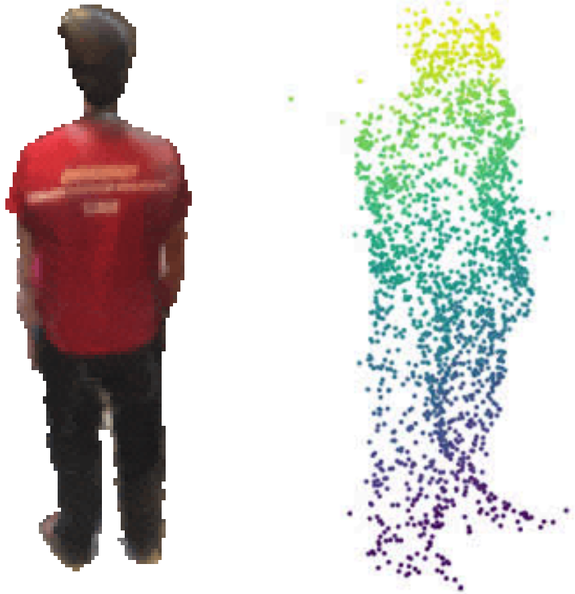


Results: Generation





Results: Real world objects



Vanilla GNN Classifier

Best: person (80.8%)

1. person	80.8%
2. plant	10.5%
3. stool	4.7%
4. door	2.0%
5. curtain	0.7%

Autoencoder Classifier

Best: person (86.2%)

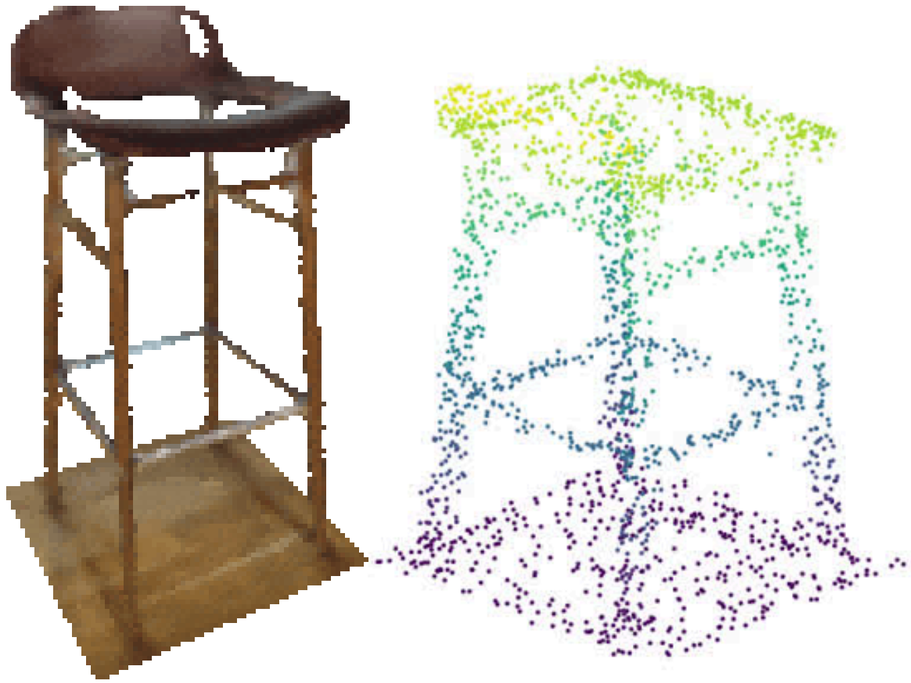
1. person	86.2%
2. flower_pot	4.9%
3. plant	4.3%
4. vase	2.0%
5. curtain	1.2%

SO(3) Invariant Classifier

Best: person (96.1%)

1. person	96.1%
2. airplane	3.1%
3. vase	0.3%
4. bottle	0.1%
5. tent	0.1%

Results: Real world objects



Vanilla GNN Classifier

Best: stool (96.7%)

1. stool	96.7%
2. table	1.0%
3. chair	1.0%
4. sink	0.5%
5. lamp	0.5%

Autoencoder Classifier

Best: stool (97.8%)

1. stool	97.8%
2. bookshelf	0.5%
3. vase	0.5%
4. chair	0.4%
5. night_stand	0.3%

SO(3) Invariant Classifier

Best: stool (57.0%)

1. stool	57.0%
2. desk	9.7%
3. sink	7.2%
4. table	6.1%
5. flower_pot	3.2%

PROBLEMS AND DIRECTIONS

Current problems:

1. Limited data for generation

2. Ambiguous object classes

3. High compute power needed

Future directions:

1. Train on a larger and more diverse dataset

2. Improve Chamfer distance efficiency

3. Implement SO(3) invariance in autoencoders

THANKS!

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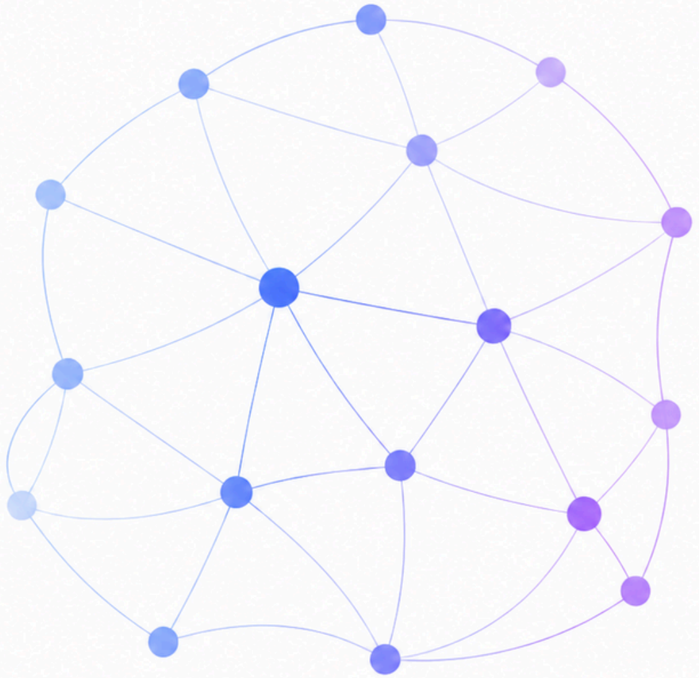

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APPENDIX

3D Point-Cloud Model Setup Details

- Dataset: ModelNet40-style point clouds
- Number of classes: 40
- Points per object: 2,048
- Point features: XYZ coordinates
- Graph construction: k-nearest neighbors
- K value: 20

APPENDIX

1. Vanilla GNN Classifier

Total parameters: 851,624

Architecture

- Input point cloud: 2048 × 3
- Build dynamic KNN graph
- Apply DGCNN / EdgeConv blocks
- Concatenate learned point features
- Apply global mean pooling and max pooling
- Use classifier MLP
- Output: 40 class probabilities

APPENDIX

2. Autoencoder Classifier

Total parameters: 2,034,232

Architecture

- Input point cloud: 2048 × 3
- DGCNN-style encoder extracts point-cloud features
- Bottleneck compresses the object into a latent vector
- Decoder reconstructs the point cloud
- Classification head uses the latent representation
- Output: 40 class probabilities

APPENDIX

3. SO(3)-Invariant Classifier

Total parameters: 853,288

Architecture

- Input point cloud: 2048 × 3
- Center and normalize point cloud
- Build KNN graph
- Use rotation-invariant scalar features:
  - radius
  - radius²
  - distance between points
- Apply invariant message-passing blocks
- Apply global mean pooling and max pooling
- Use classifier MLP
- **Output: 40 class probabilities**

APPENDIX

4. Graph CVAE

Total parameters: 2,572,295

Architecture

- Input point cloud: 2048 × 3
- Input class label: one of 40 classes
- Label embedding adds class information
- DGCNN-style encoder extracts object features
- Encoder predicts latent distribution:
  - mean
  - log variance
- Sample latent vector z
- Decoder generates a point cloud conditioned on:
  - latent vector
  - class label