PU-Dense: Sparse Tensor-Based Point Cloud Geometry Upsampling

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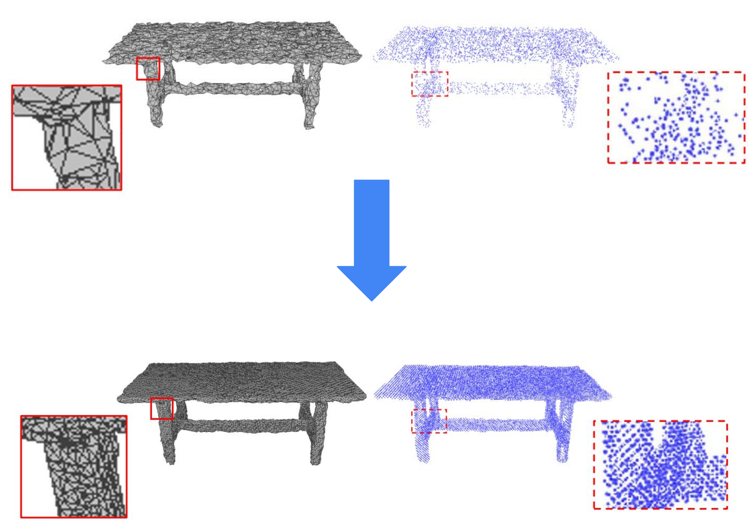
GOAL

INPUT
Sparse point cloud

OUTPUT
Upsampled dense point cloud



PREVIOUS WORK

OPTIMIZATION BASED

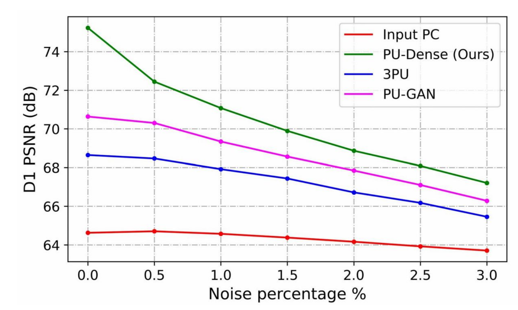
- requires additional attributes
- computationally intensive
- not scalable to large point clouds

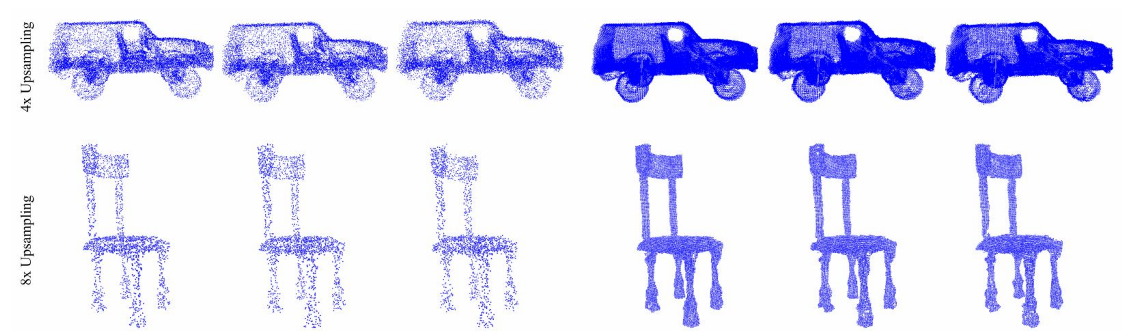
DEEP LEARNING BASED

- unable to learn from global context
- small fixed input size
- based on method for 2D, inefficient for 3D
- computationally intensive
- memory issues

CONTRIBUTIONS

- Hierarchical U-Net encoder-decoder structure
- Fully-convolutional geometry upsampling method
- Variable input size
- Translation invariant
- Works on both sparse and dense point clouds
- Faster and memory-efficient
- Robust against noise





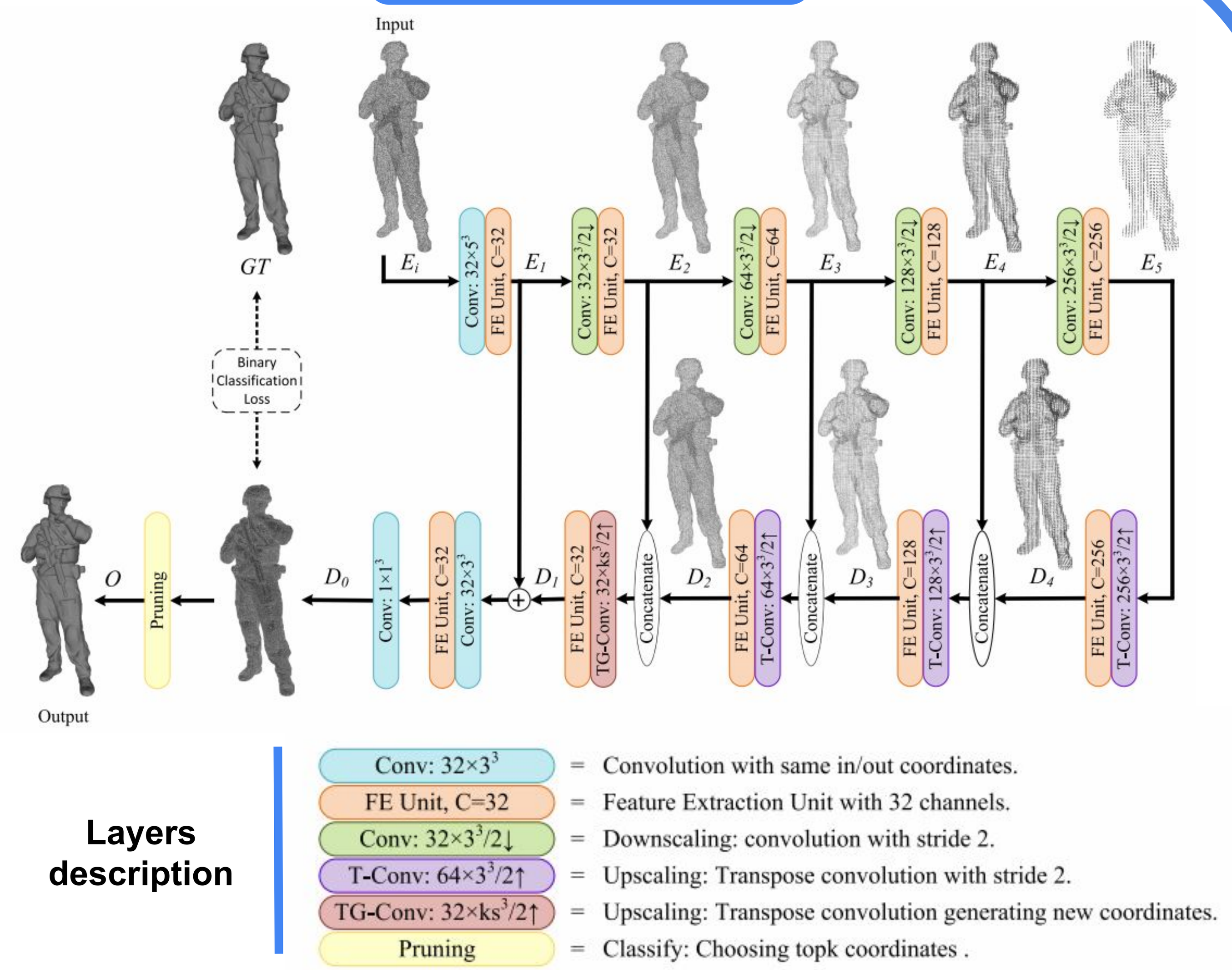
Input with noise from ShapeNet (Gaussian 0% 1% 2%)

Results of upsampling

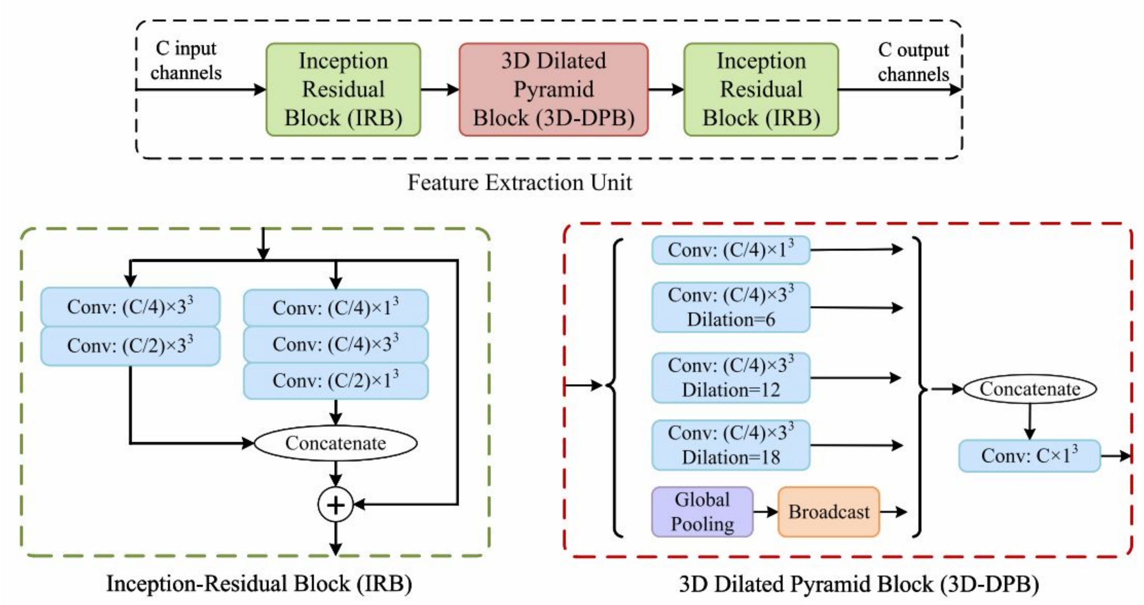
PREPROCESSING

1) **voxelization**
   - ➢ allows the use of 3D convolutions to learn 3D features
2) to each voxel assign **feature f**
   - ➢ *f (x,y,z) = 1* if occupied
   - ➢ *f (x,y,z) = 0* otherwise
3) **data tensor** with
   - ➢ a set of coordinates *C*
   - ➢ their associated features *F*

MODEL



FEATURE EXTRACTOR:



LOSS FUNCTION:

voxel-based binary occupancy classification loss

- ➢ allows to process millions of points at a time

DATASETS

TRAIN
ShapeNet: mesh based

TEST

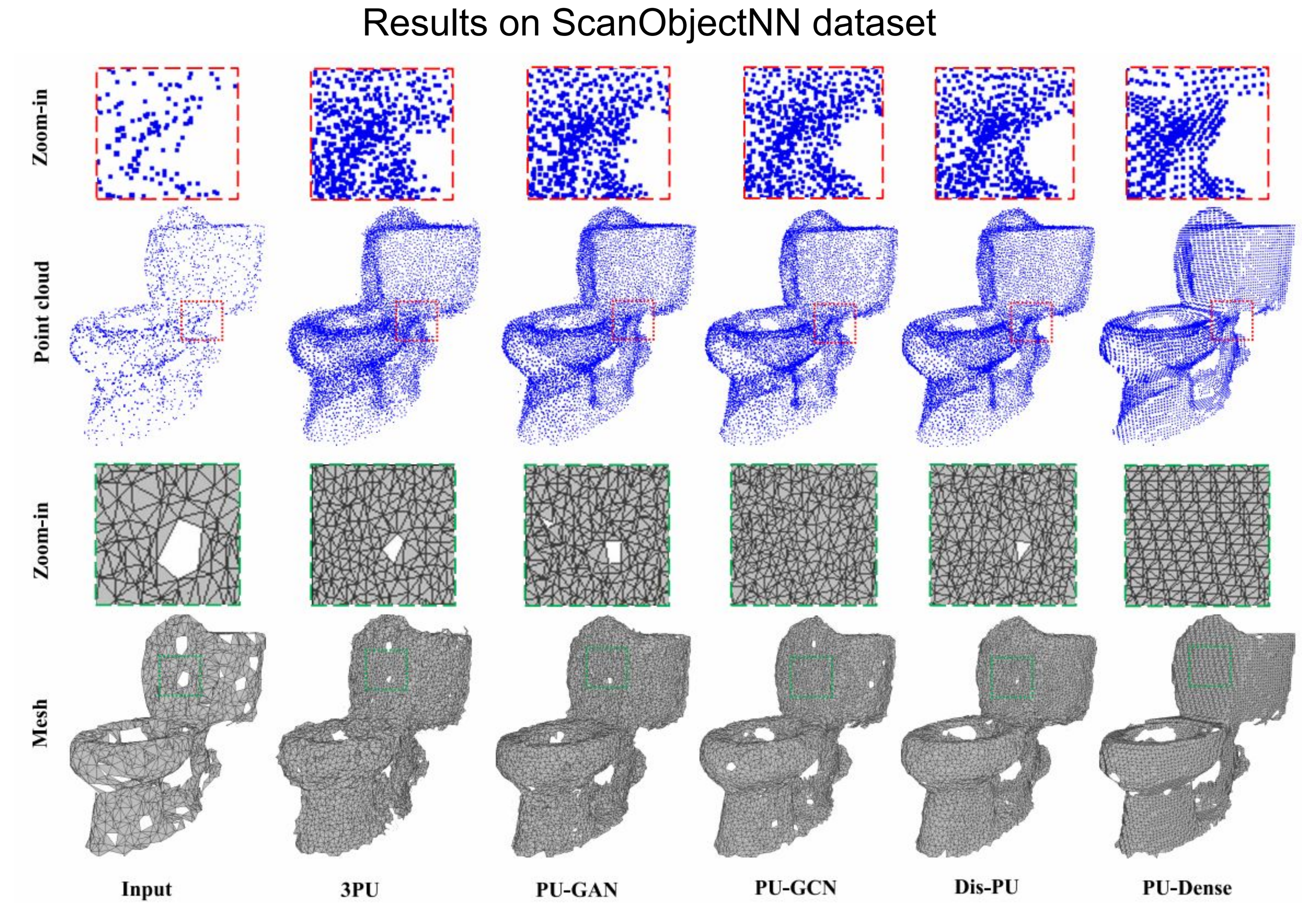
- mesh based: ShapeNet
- dynamic: 8iVFB, 8iVSLF, Technicolor
- sparse: ScanObjectNN, KITTI

RESULTS

Dataset	Upsampling Method	4x CD (10^{-2}) ↓	4x MSE PSNR (dB) ↑	8x CD (10^{-2}) ↓	8x MSE PSNR (dB) ↑
ShapeNet	Downsampled PC	108.18	64.63	199.94	61.96
	3PU	76.36	68.65	149.20	65.37
	PU-GAN	49.41	70.64	174.58	64.88
	PU-GCN	48.15	70.90	65.81	69.59
	Dis-PU	36.23	72.19	55.62	70.23
	PU-Dense (Ours)	**18.82**	**75.24**	**30.52**	**73.11**
8iVFB	Downsampled PC	114.63	64.38	222.91	61.49
	3PU	67.04	69.41	105.43	66.83
	PU-GAN	45.60	70.92	117.66	66.19
	PU-GCN	46.30	70.96	63.71	69.78
	Dis-PU	32.47	72.72	51.68	70.59
	PU-Dense (Ours)	**19.38**	**75.05**	**33.18**	**72.57**

Metrics: Chamfer Distance, Mean Squared Error Peak Signal-to-Noise Ratio

Results on ScanObjectNN dataset



Upsampling Method	Trainable parameters	Inference time (sec)	Computation time (min)
3PU	152,054	123.76	24.49
PU-GAN	541,601	31.55	23.60
PU-GCN	75,971	**19.64**	23.20
Dis-PU	1,046,966	34.13	23.77
PU-Dense (Ours)	**13,172,441**	40.76	**00.79**

LIMITATION:

not suitable for inpainting