FOLDING-BASED COMPRESSION OF POINT CLOUD ATTRIBUTES

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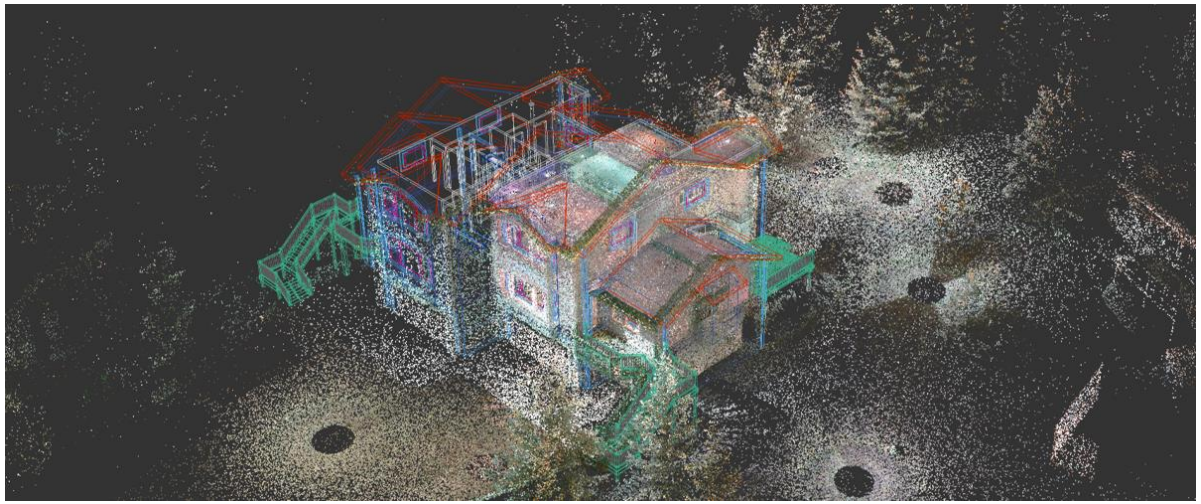
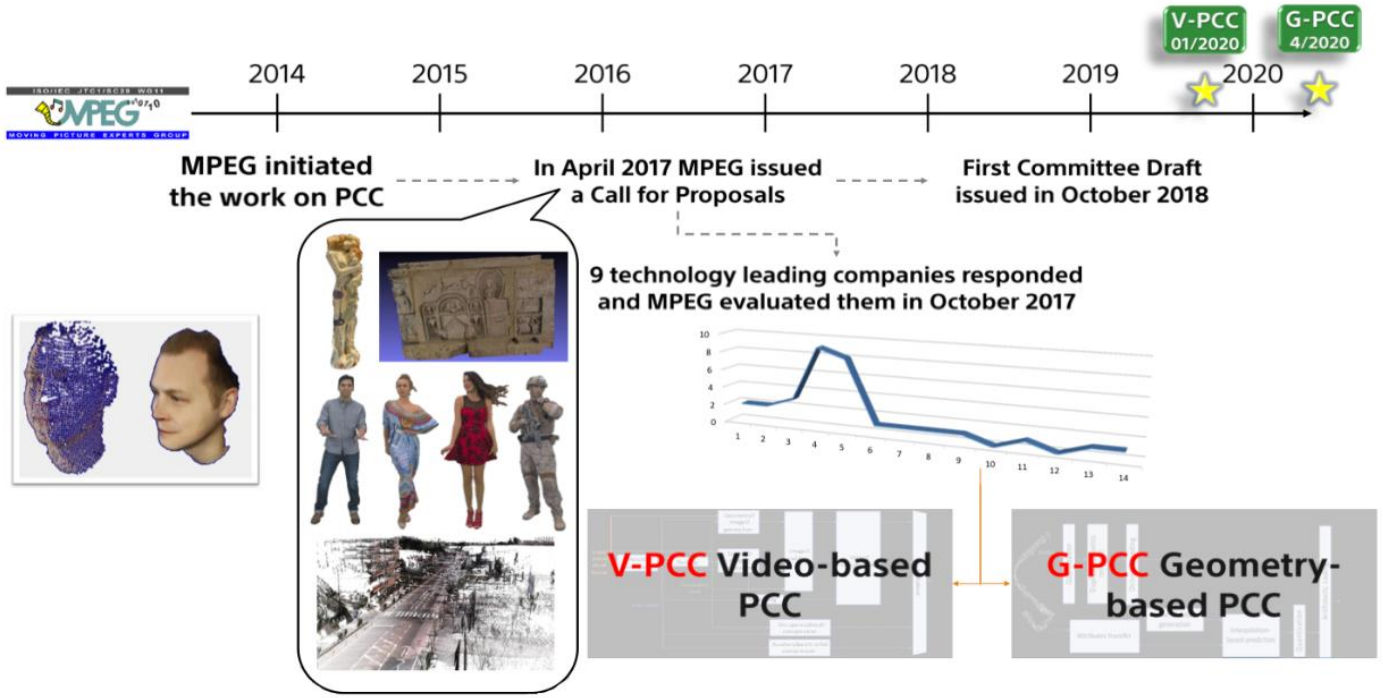
ID: REVERY ANR-17-CE23-0020

Point Cloud

- Set of (x, y, z) elements
- Point attributes: colors, normals...



MPEG Point Cloud Compression (PCC)



from Danillo Graziosi

Point Cloud Compression Attributes

- Previous work
  - Graph transform [1]
  - Gaussian process transform [2]
  - Region-Adaptive Hierarchical Transform (RAHT) [3]
  - Volumetric functions [4]
- Our work
  - Interpret point clouds as 2D manifolds in 3D space
  - Obtain a 2D parameterization of the point cloud
  - Compress attributes using image compression

References

[1] C. Zhang, D. Florêncio, and C. Loop, 'Point cloud attribute compression with graph transform', in *2014 IEEE International Conference on Image Processing (ICIP)*, Oct. 2014, pp. 2066–2070, doi: 10.1109/ICIP.2014.7025414.

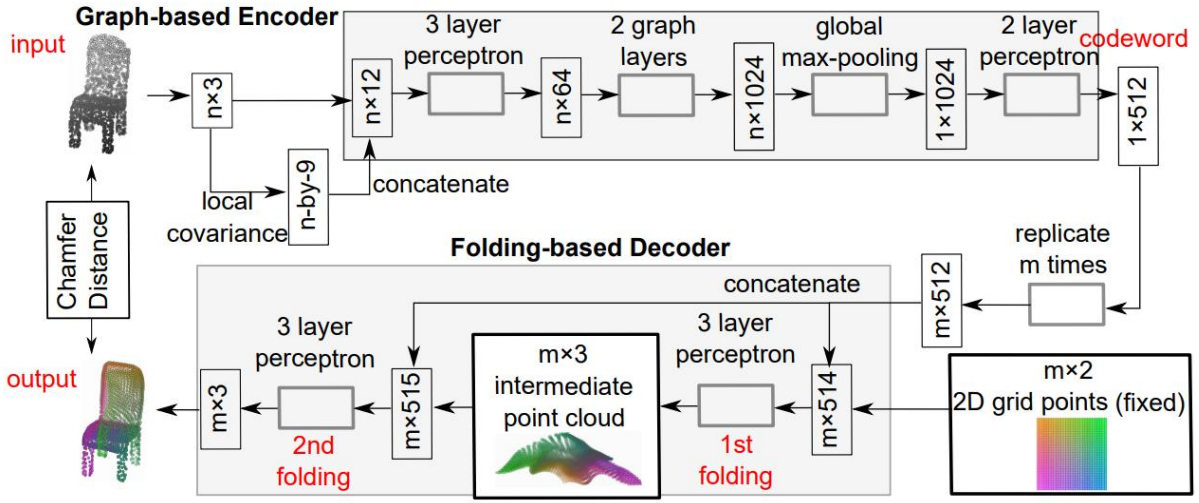
[2] P. A. Chou and R. L. de Queiroz, 'Gaussian process transforms', in *2016 IEEE International Conference on Image Processing (ICIP)*, Sep. 2016, pp. 1524–1528, doi: 10.1109/ICIP.2016.7532613.

[3] R. L. de Queiroz and P. A. Chou, 'Compression of 3D Point Clouds Using a Region-Adaptive Hierarchical Transform', *IEEE Transactions on Image Processing*, vol. 25, no. 8, pp. 3947–3956, Aug. 2016, doi: 10.1109/TIP.2016.2575005.

[4] M. Krivokuća, M. Koroteev, and P. A. Chou, 'A Volumetric Approach to Point Cloud Compression', *arXiv:1810.00484 [eess]*, Sep. 2018, Accessed: Oct. 15, 2018. [Online]. Available: http://arxiv.org/abs/1810.00484.

FoldingNet

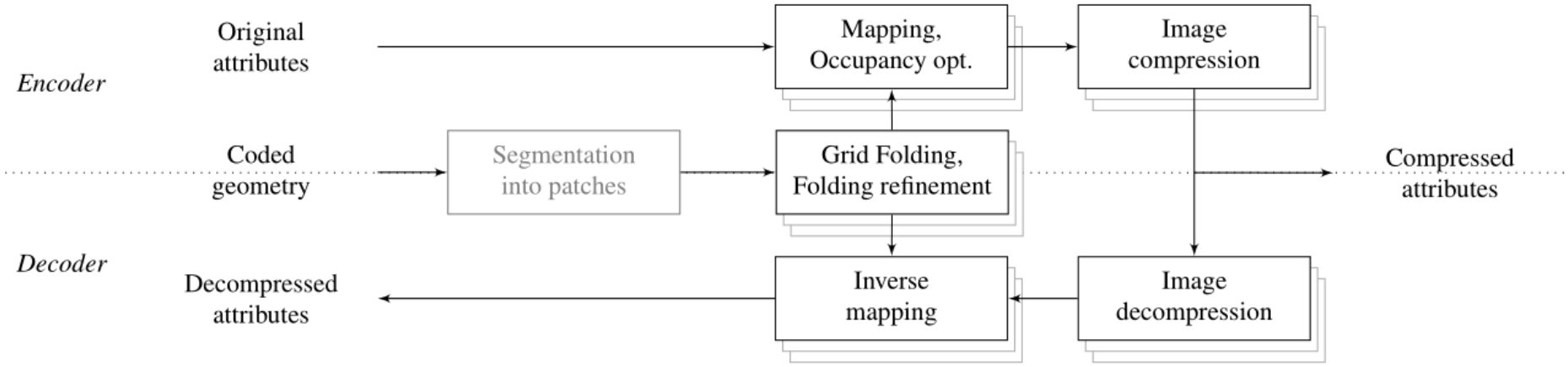
- Point Cloud Autoencoder
- Deep grid deformation
- Reconstructions not accurate enough for attribute compression
  - Fit grid onto a **single** point cloud (equivalent to overfitting the network on a single example)
- Mapping attributes between the folded grid and the point cloud
  - Mapping is not one-to-one => mapping distortion
  - One-to-one mapping => no mapping distortion
  - More accurate reconstructions => better mappings => less mapping distortion



Y. Yang, C. Feng, Y. Shen, and D. Tian, "FoldingNet: Point Cloud Auto-encoder via Deep Grid Deformation," in *2018 IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 2017.

Contributions

- Folding-based method to transfer point cloud attributes onto a grid and compress them
- Improvements to minimize mapping distortion: folding refinement, adaptive mapping and occupancy optimization



Folding

- Fold a 2D grid (in 3D space) onto a point cloud to obtain its 2D parameterization

Original PC

8) Backward attribute mapping

4) Forward attribute mapping

1) Encode

2) Fold grid

(One-to-one mapping)

3) Folding refinement

Folded Grid

5) Transfer to grid

7) Transfer back to folded grid

Grid

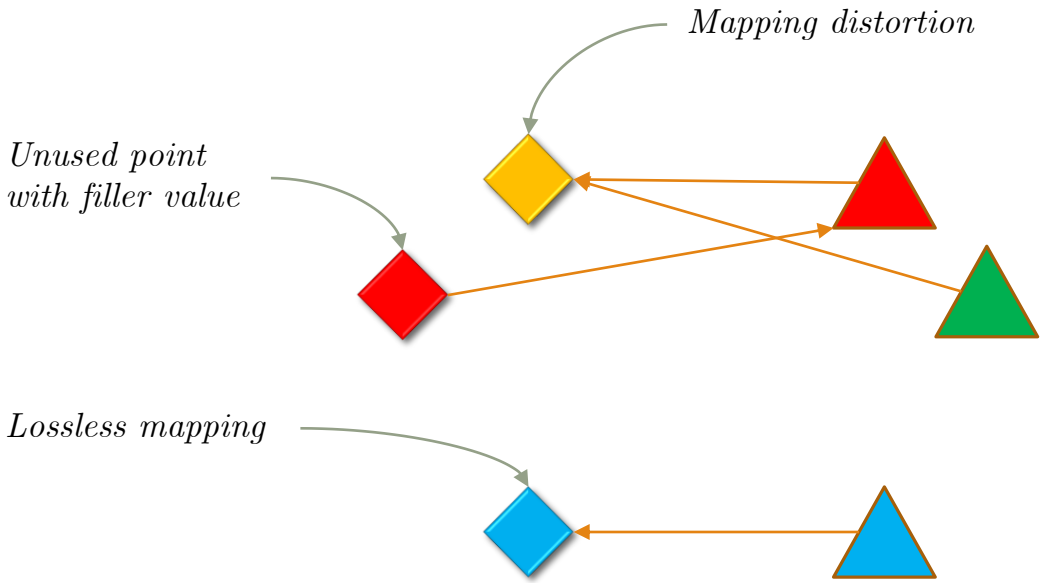
6) Image compression (or any other image processing techniques!)

Naive attribute mapping

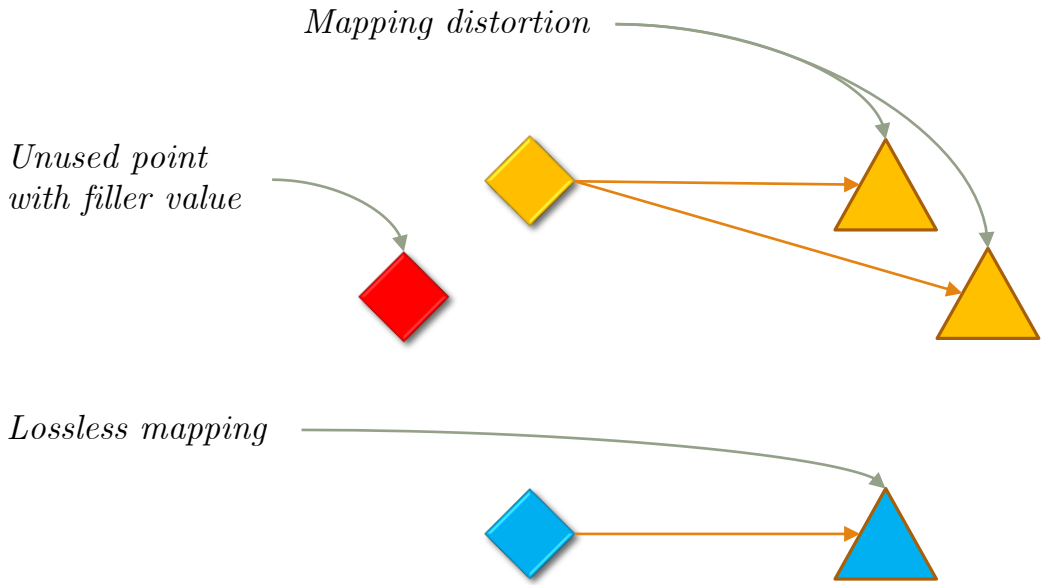
- Attribute mapping using nearest neighbours

◇ $\tilde{\mathbf{x}}$: folded grid

△ $\mathbf{x}$: original point cloud



a) Forward mapping process



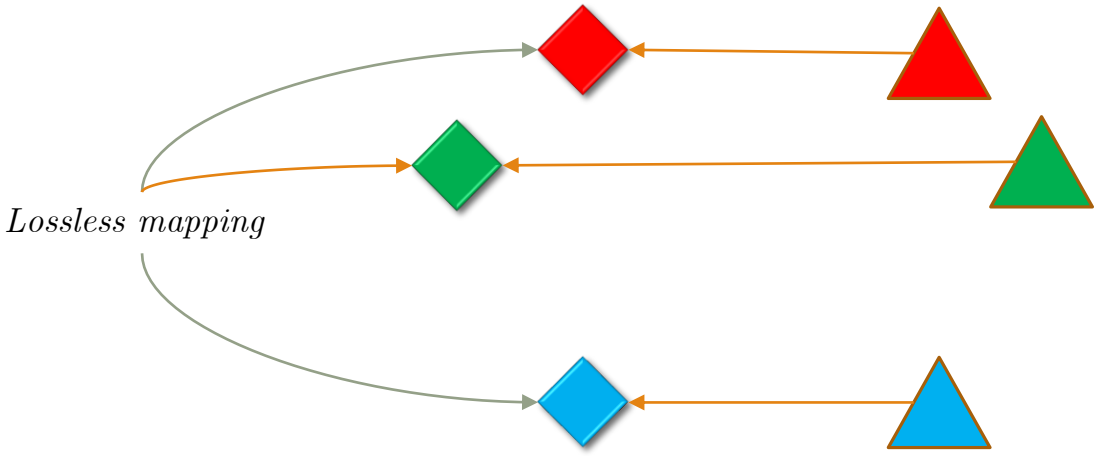
a) Backward/inverse mapping process

Adaptive mapping

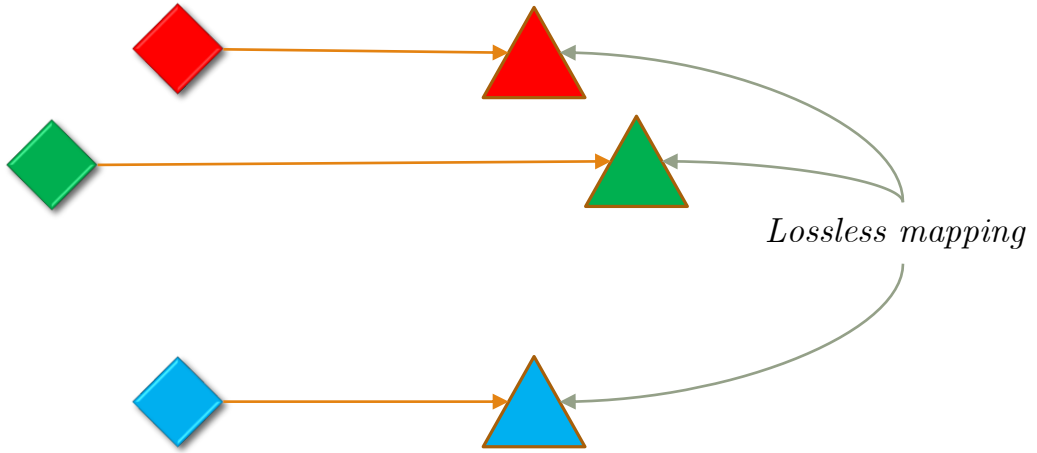
- Iterative process that minimizes the occupancy of each point in $\tilde{\mathbf{x}}$, that is the number of points in $\mathbf{x}$ affected to each point in $\tilde{\mathbf{x}}$
- For each point $\mathbf{x}$, we assign it to the neighbour, among its k nearest neighbours, that minimizes its occupancy multiplied by its distance to $\mathbf{x}$

◇ $\tilde{\mathbf{x}}$: folded grid

△ $\mathbf{x}$: original point cloud

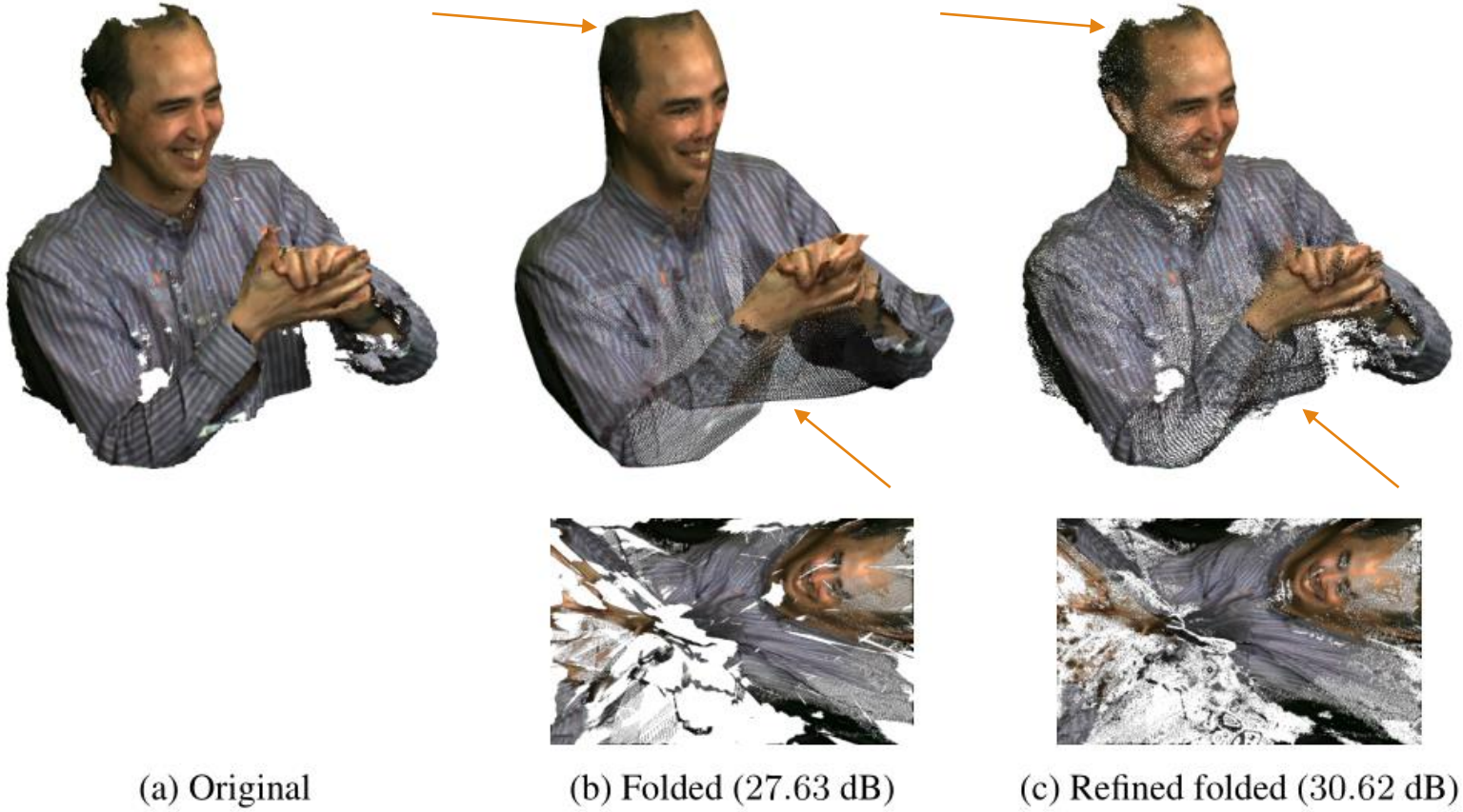


a) Forward mapping process



a) Backward/inverse mapping process

Folding Process



(a) Original (b) Folded (27.63 dB) (c) Refined folded (30.62 dB)

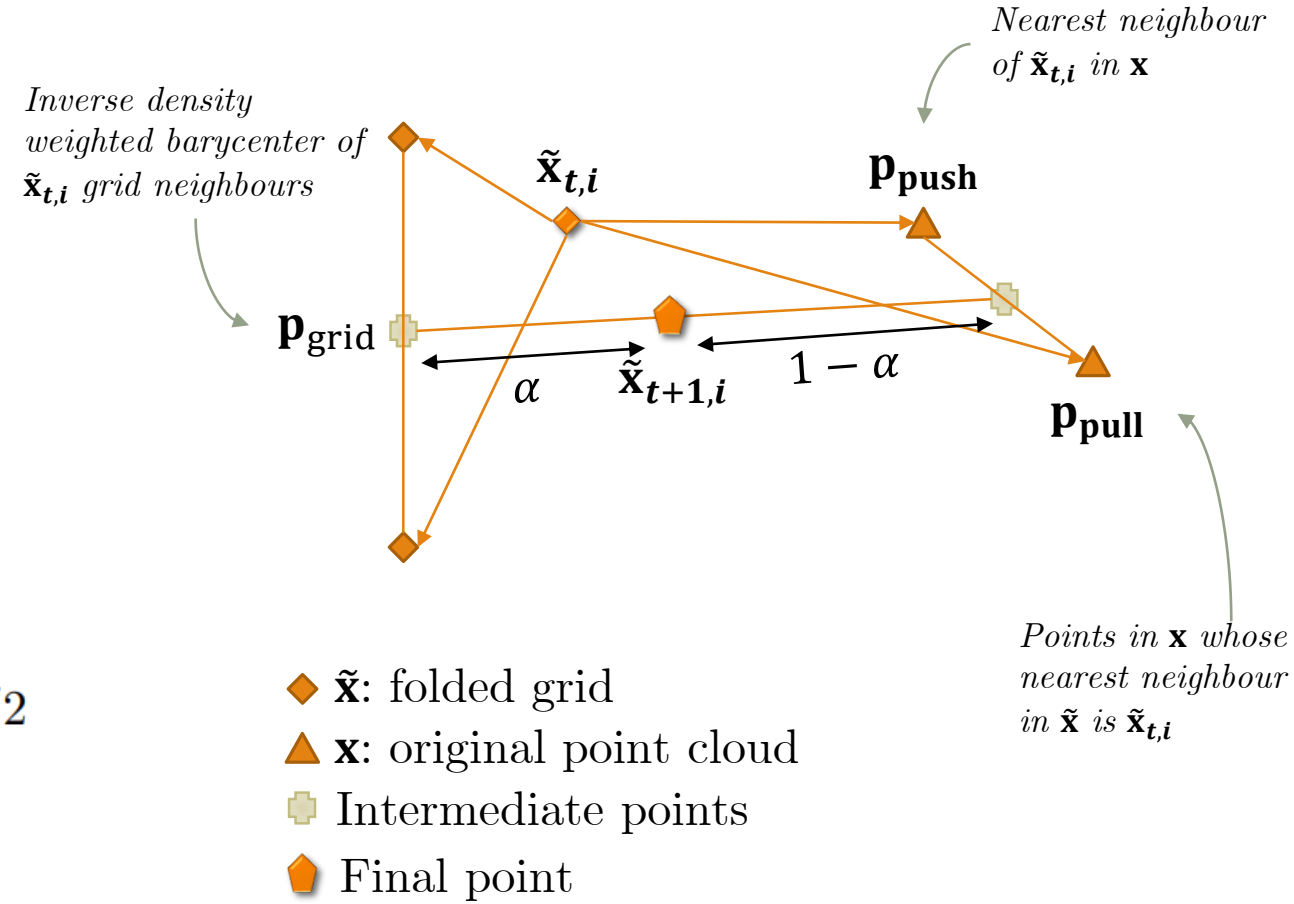
Comparison of mapping distortions with proposed improvement steps

Folding refinement

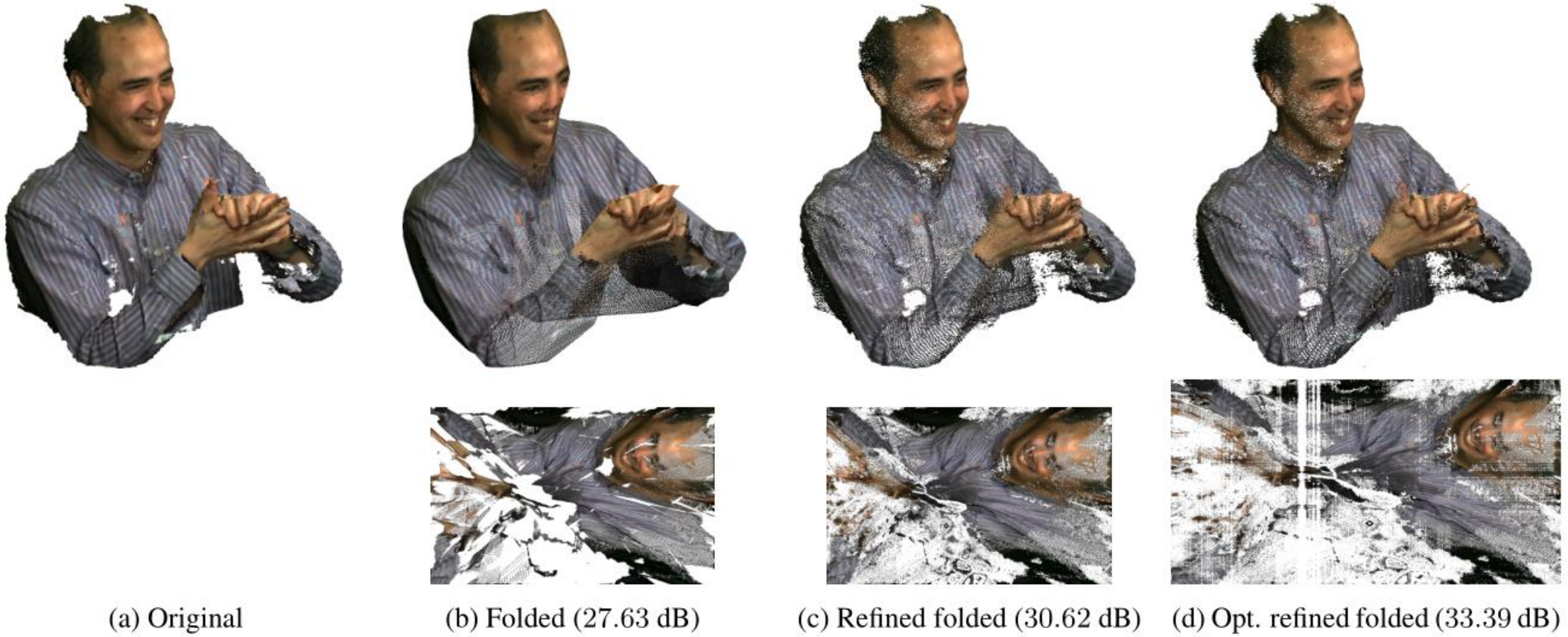
- Mismatch between original PC and folded grid causes **mapping distortion**. Two main issues:
  - 1) Local density mismatch
  - 2) Inaccurate reconstruction for complex shapes
- Physics-inspired solution based on attraction forces
- 1) Density-aware grid structure preservation forces: attraction towards grid neighbours with $\mathbf{p}_{\text{grid}}$
- 2) Bidirectional attraction forces: push and pull attraction forces between $\mathbf{x}$ and $\tilde{\mathbf{x}}$
- **Final iterative system**

$$\tilde{\mathbf{x}}_{t+1,i} = \alpha \mathbf{p}_{\text{grid}_{t,i}} + (1-\alpha)(\mathbf{p}_{\text{push}_{t,i}} + \mathbf{p}_{\text{pull}_{t,i}})/2$$

$\boldsymbol{\alpha}$ balancing controls convergence speed



Folding Process

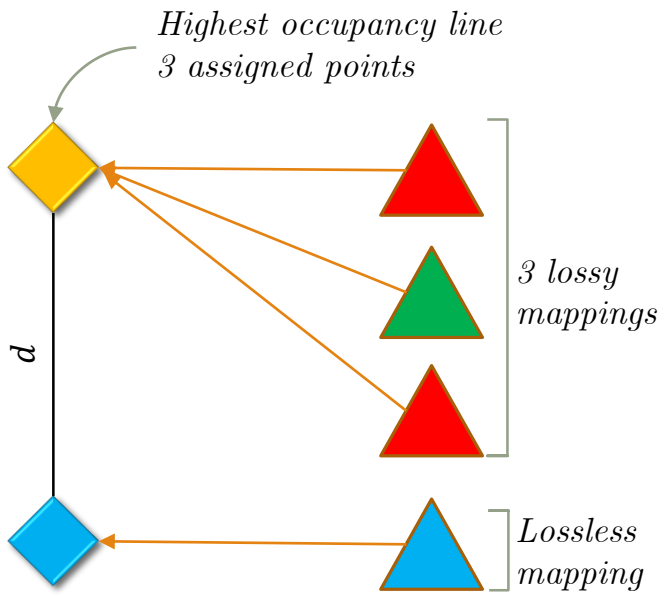


(a) Original (b) Folded (27.63 dB) (c) Refined folded (30.62 dB) (d) Opt. refined folded (33.39 dB)

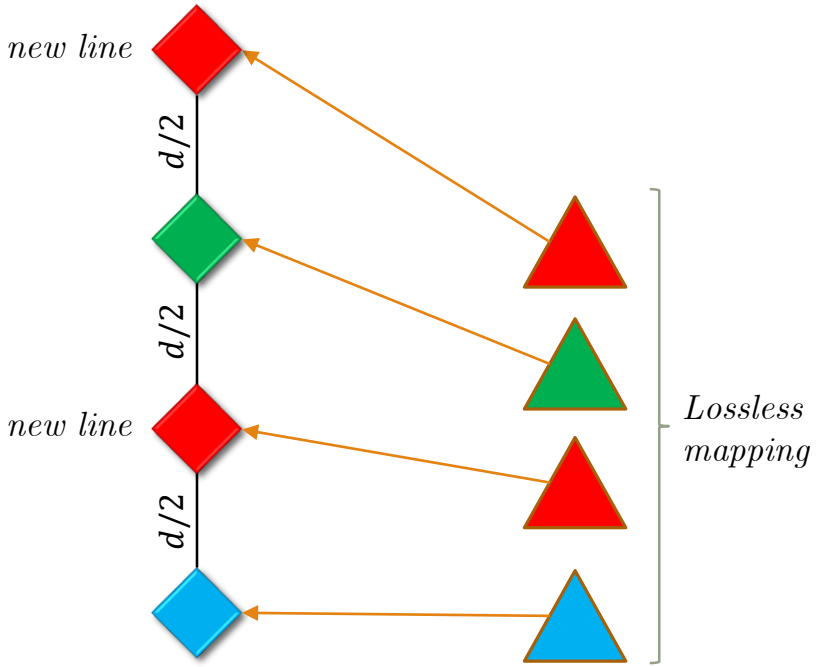
Comparison of mapping distortions with proposed improvement steps

Occupancy optimization

- We add lines and columns to the grid in order to minimize occupancy
- Each iteration, we add lines/columns around the line/column with highest occupancy



a) Without occupancy optimization



b) occupancy optimization (1 iteration)

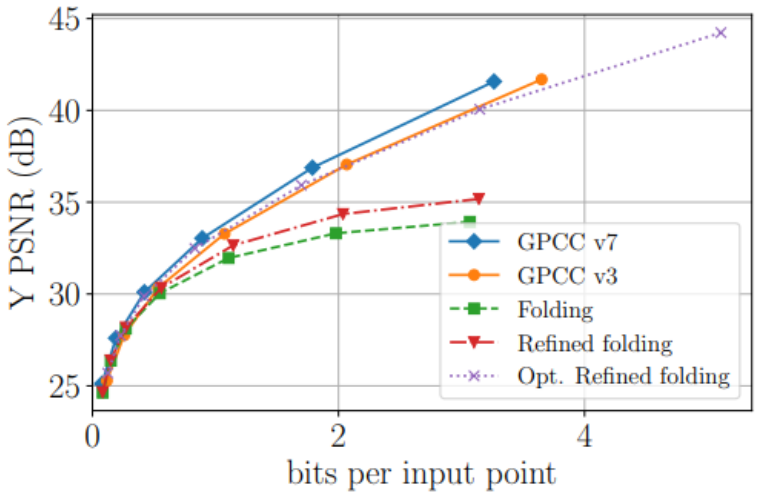
◇ $\tilde{\mathbf{x}}$: folded grid

△ $\mathbf{x}$: original point cloud

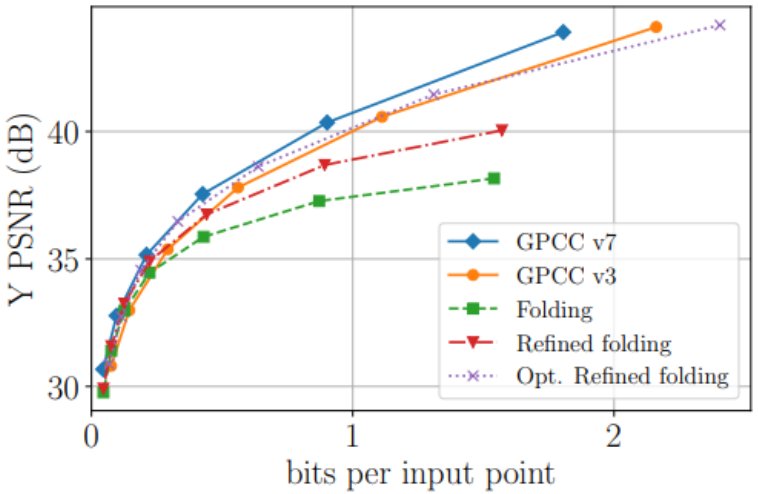
Evaluation

- Comparison against GPCC
- 3 voxelized point clouds: longdress, redandblack and soldier
- We divide point clouds into patches manually to minimize mapping distortion
- Image compression using BPG (HEVC intra)

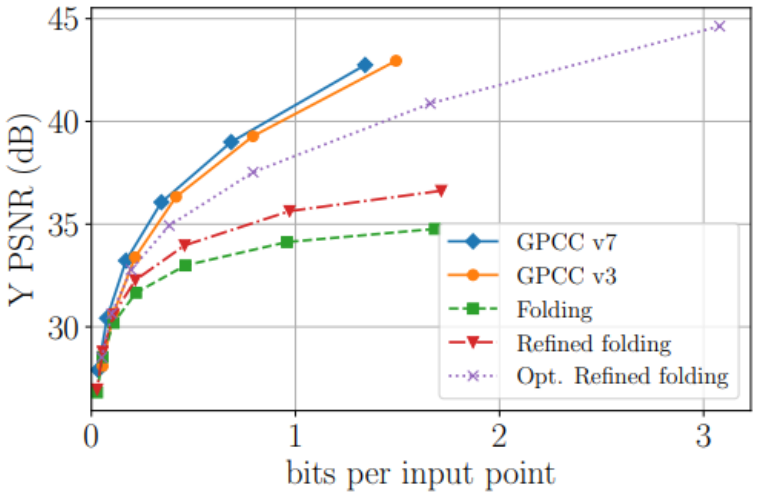
Quantitative results



a) longdress



b) redandblack



c) soldier

Conclusion

- Novel way of transferring point cloud attributes onto a grid applied on Point Cloud Attribute Compression
- Attribute compression performance comparable to GPCC v7
- Opens up new possibilities as image processing techniques become applicable on point cloud attributes

Thank you for your attention.

Source code: https://github.com/mauriceqch/pcc_attr_folding