What is up with
Point Cloud Compression and Representation

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Point clouds: the case for them

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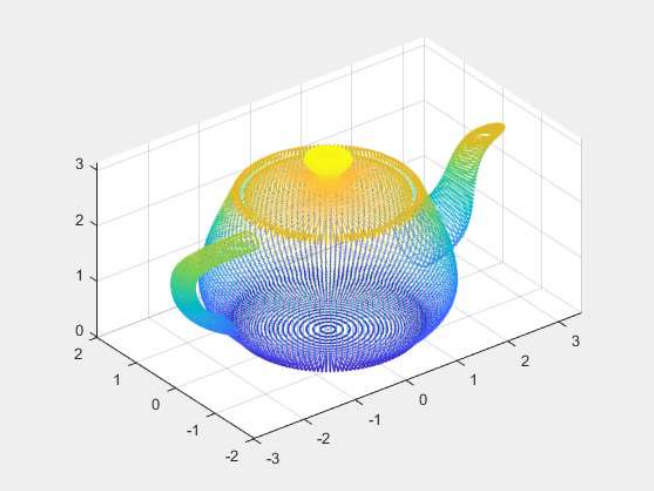
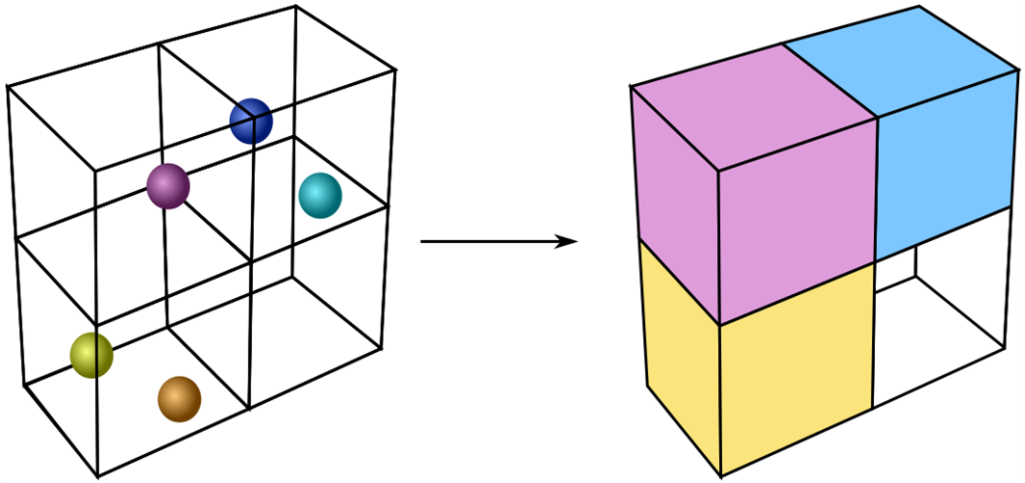
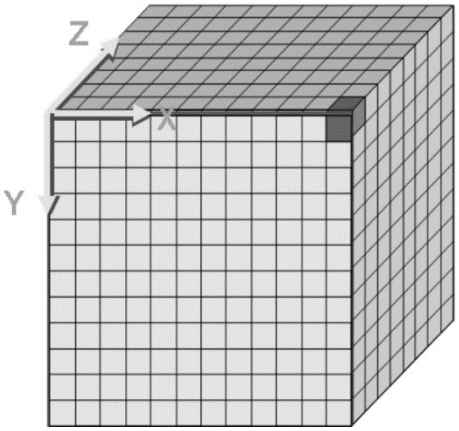
Voxels and points







- Voxelized point cloud (e.g. 512x512x512 grid)
- Voxels $V_i = [x_i, y_i, z_i, R_i, G_i, B_i, A_i]$

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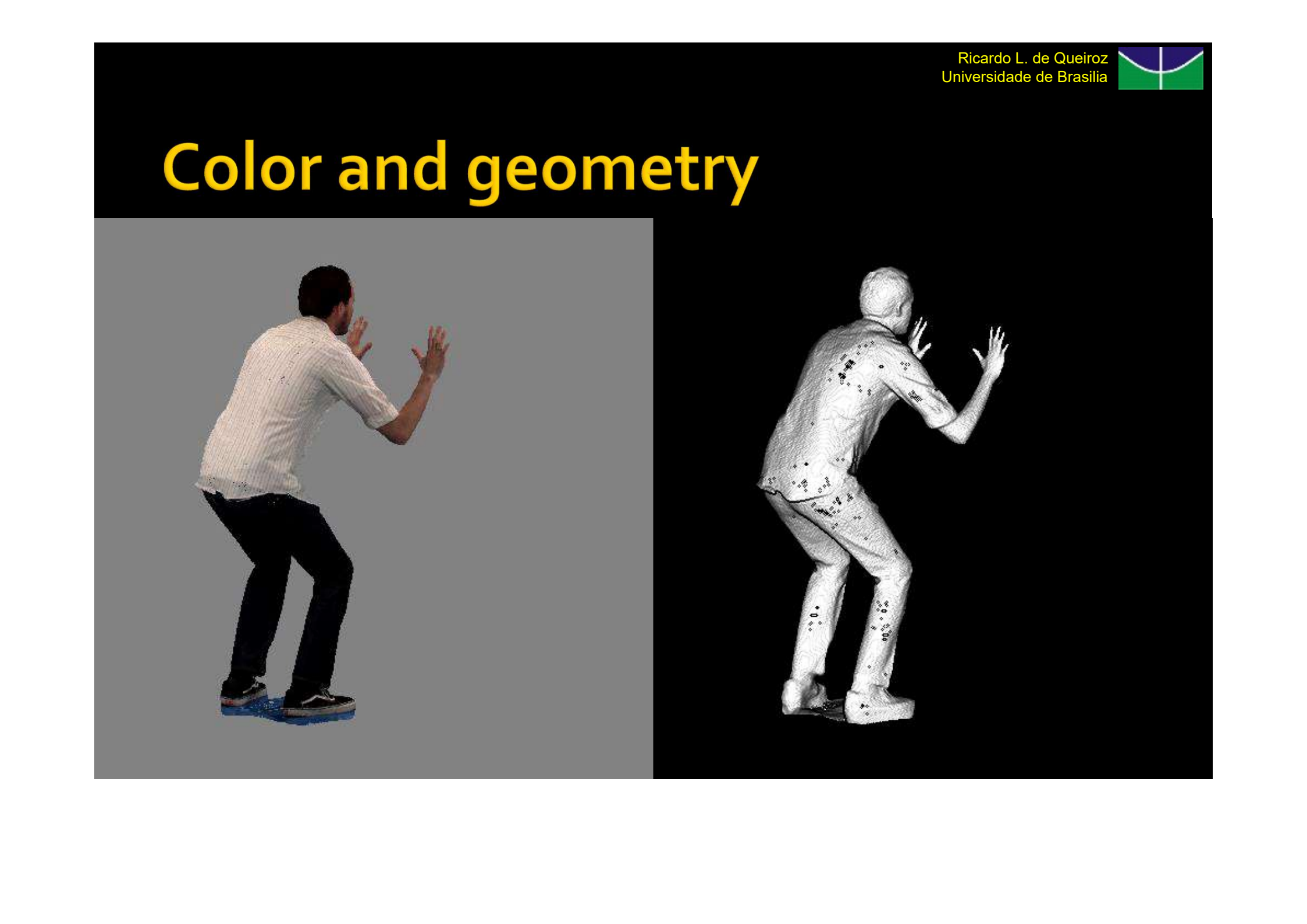

Color and geometry

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Telepresence

Idea for point clouds:

- Scan a 3D real-time volumetric information of a person;
- Encode the data and send it to decoder;
- Receiver immerses the 3D data in his own environment;
  - ❖ using equipment such as Hololens or even smart phones

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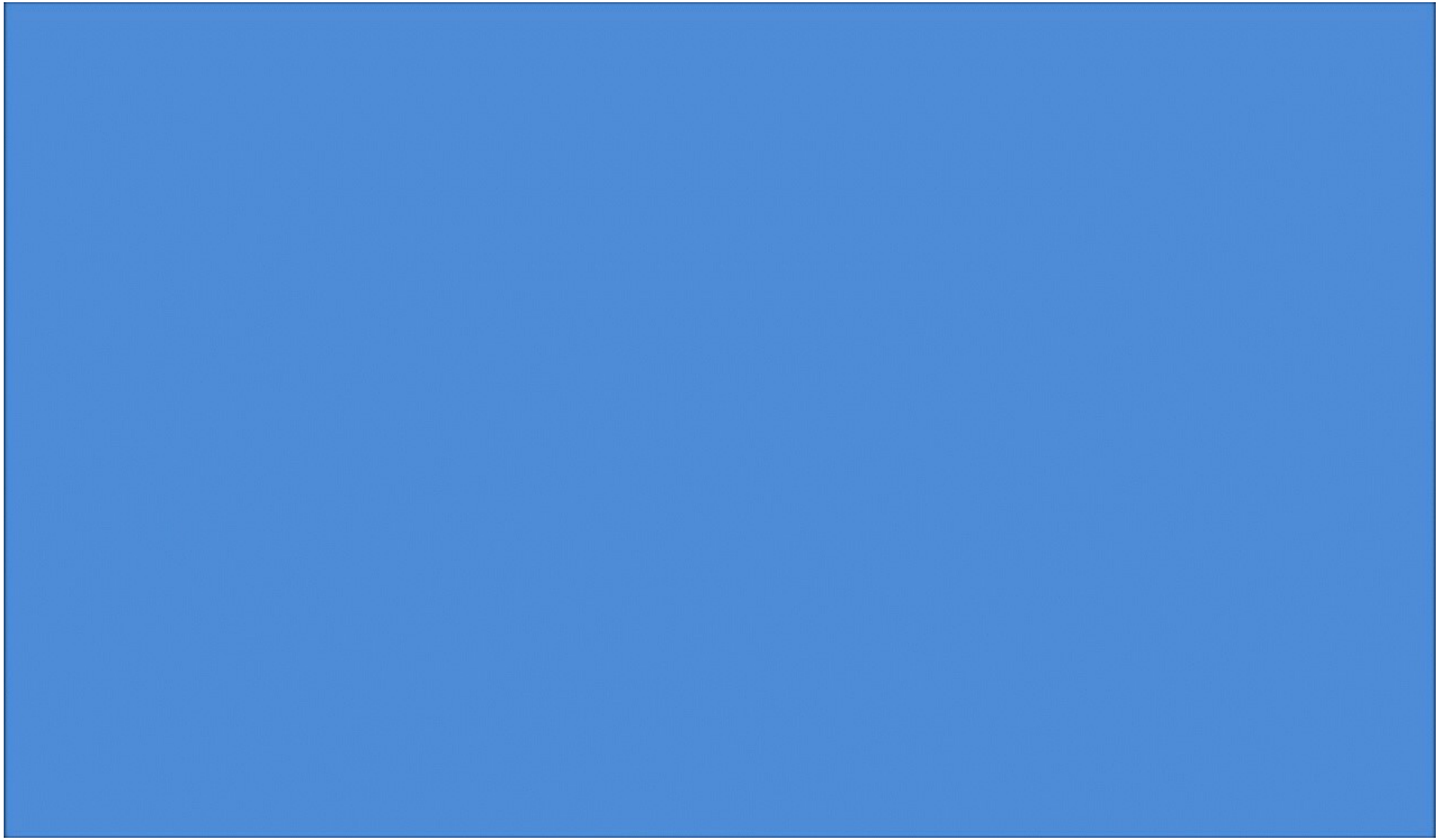
First Real-time Voxelization at MSR



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Second real-time MSR voxelization

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Second Real Time Voxelization

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Holoportation at MSR

- Capture a point cloud of the person/object
  - List of occupied voxels: (x,y,z) (r,g,b)
- Transmit point cloud
- Immerse object into scene- render on Hololens

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Holoportation

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holoportation

http://research.microsoft.com/holoportation

Interactive 3D Technologies

http://research.microsoft.com/groups/i3d

Microsoft Research

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MPEG and PCC

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- History
- V-PCC
- G-PCC
- Extras (plenoptic, ML, interpolation)

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Microsoft upper body

(9 and 10 levels, 200 frames)

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8i full body (10 levels, 300 frames)

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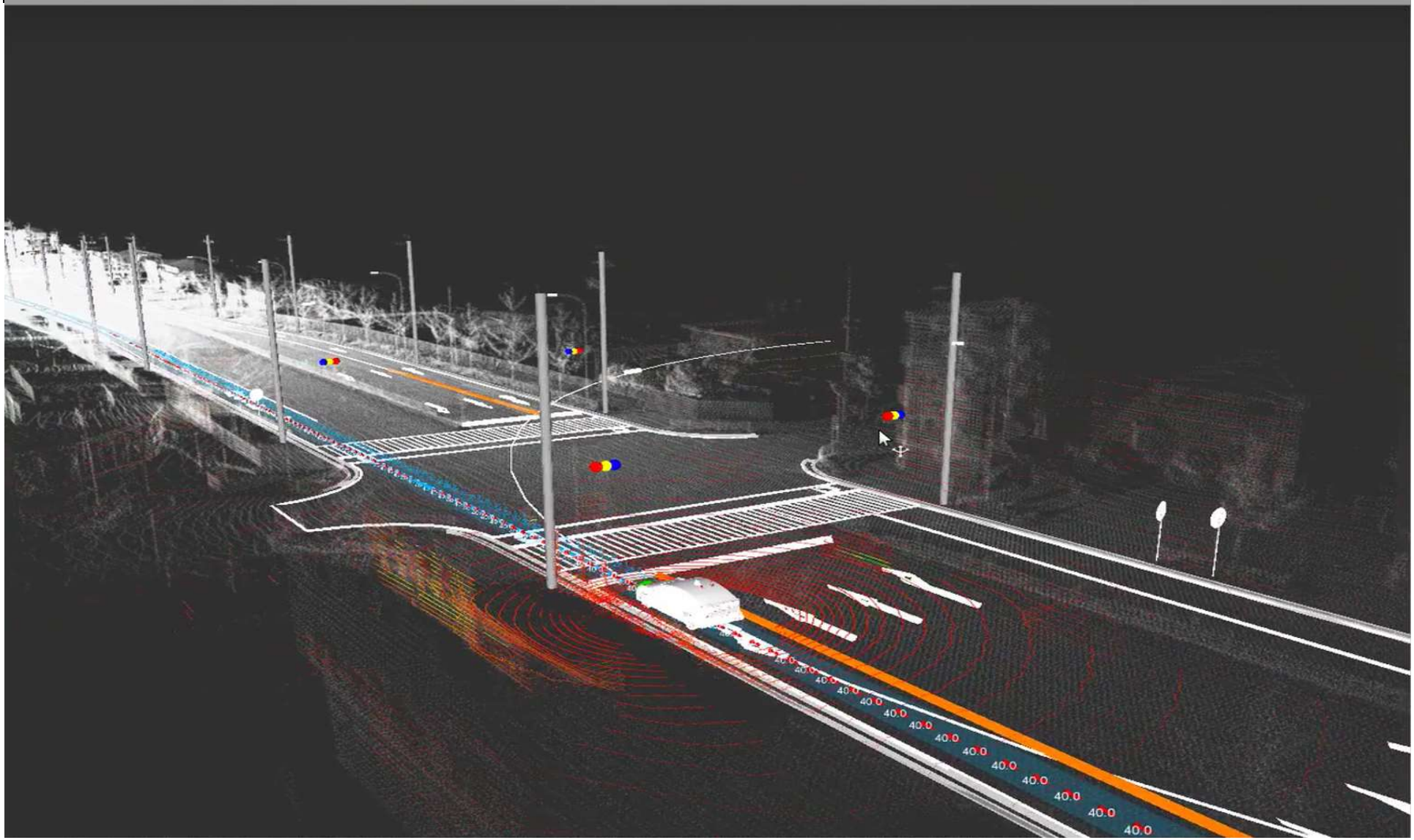
HD Maps



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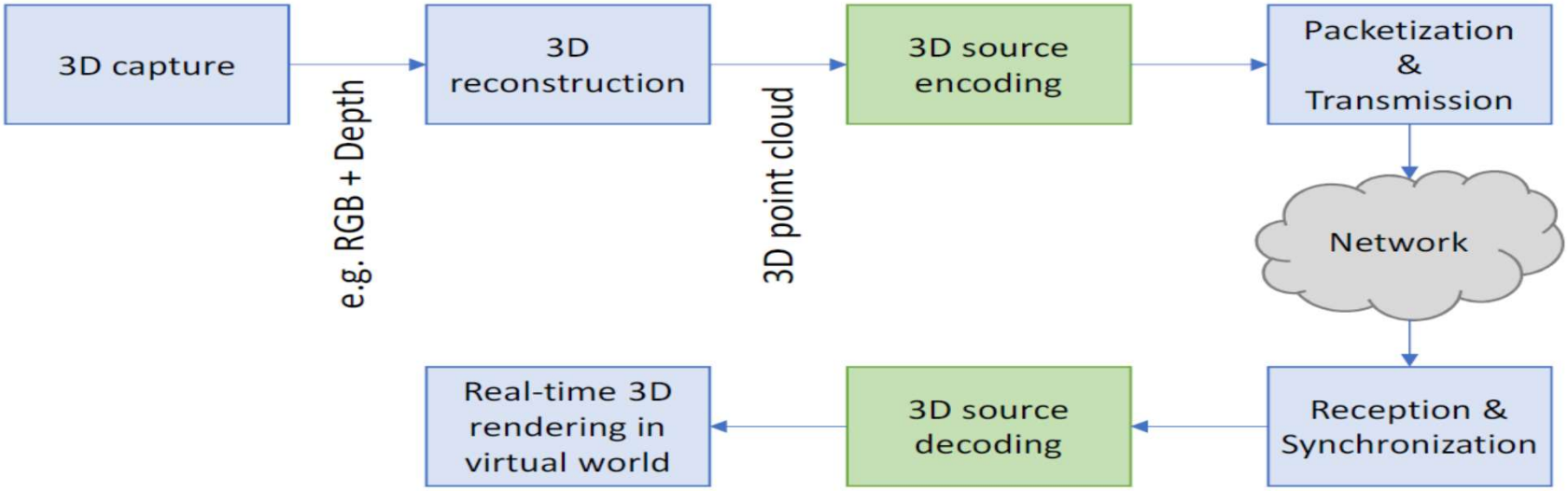
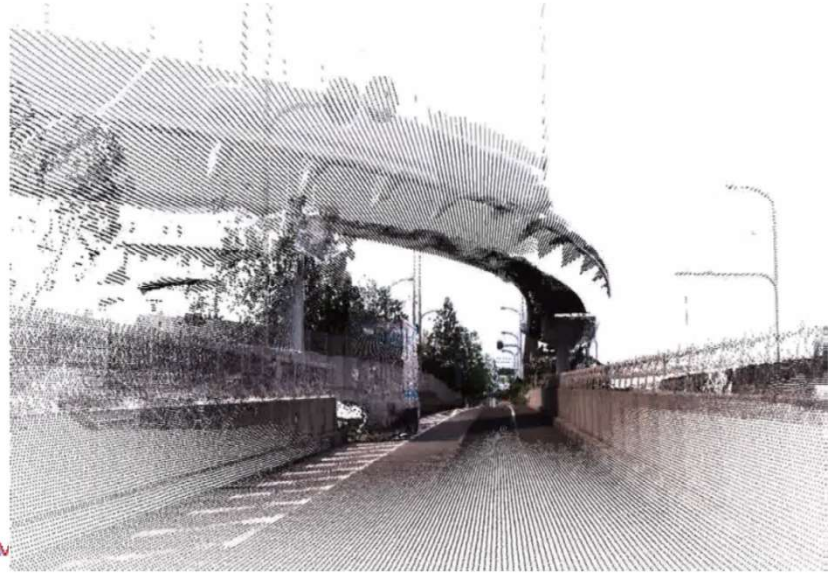
MPEG





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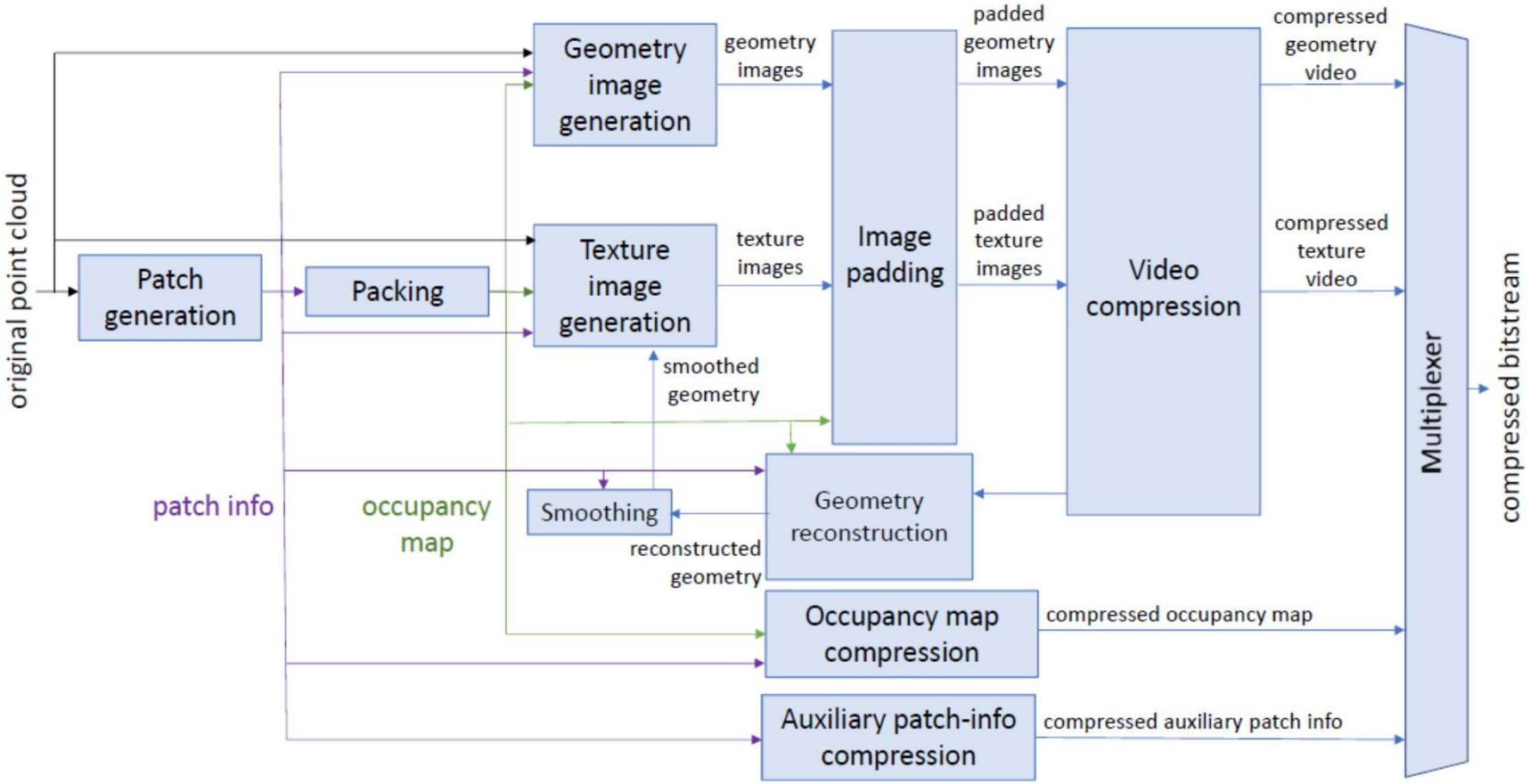
V-PCC

- Video-based solution
- Quick time-to-Market. (use existing HEVC decoding hardware)



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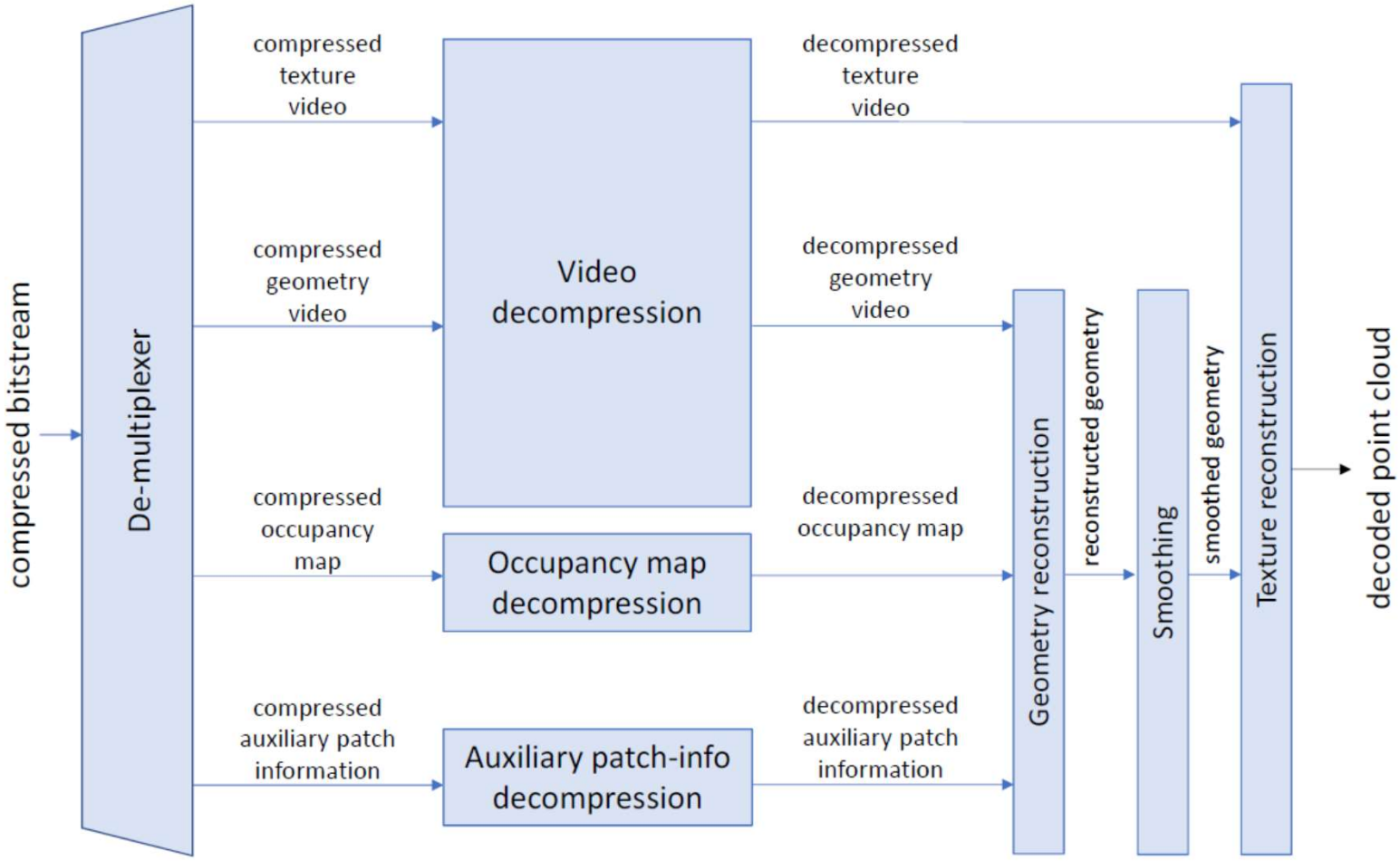
V-PCC Decoder



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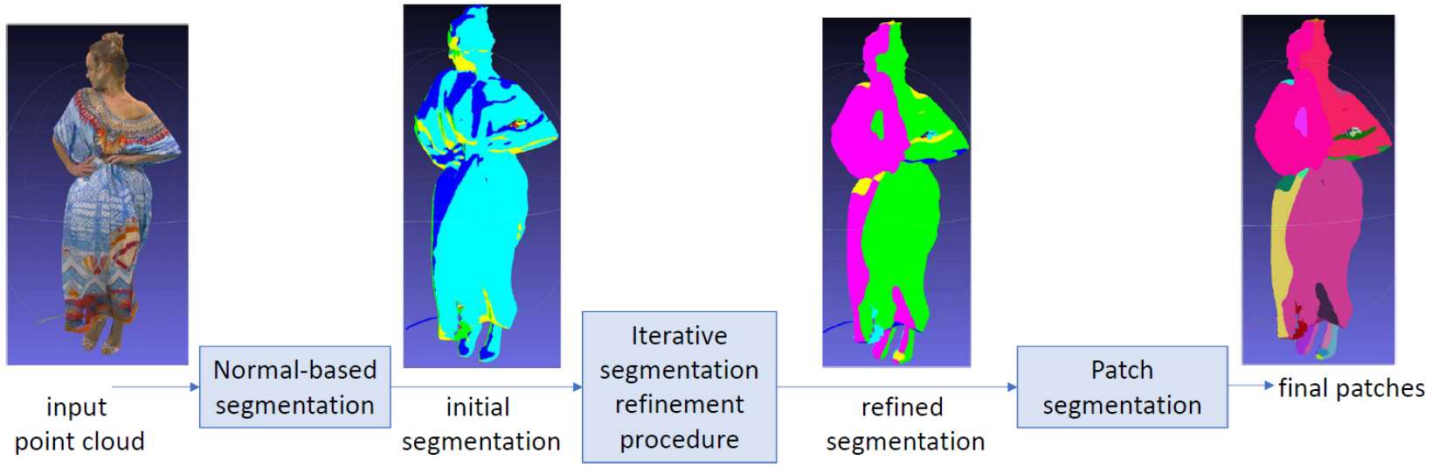
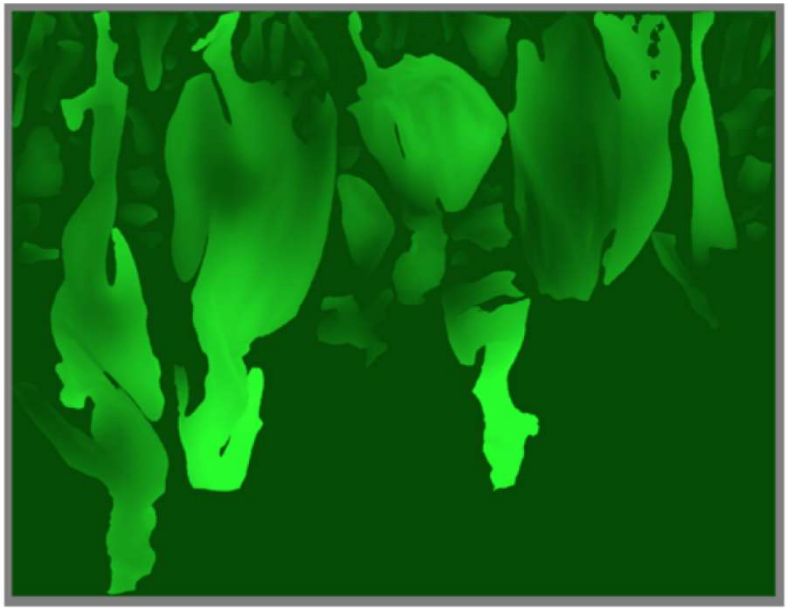
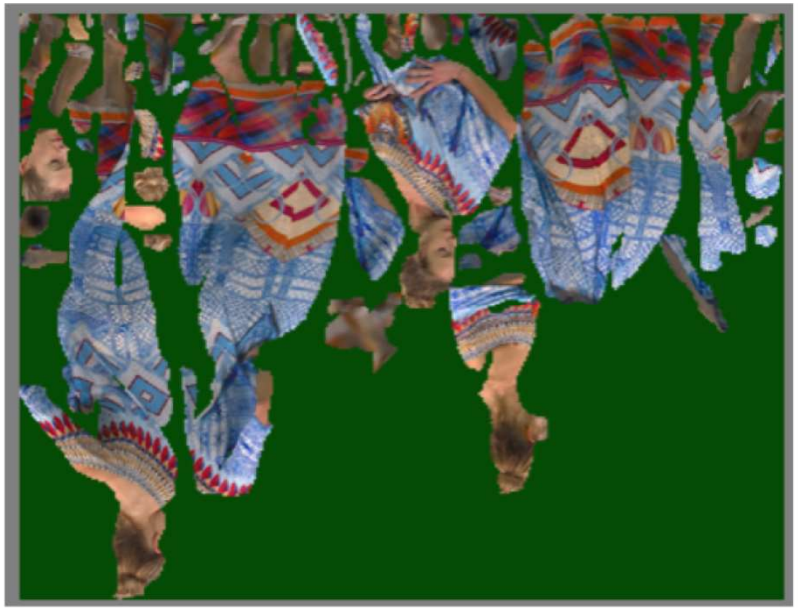
V-PCC projections on patches







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V-PCC (TMC-2)

Low quality

Good quality

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V-PCC (best quality)

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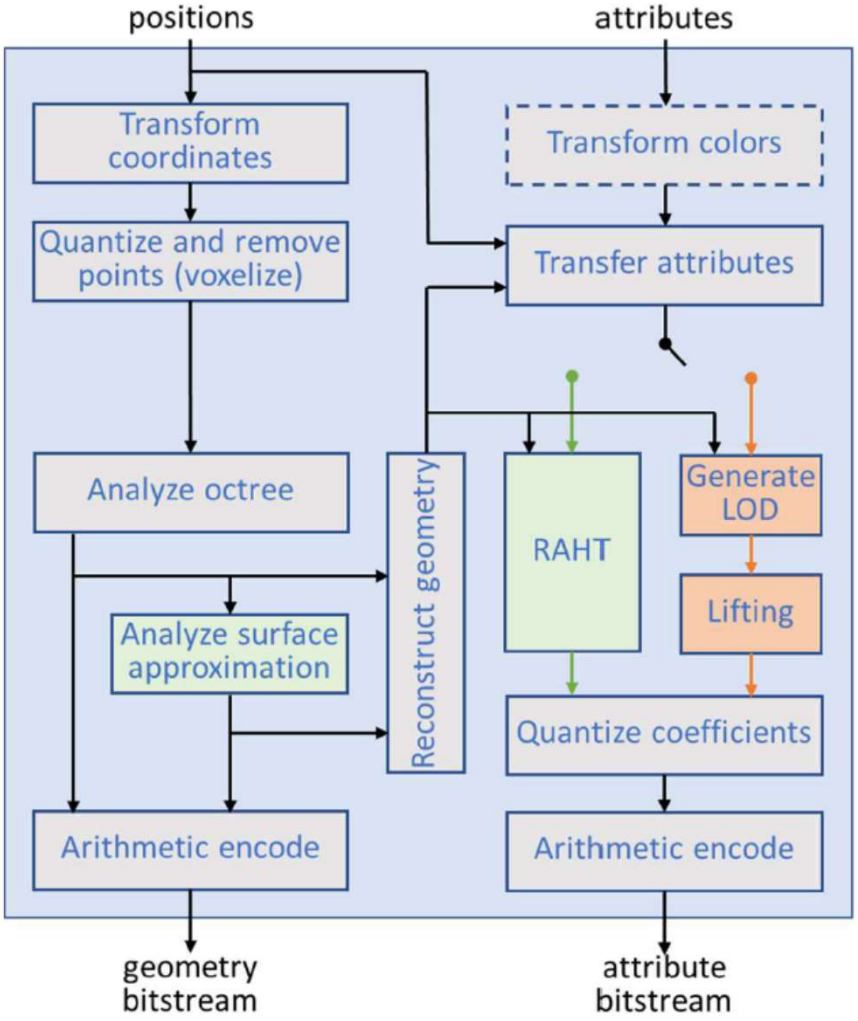
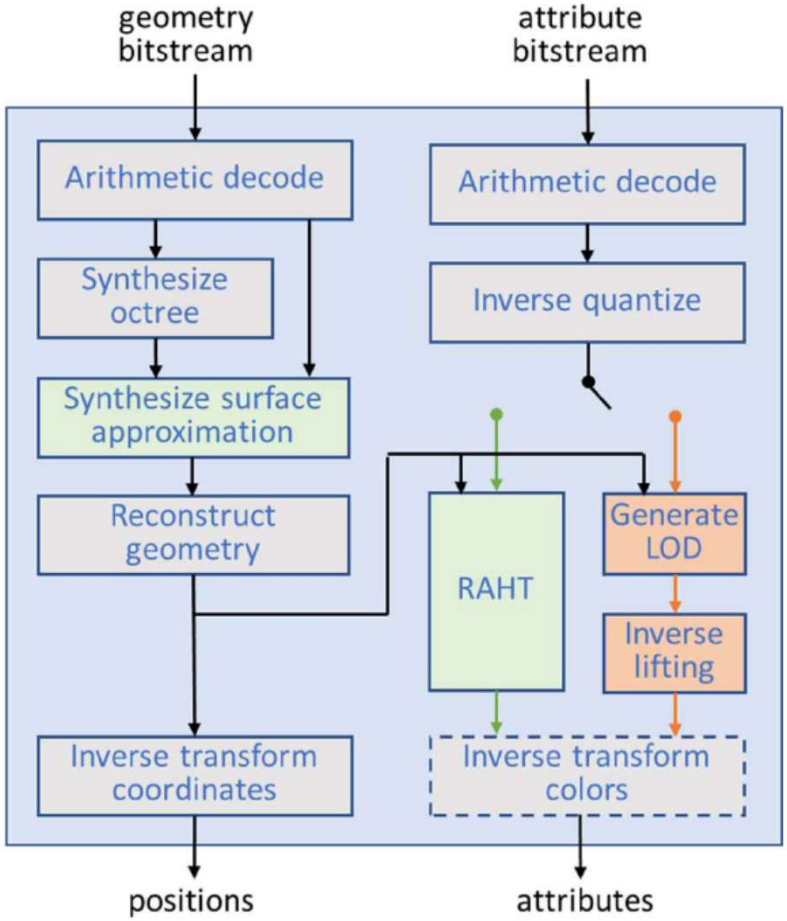
G-PCC





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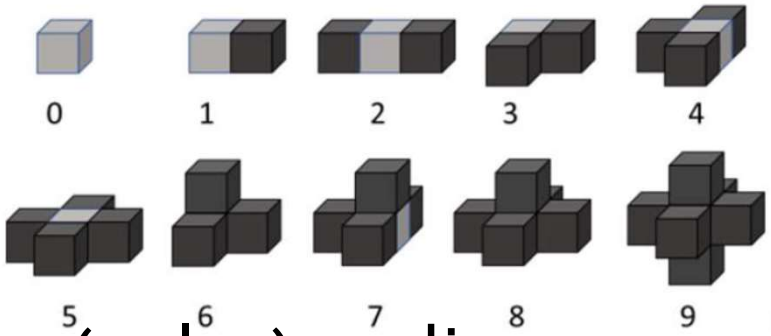
G-PCC coding

- Geometry coding
  - Neighbour-dependent Entropy Context



- Attribute (color) coding
  - RAHT
    - coefficient coding with inter-depth up-sampling
  - LoD

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Exchange degradations

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G-PCC (RAHT) lossless geometry

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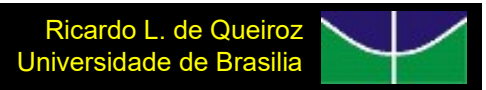

Octree/PredLift (r01 r02 r03 r05)

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Octree/RAHT (r01 r02 r03 r05)




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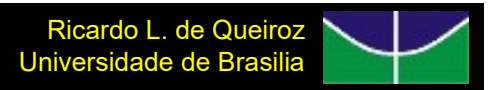

Trisoup (raht r01 r03 r05 r06)

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New Trends in PCC

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What is up

- ML PCC
- LIDAR
  - Radial prediction of geometry
  - Radial prediction of attributes
  - LL-LC (low latency low complexity)
- Motion estimation
- Scalability – embededness

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ML-PCC

- MPEG is investigating machine-learning-based point cloud compression

- A. Guarda, A. ; N. M. M. Rodrigues, F. Pereira, F. , Adaptive Deep Learning-based Point Cloud Geometry Coding, IEEE Journal of Selected Topics in Signal Processing Vol. 15, Nº 2, pp. 415 - 430, February, 2021.
- M. Quach, G. Valenzise, F. Dufaux, Improved Deep Point Cloud Geometry Compression arXiv:2006.09043 2020
- Jianqiang Wang, DandanDing, Zhu Li, Zhan Ma, "Multiscale Point Cloud Geometry Compression", arXiv:2011.03799v1, 2020.

- ISO/IEC JTC 1/SC 29/WG 7 N0174, "Performance Analysis of Currently AI-based Available Solutions for PCC". (Under editing / A. Zaghetto).

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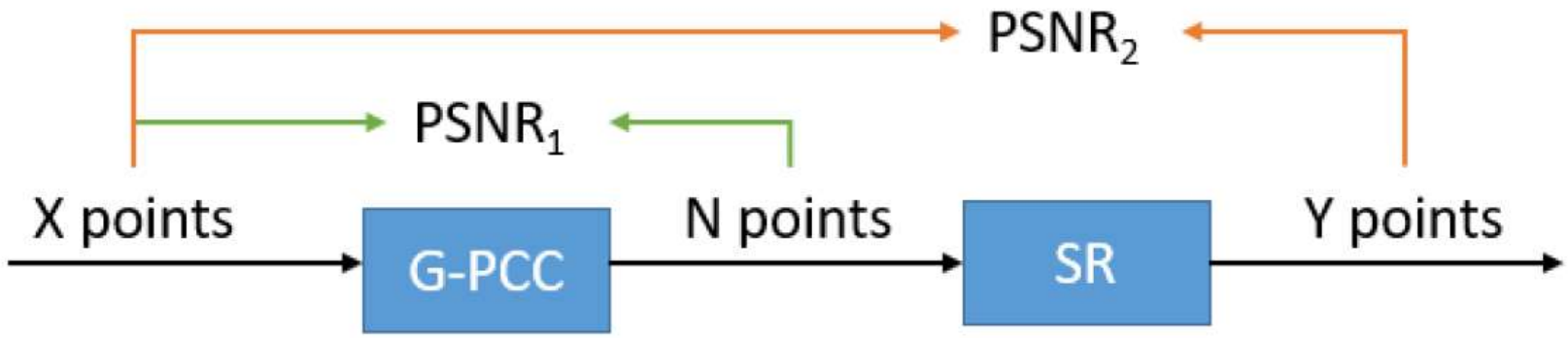
ML-PCC

- Also included results using RDO downsampling (into G-PCC) and post-processing by Fractional Super-resolution



- T. M. Borges, D. C. Garcia and R. L. de Queiroz, `` Fractional Super-Resolution of Voxelized Point Clouds , TechRxiv, preprint, https://doi.org/10.36227/techrxiv.15032052.v1, 2021.

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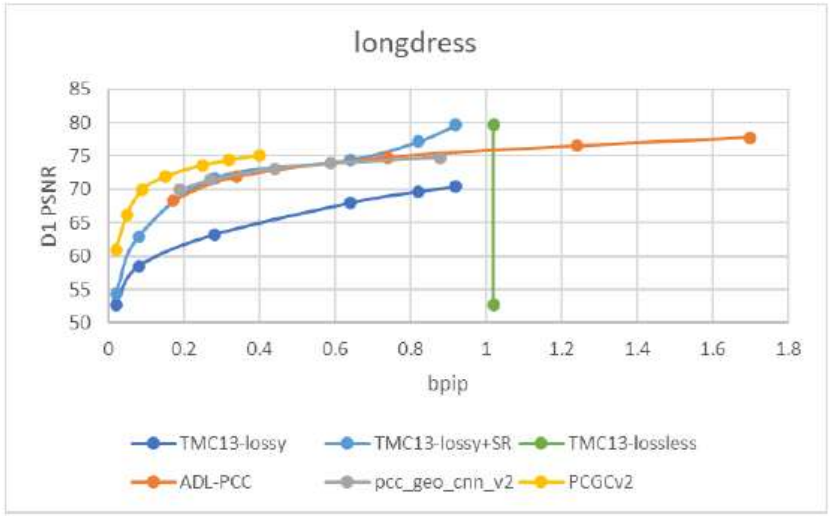
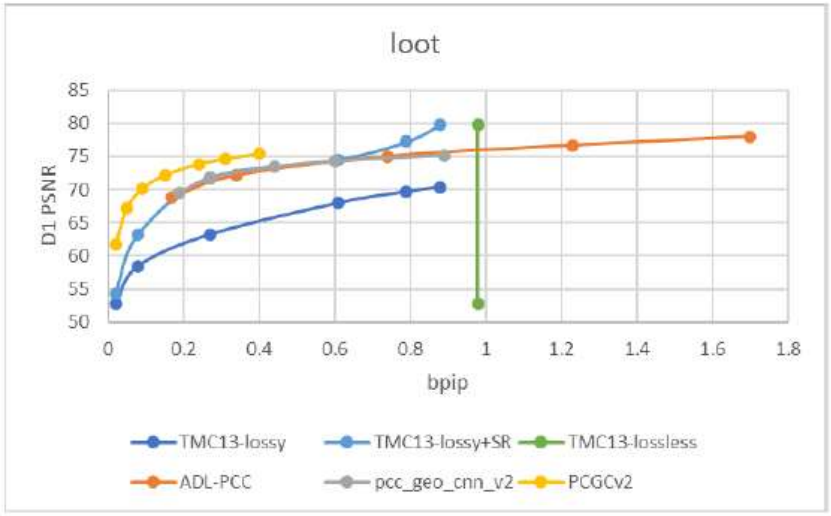
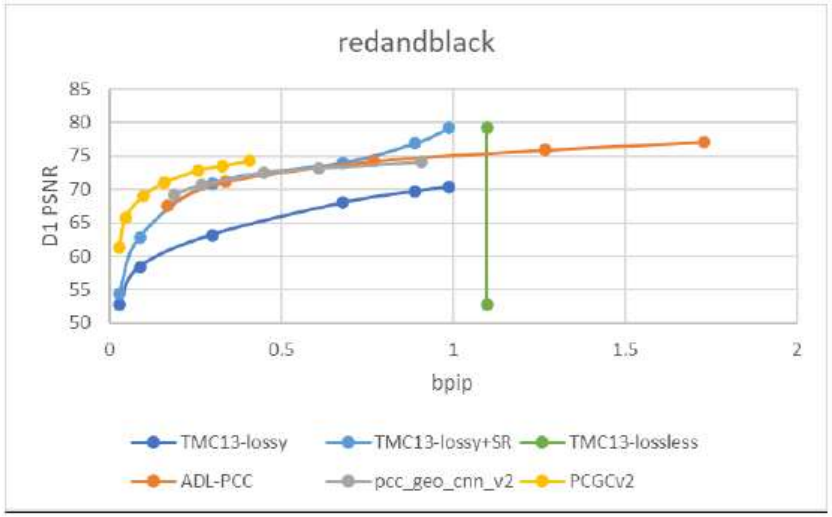
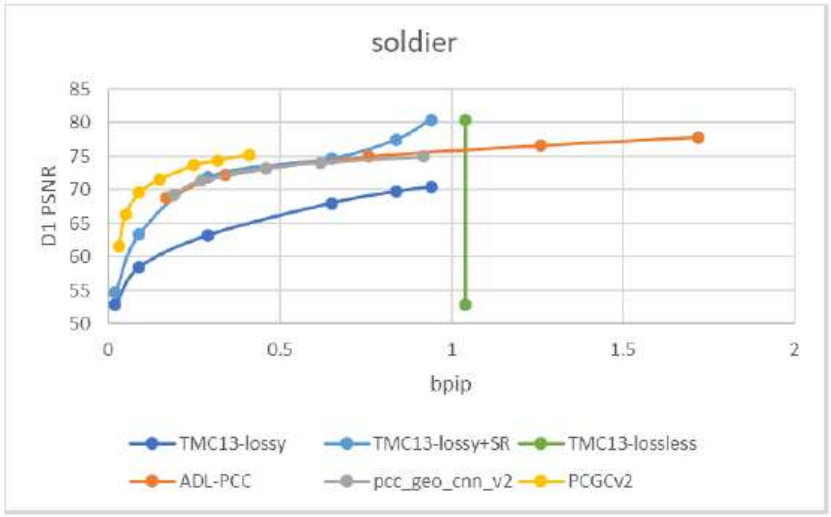
ML-PCC preliminary tests









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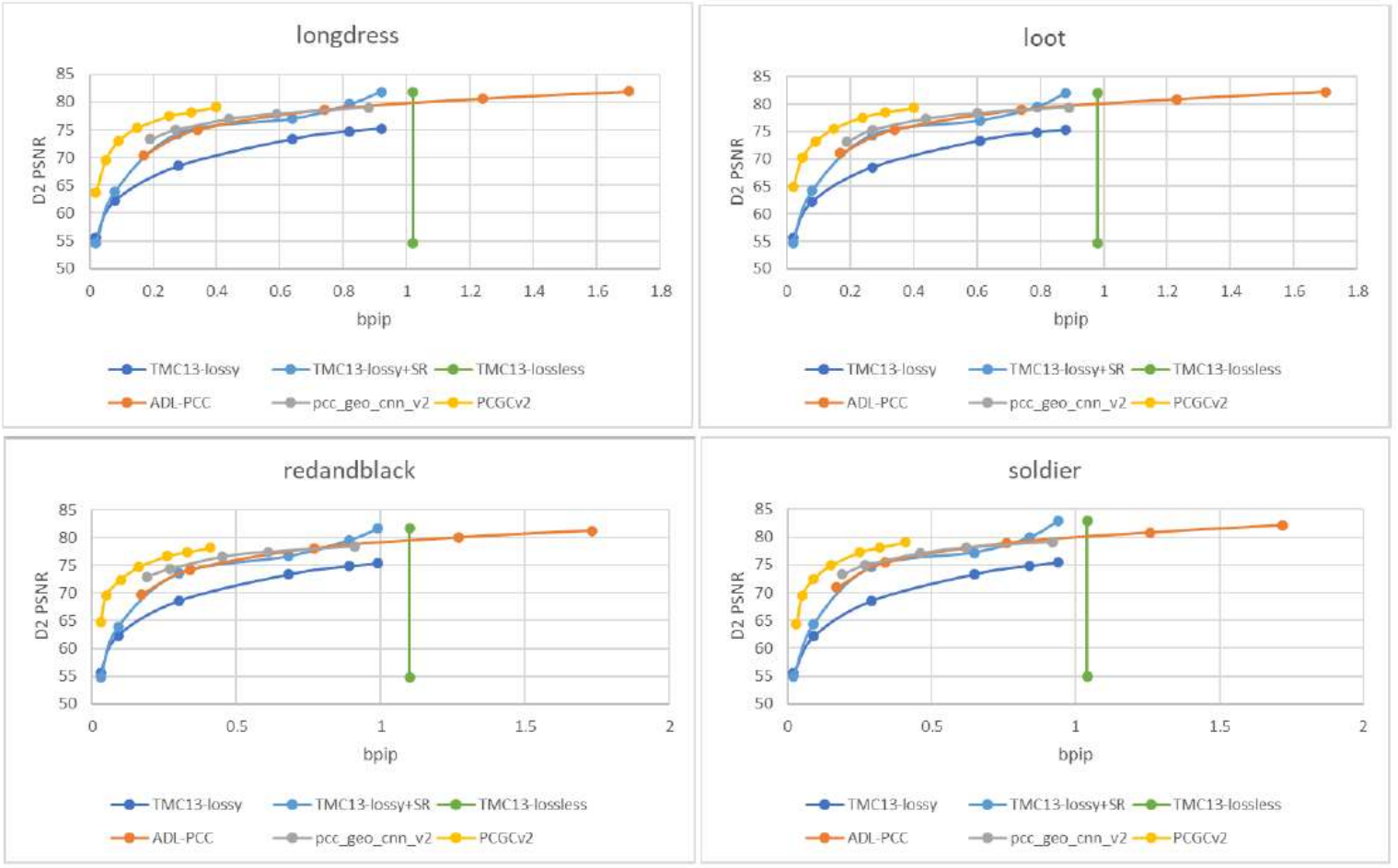
ML-PCC preliminar tests



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LIDAR – different data

- Laser scans are radial passes
- Better encoding of the geometry in polar coordinates

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LIDAR data coding

- Predictive Geometry Coding
  - Adaptive Azimuthal Angle Quantization
  - Improved Coding of Azimuthal Angle Residual
  - Improved Coding of Number of Azimuthal Angle Steps
  - Improved Radius Residual Sign Coding and Points Ordering
  - Improved Predictor List
- Octree Geometry Coding
  - Residual Coding of Angular Mode in IDCM
  - Improved Azimuthal Mode in IDCM
  - Context Enhancement of Azimuthal IDCM
- Inter Prediction for Octree Geometry Coding
  - Inter Prediction for Octree Geometry Coding Based on Global Motion
  - Improved Planar Mode Coding for InterEM
- Inter Prediction for Predictive Geometry Coding
  - Inter Prediction for Predictive Geometry Coding
  - Additional Predictor Candidate
  - Improved Inter Prediction Flag Coding
- Low-Latency and Low-Complexity Dedicated Codec (LL-LC²)

- Laser scans are radial passes
- Better encoding of the geometry in polar coordinates

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LIDAR sample technologies

- **Predictive Geometry Coding**
  - **Adaptive Azimuthal Angle Quantization**
  - Improved Coding of Azimuthal Angle Residual
  - Improved Coding of Number of Azimuthal Angle Steps
  - Improved Radius Residual Sign Coding and Points Ordering
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- **Low-Latency and Low-Complexity Dedicated Codec (LL-LC²)**

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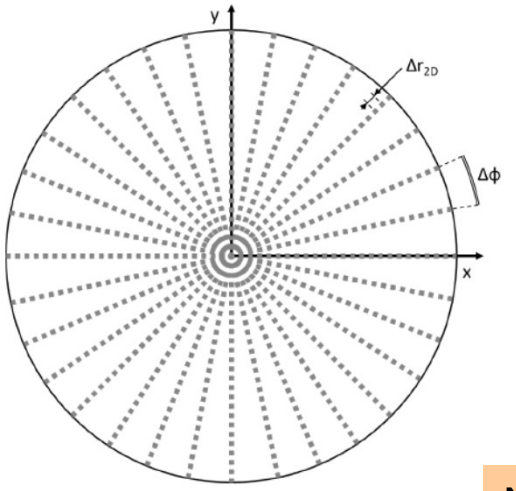
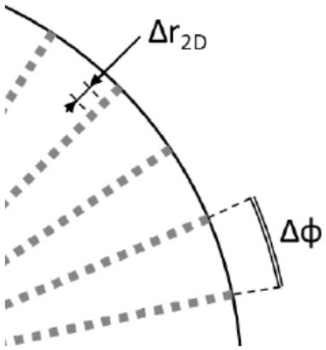
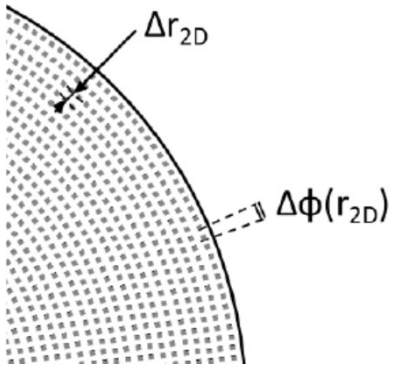
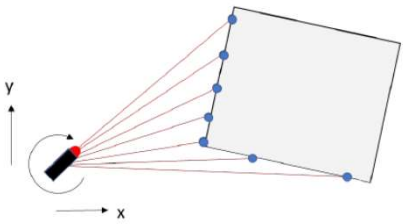
LIDAR Predictive geometry

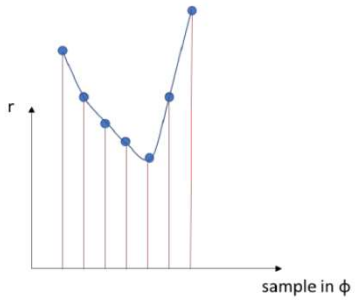






Non-uniform quantization of ϕ depending on r.





Better prediction and encoding of the residual for the (r,ϕ) pairs

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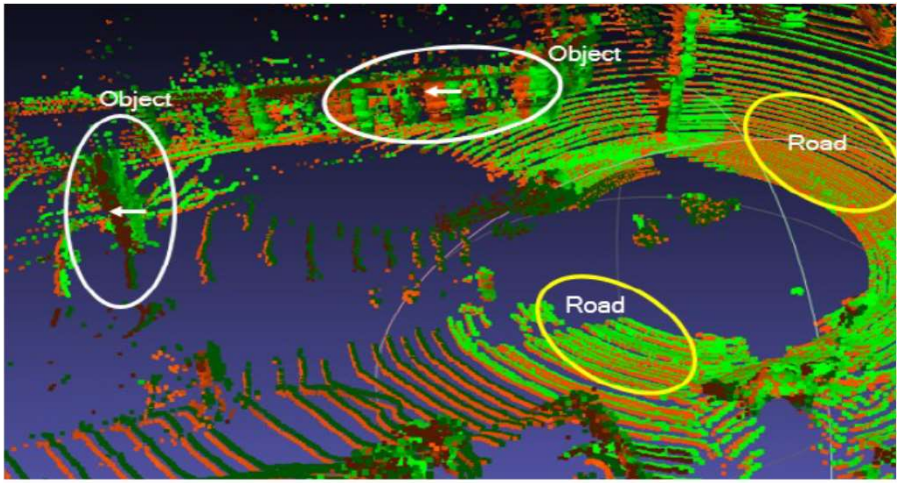
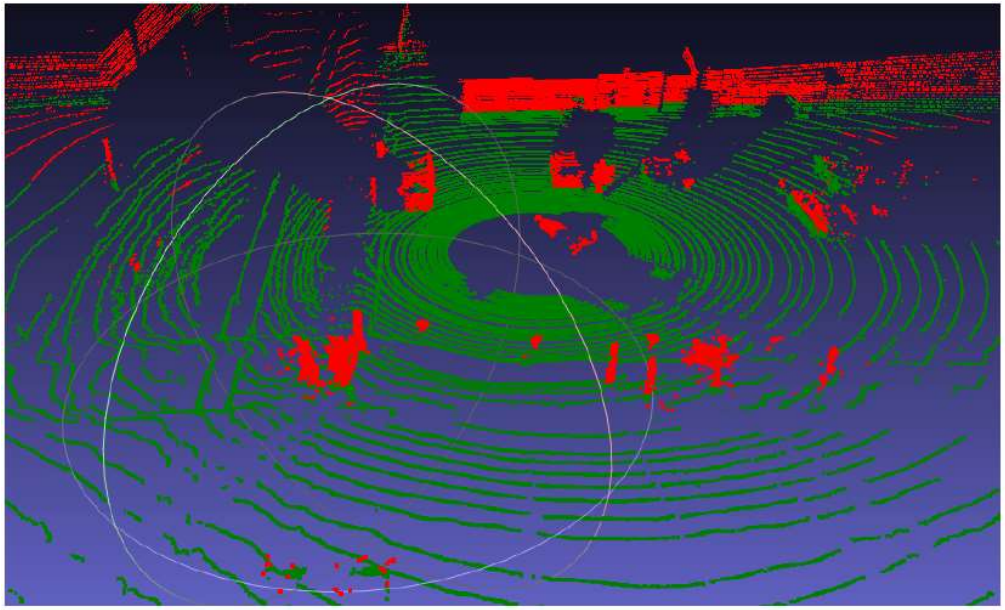
LIDAR Inter-prediction contexts

- *Inter Prediction for Octree Geometry Coding*
  - *From ping to ping*
- *Use Global Motion but separate road from objects*
  - *Objects move differently; road is mostly the same*
- *Two-Threshold Classification of point height*





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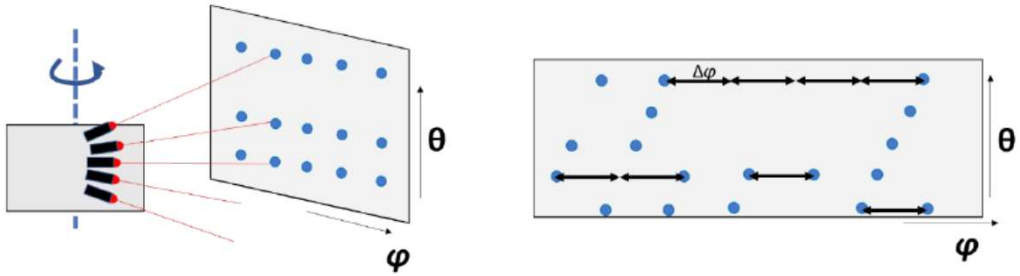
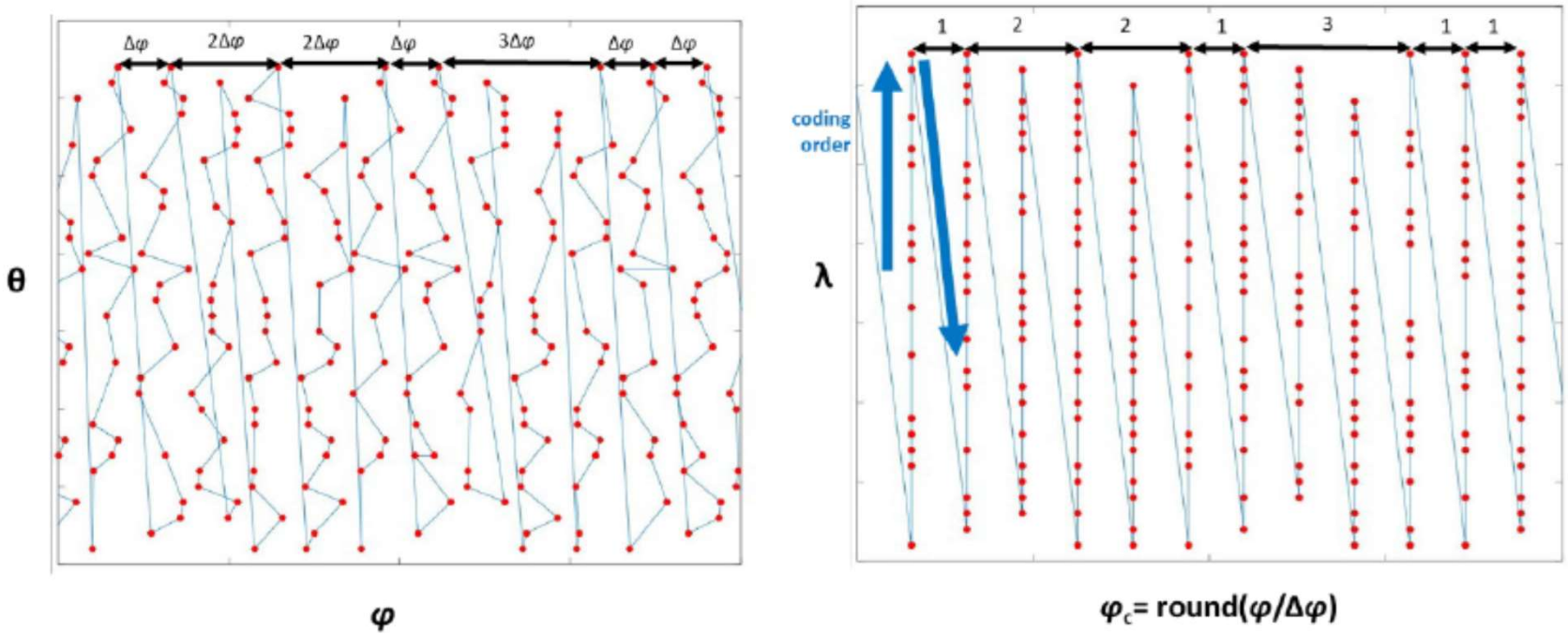
LL-LC² (low latency–low complexity)

- Rotating LiDAR
- Coarse positions, then residues





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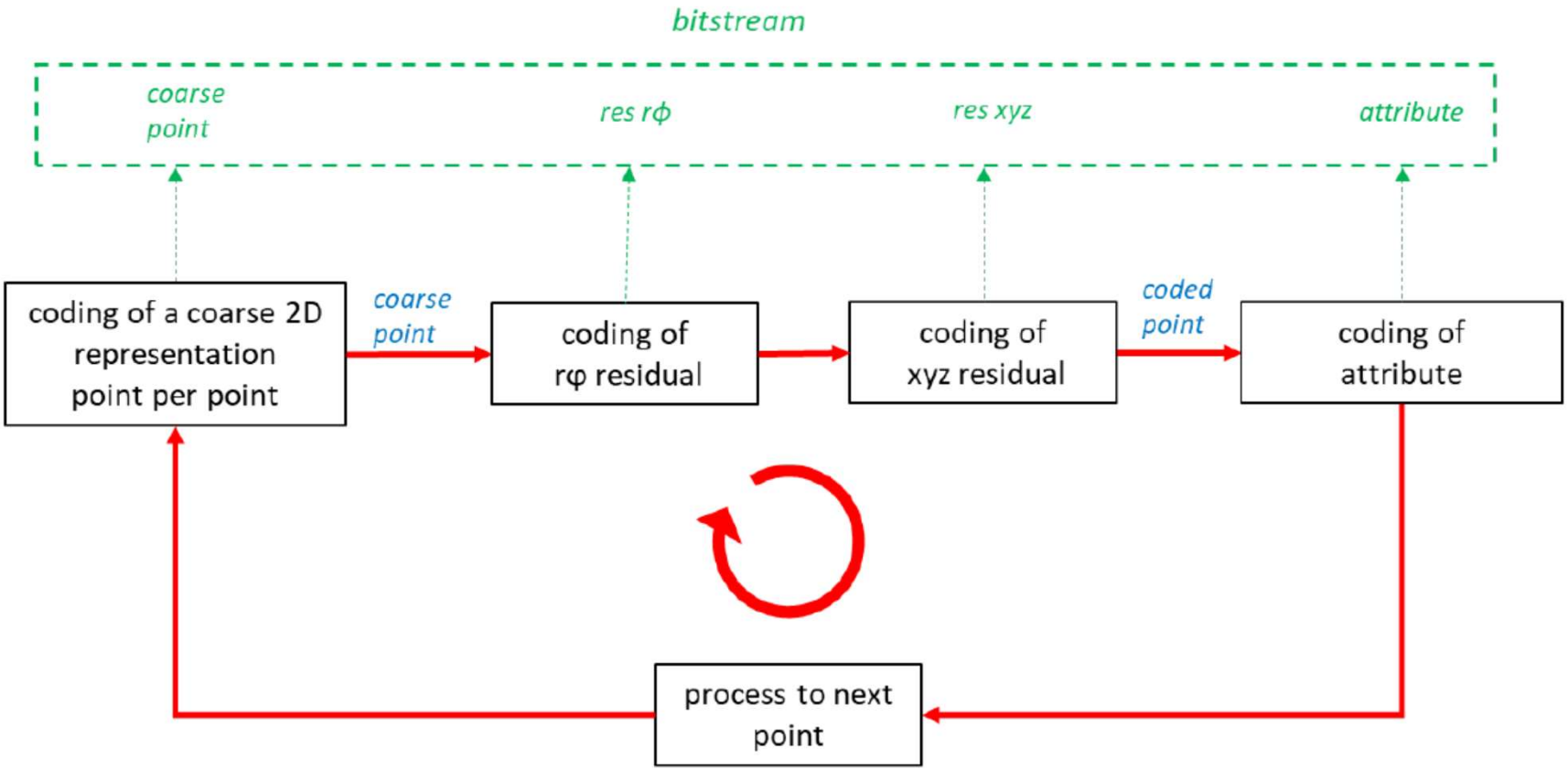
LIDAR LL-LC coder



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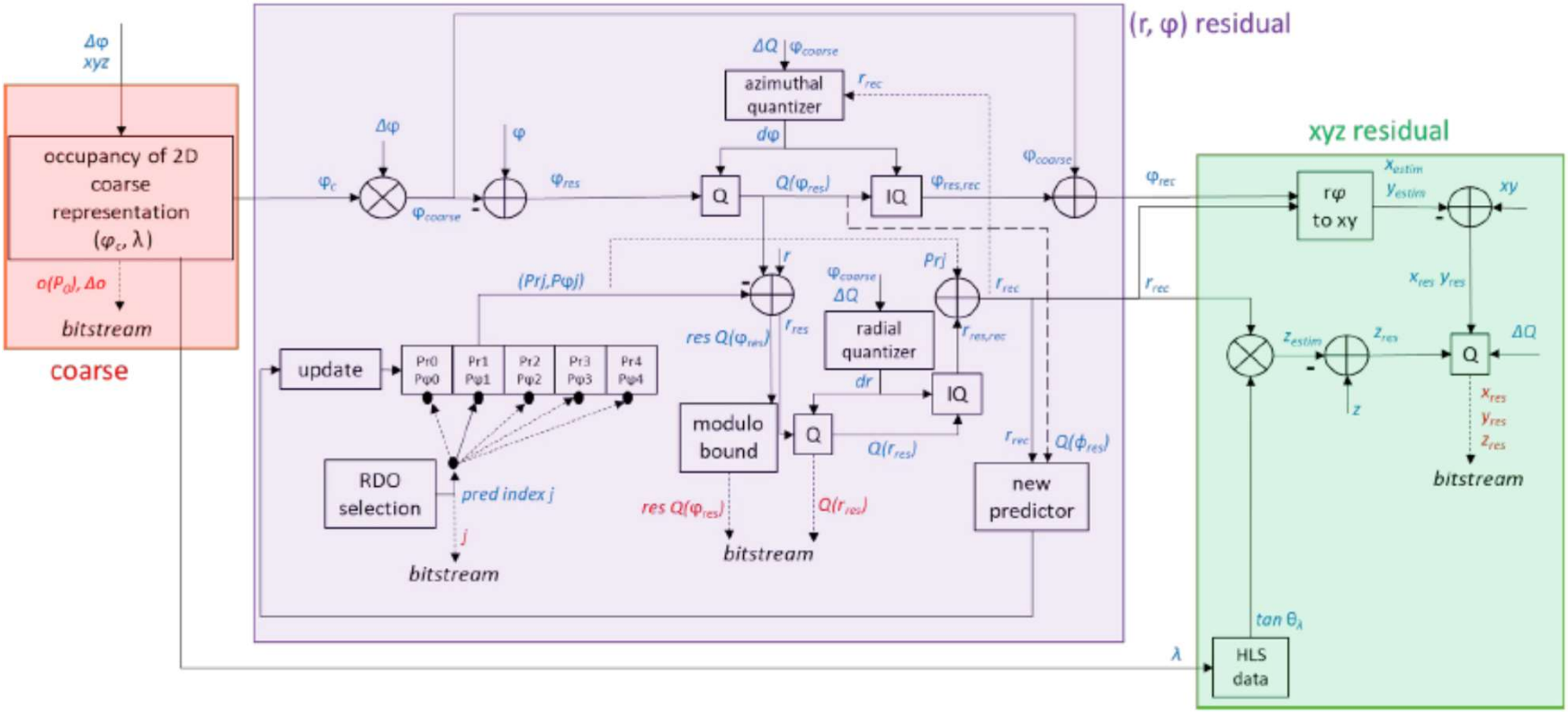
LIDAR LL-LC coder



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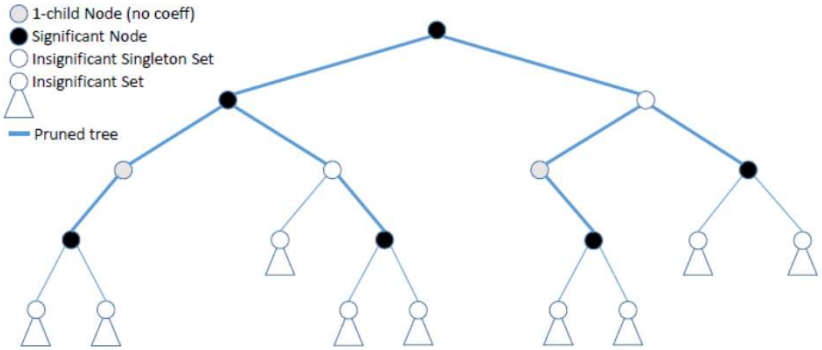
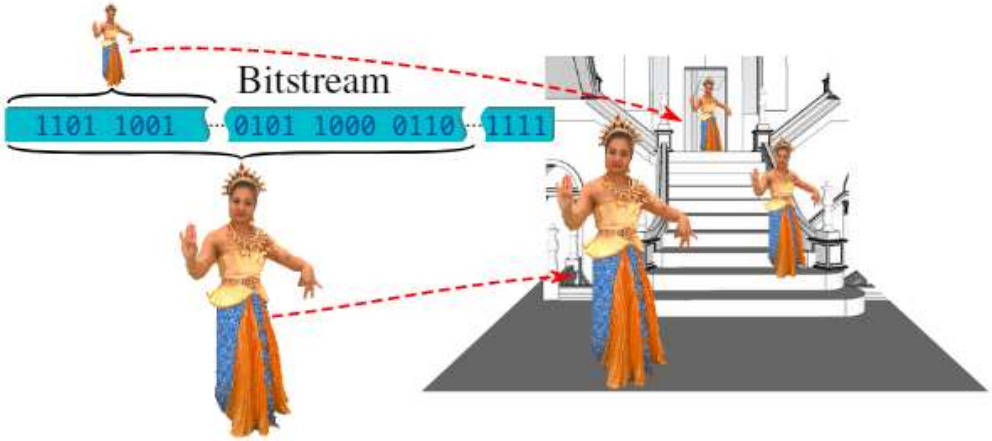
Other topics

- Motion estimation
  - Point cloud blocks
  - Fast search
- Scalability and embedded coders
  - SPIHT for RAHT





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Are these point clouds right?

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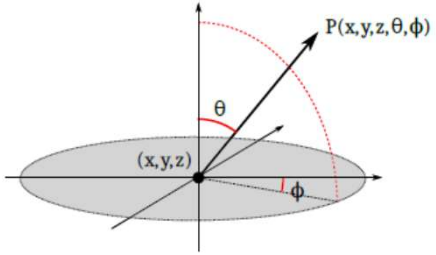
Plenoptic Point Clouds

Surface specularity causes a change of appearance of a given object point at different viewing orientations, caused by illumination reflection.

We may be better off representing a plenoptic function to describe the light seen by viewers of any point at any direction.



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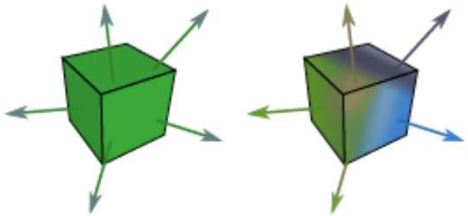
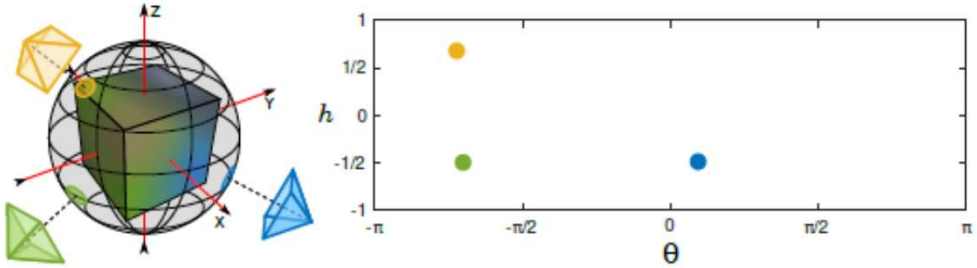
Plenoptic Point Clouds



If we want to make voxels seen differently at different directions one options is to describe a continuous spherical function around the voxel. However, since all the information comes from observing the object from a fixed set of cameras, another alternative is to describe the camera colors for each voxel.



We have a list of colors per voxel per camera.

We end up with a list of data (x,y,z) (r_0, g_0, b_0) (r_1, g_1, b_1) ... (r_n, g_n, b_n)

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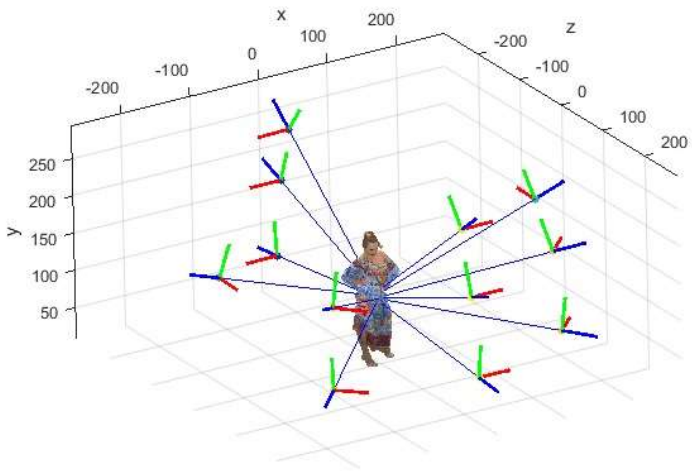
Plenoptic point cloud

- A particular projection using the colors seen by one given camera



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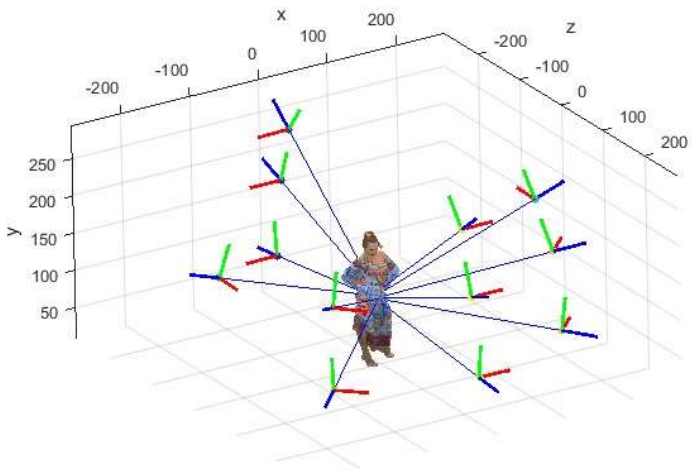
Plenoptic point cloud

- A particular projection using the colors seen by one given camera



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Plenoptic point cloud

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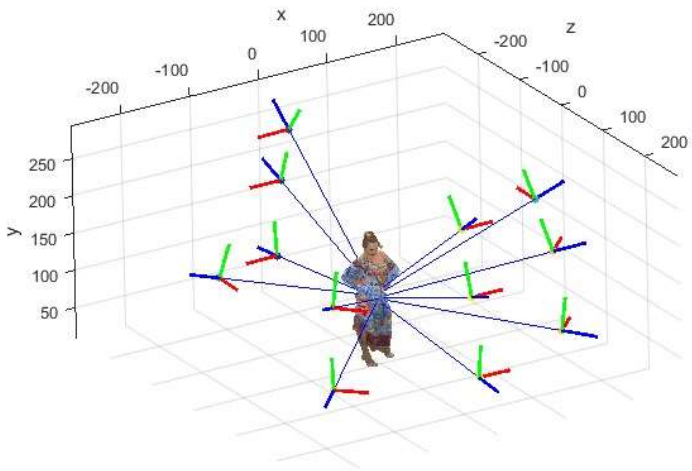

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Plenoptic point cloud

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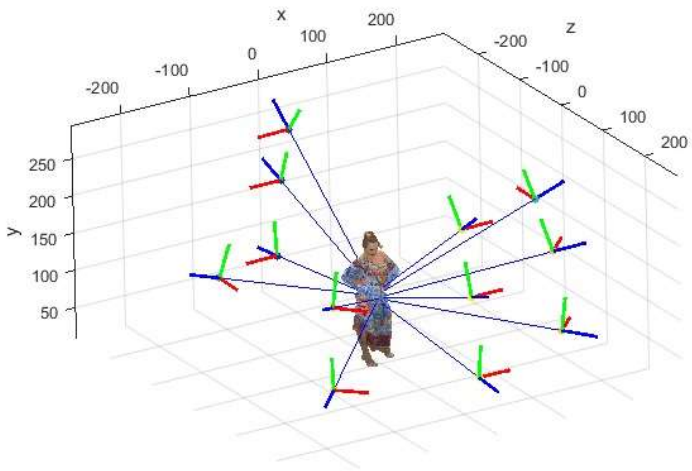

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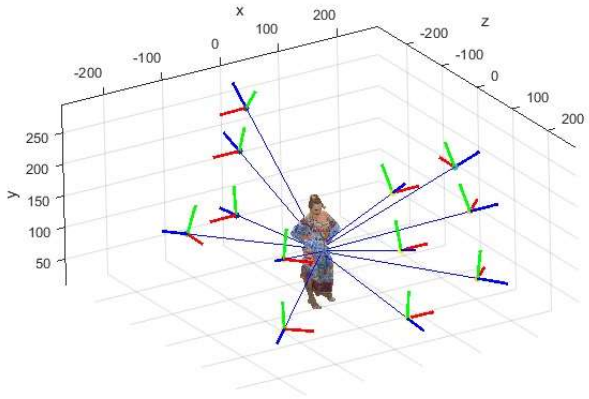
Plenoptic Point Cloud

- We expect the view-dependent representation of the voxels to give an extra degree of realism to the rendering of the point cloud



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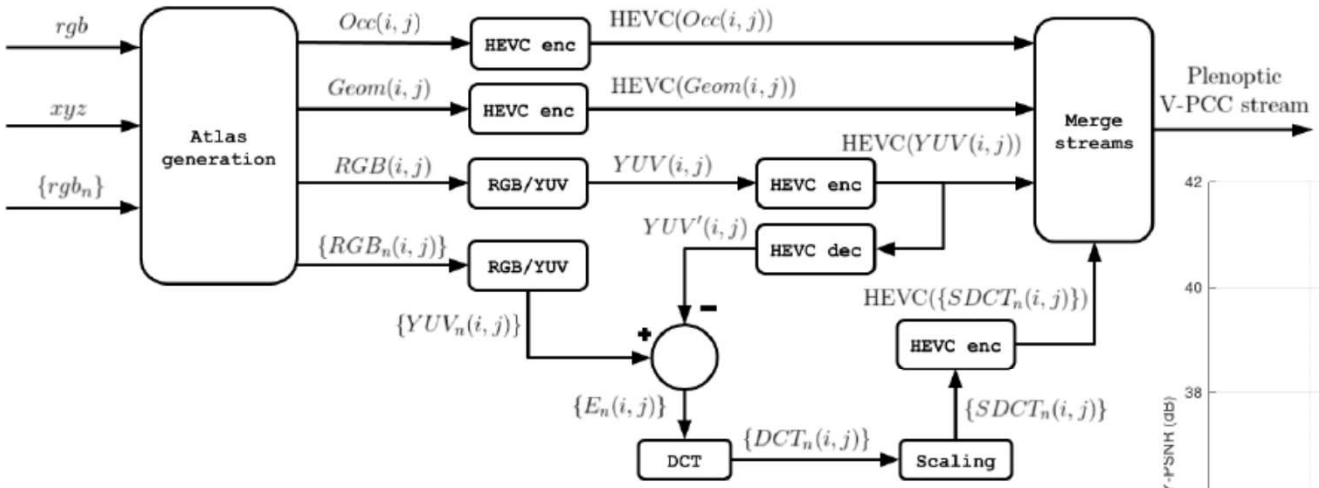
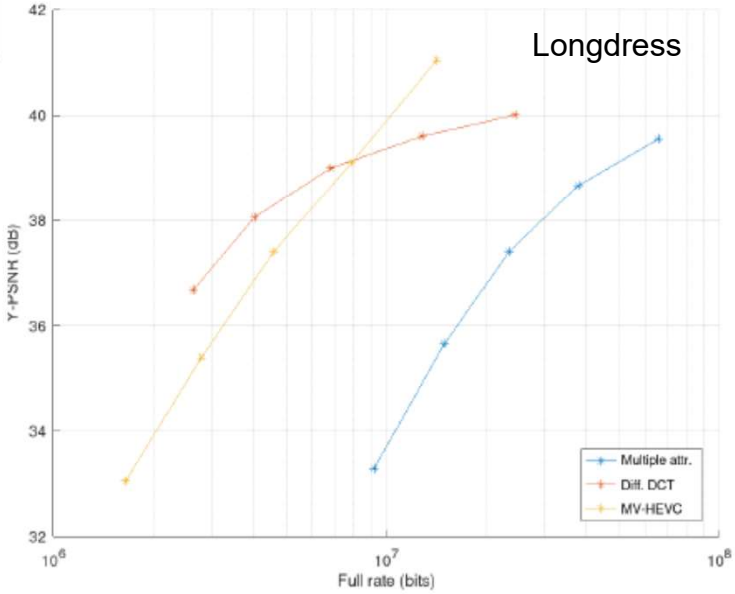
V-Plenoptic PCC (VPPCC)

Plenoptic enhancement differential encoder





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Model-centric point cloud

- Only reflects the model characteristics.
- Lighting- and camera-independent.
- May represent glass, fog, mirrors, fish bowls etc.
- 7 attributes inspired in electromagnetic properties.
- At each voxel boundary, the renderer can calculate Snell and Fresnel.

	Min.	Meaning	Max.	Meaning
R_t	0.0	All red transmitted	1.0	All red reflected
G_t	0.0	All green transmitted	1.0	All green reflected
B_t	0.0	All blue transmitted	1.0	All blue reflected
R_a	0.0	No red attenuation	1.0	All red absorbed
G_a	0.0	No green attenuation	1.0	All green absorbed
B_a	0.0	No blue attenuation	1.0	All blue absorbed
D	0.0	Perfect specularity	1.0	Lambertian diffusion

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Conclusions

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Thank you