Point Cloud Streaming using Temporal Hierarchical GMMs

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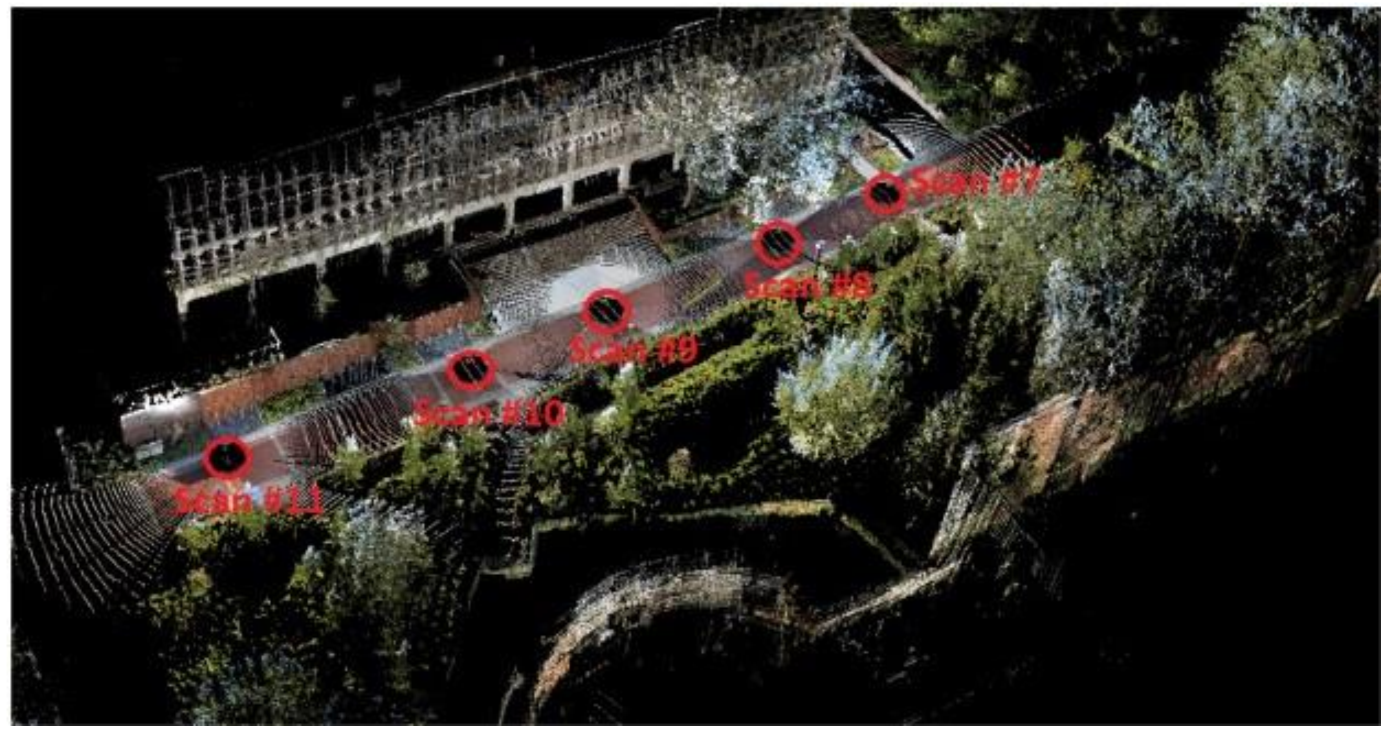
Motivation

- Point clouds important for robotics, telepresence, …



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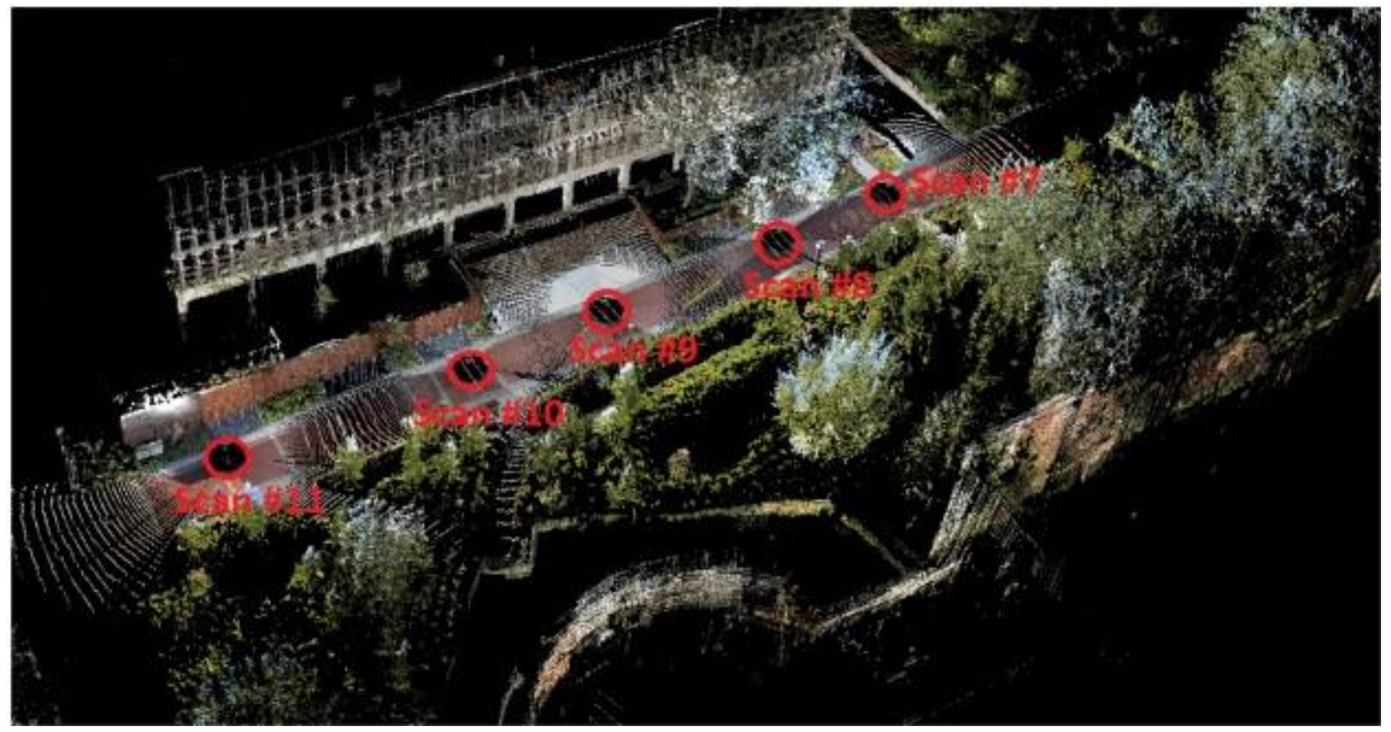
  - Goals: Efficient processing, accurate representation
  - Issues: Sensor noise, huge data loads



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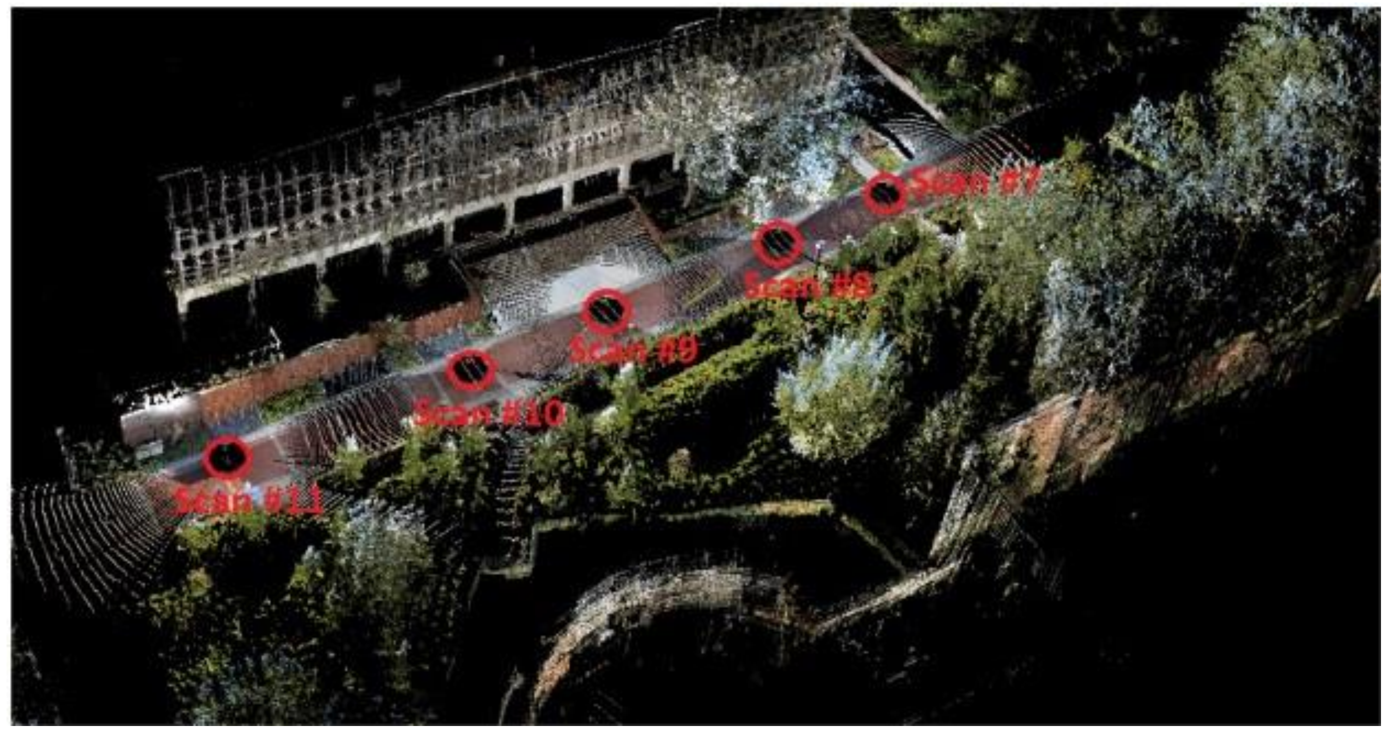
- Challenging for web/streaming applications!
- How to maximize speed + compactness?



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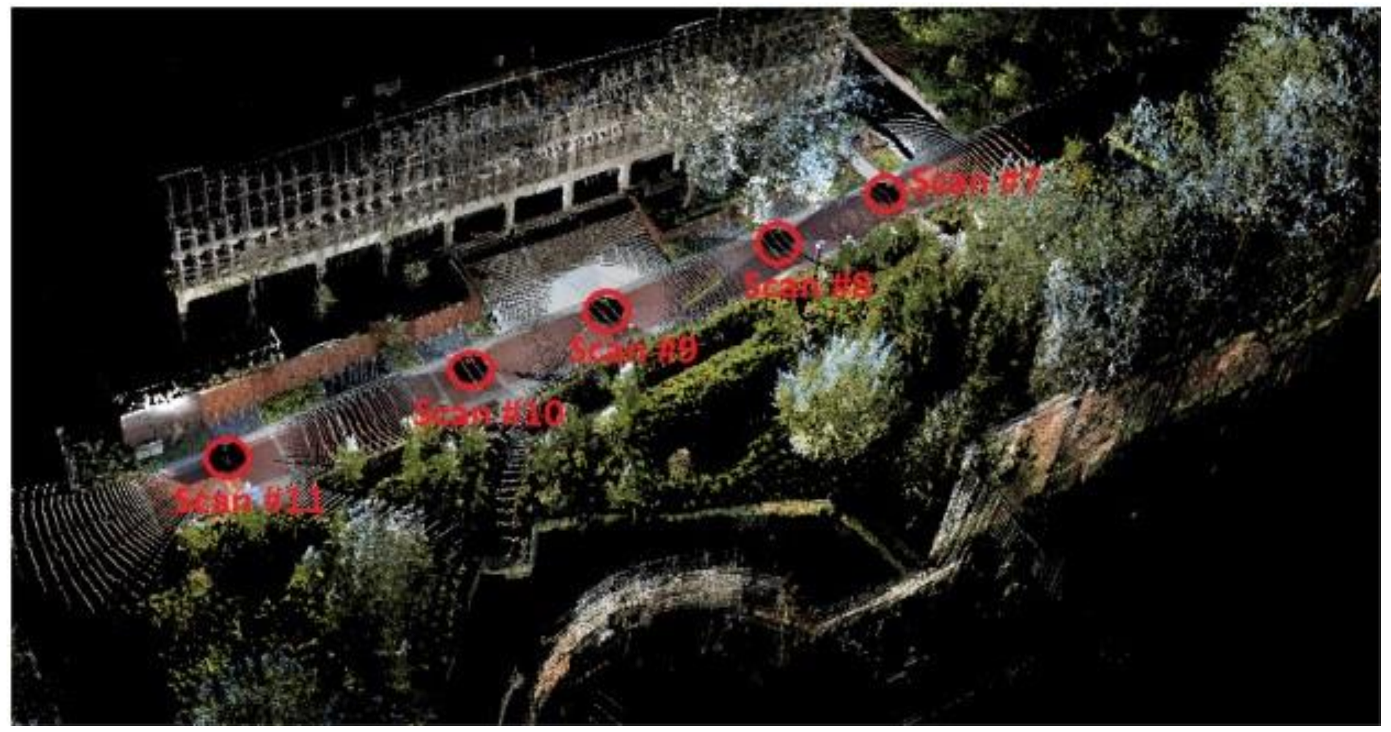
⬇

- Generative probabilistic models (e.g., GMMs)
  - Continuous, model complex distributions, handle uncertainty



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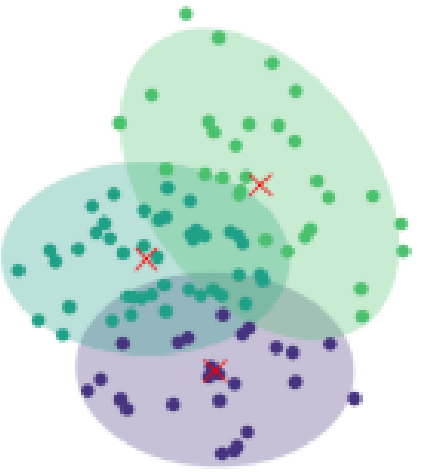

Related Work

- GMMs for occupancy modelling, SLAM [O'Meadhra 23, Dong 22]

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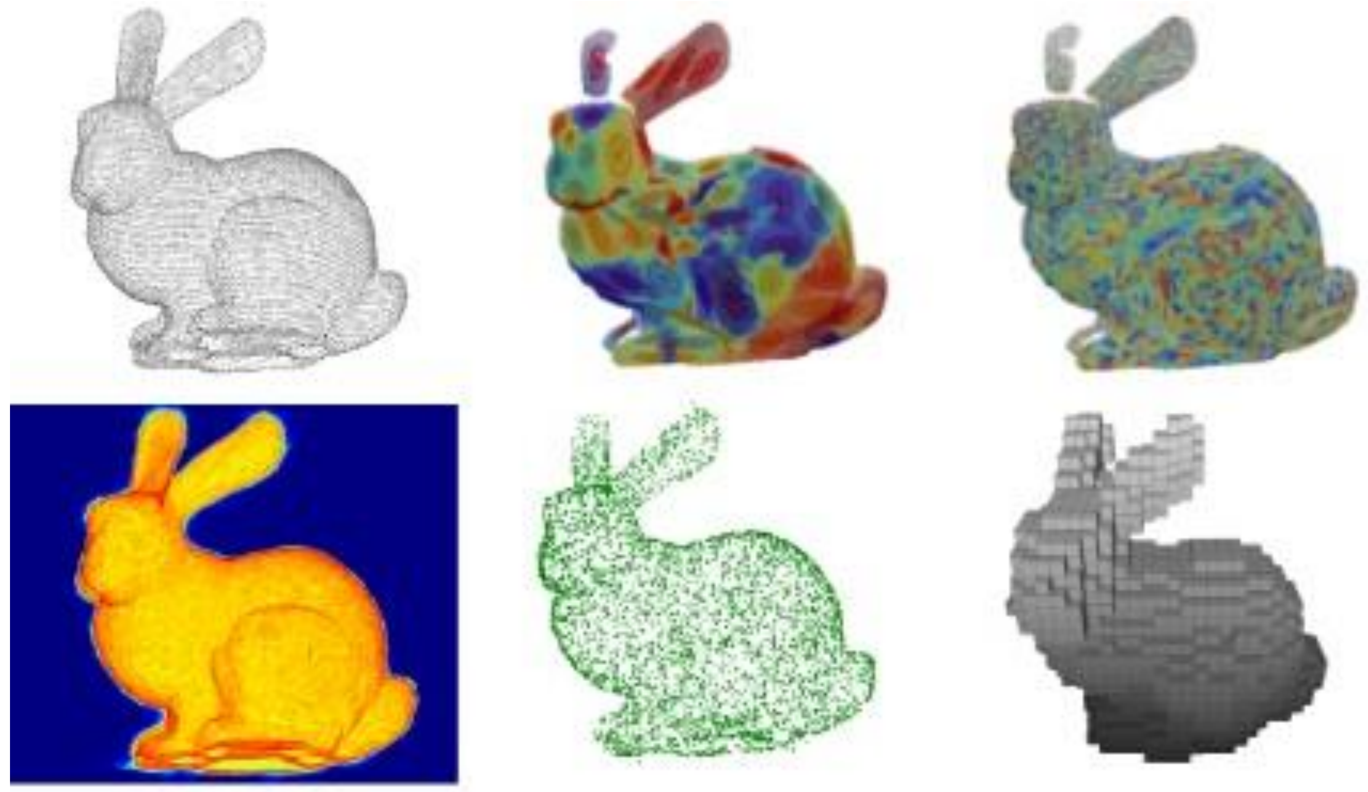
- GMM hierarchy + parallel EM algorithm for point cloud representation/processing [Eckart 16]



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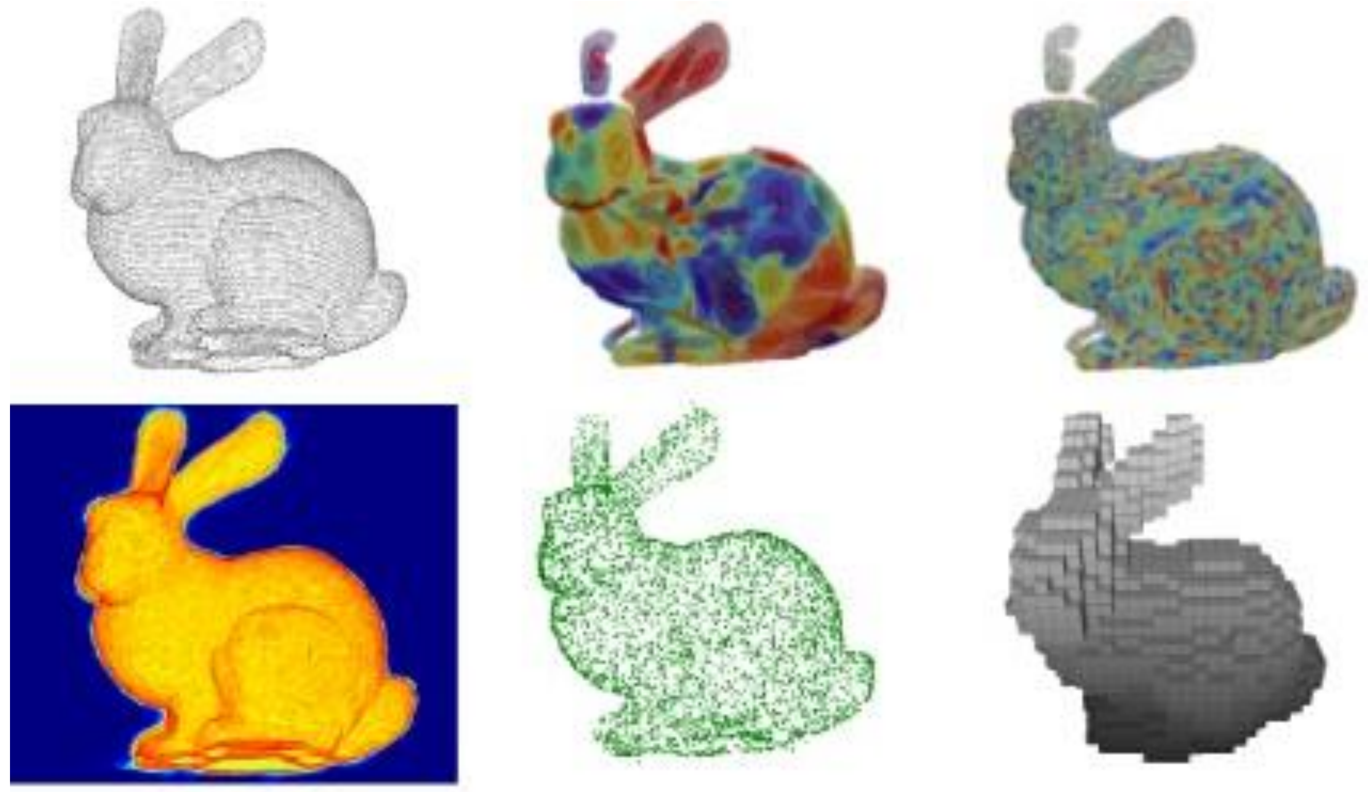
- GMMs for occupancy modelling, SLAM [O'Meadhra 23, Dong 22]
- GMM-based 3D compression [Sun 23]
  - Not real-time capable
- GMM hierarchy + parallel EM algorithm for point cloud representation/processing [Eckart 16]
  - Fast construction, enables LODs
  - No progressive rendering, doesn't consider sequential data



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  - Hierarchy of GMMs + adapted EM algorithm
  - Level-by-level construction -> dynamic LODs, adaptive transmission
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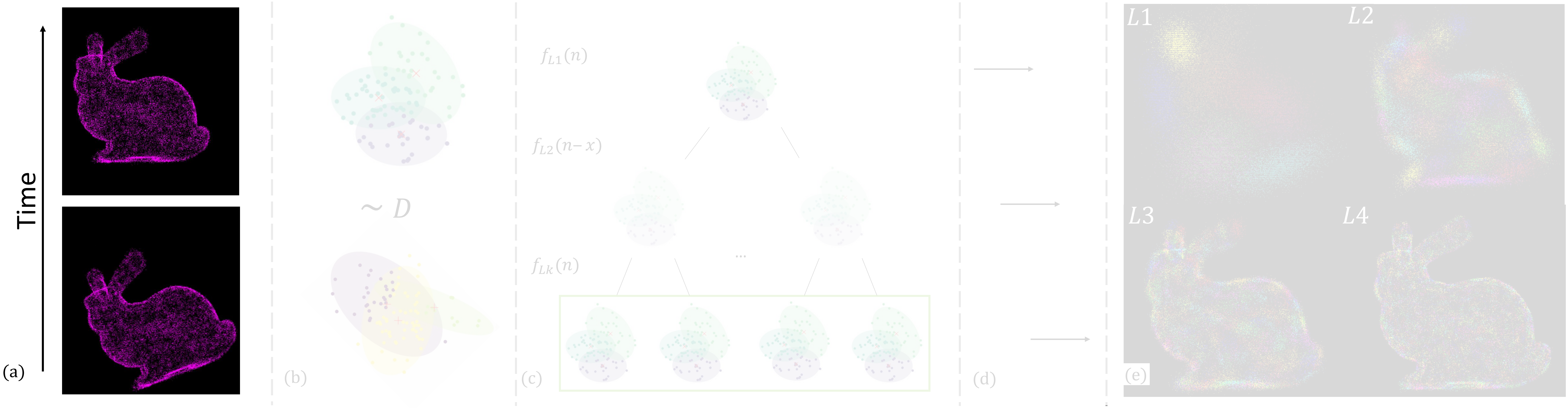
Our Contributions

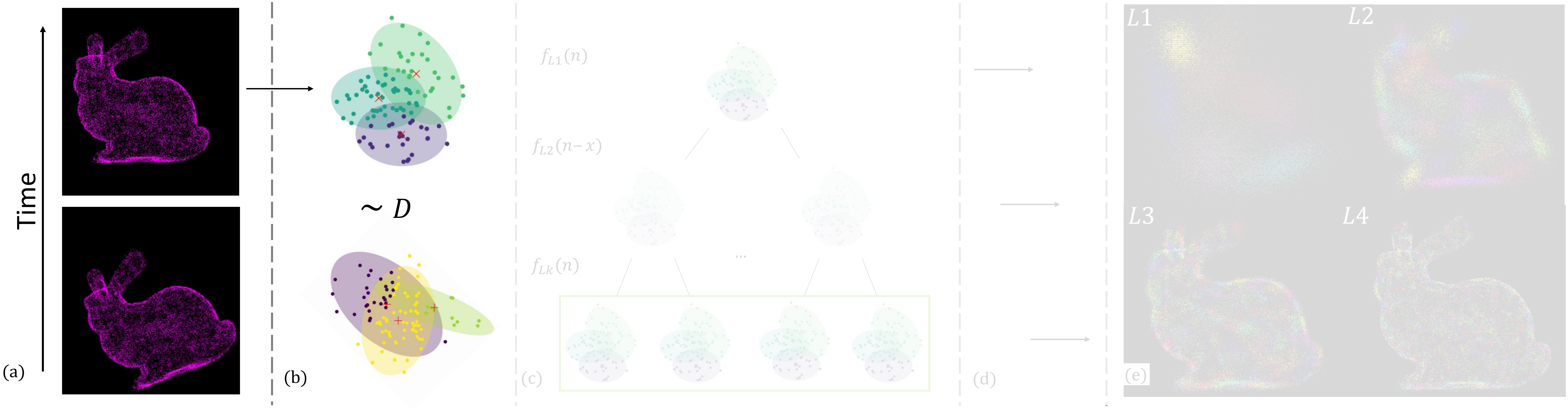
- Novel approach for compact point cloud representation + streaming
  - Hierarchy of GMMs + adapted EM algorithm
  - Level-by-level construction -> dynamic LODs, adaptive transmission
  - Exploiting temporal coherence in streaming input
  - Parallel CUDA implementation
- Comprehensive evaluation
  - Speed, size, accuraccy

Overview



Continous Point
Cloud Input

Overview



Continous Point Cloud Input

Compute GMM, Divergence to Previous Input (L1)

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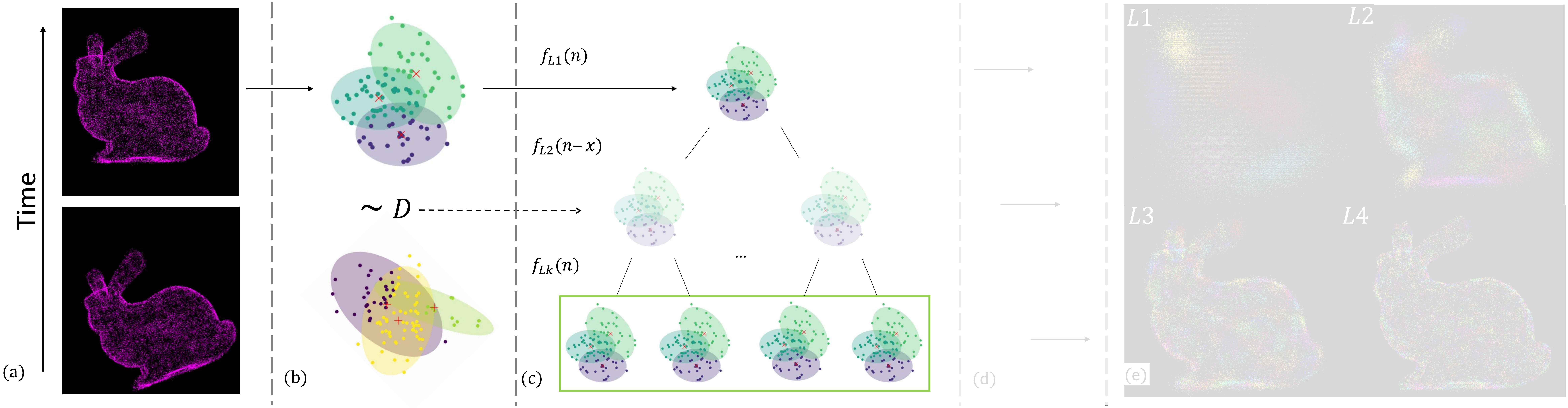

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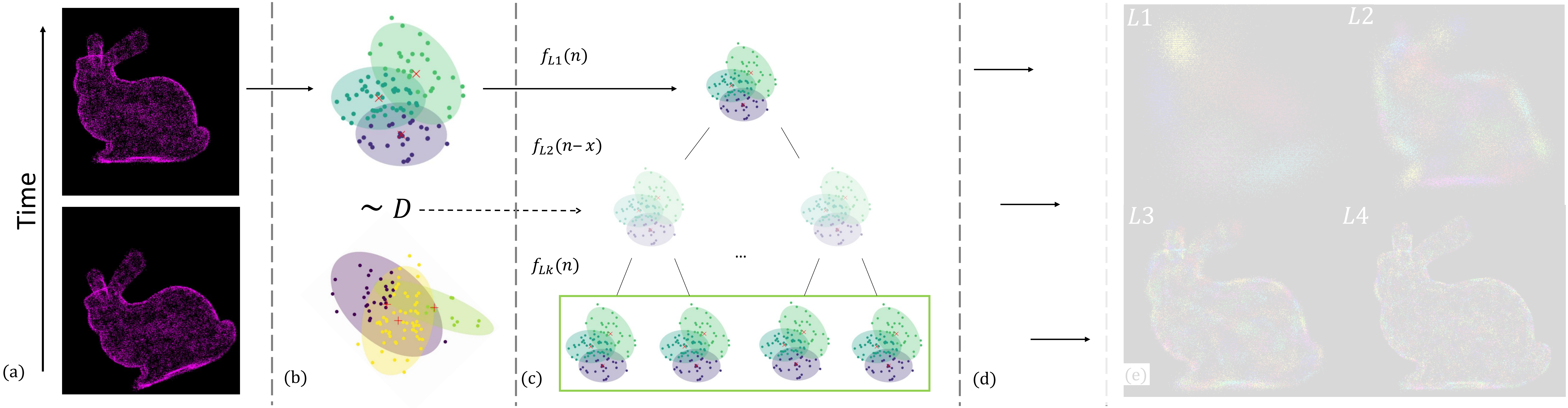

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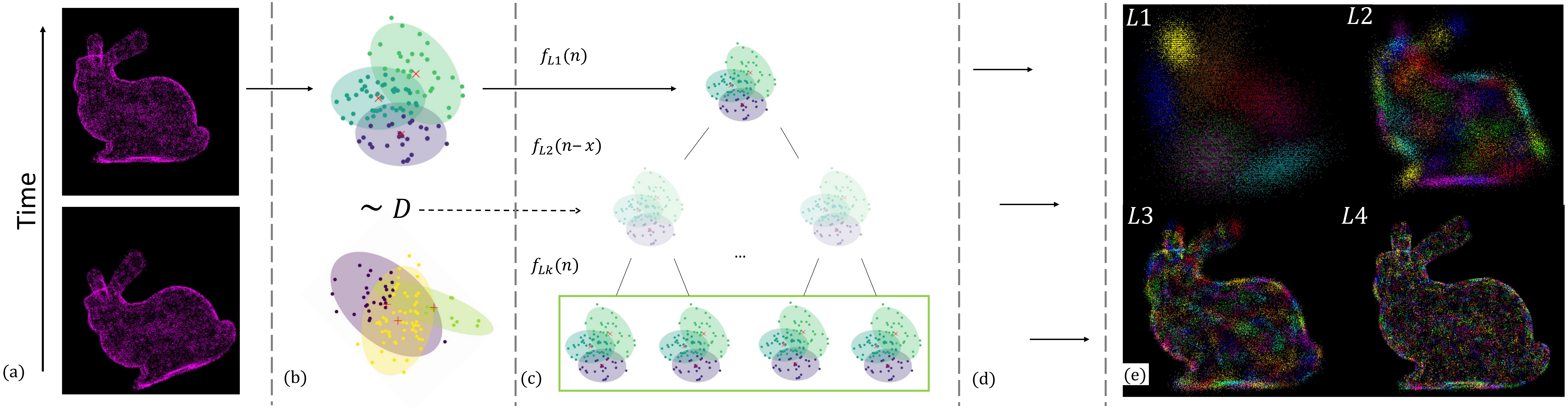

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Compute GMM, Divergence to Previous Input (L1)

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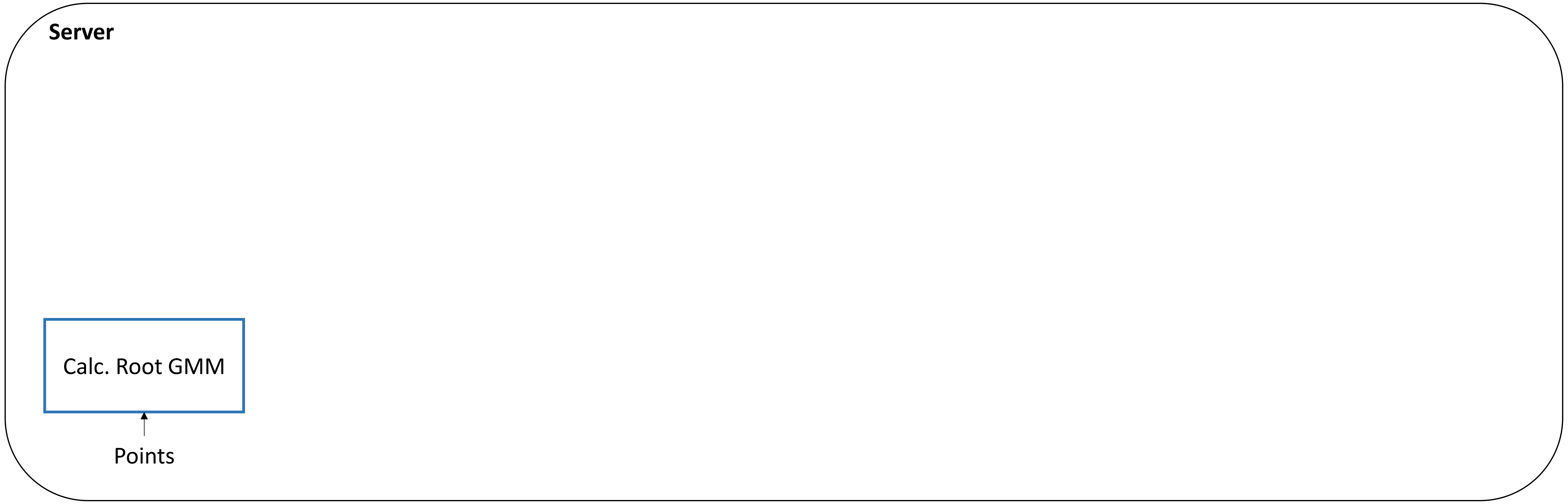
Progressive Streaming

LODs for Reconstruction

Method Details



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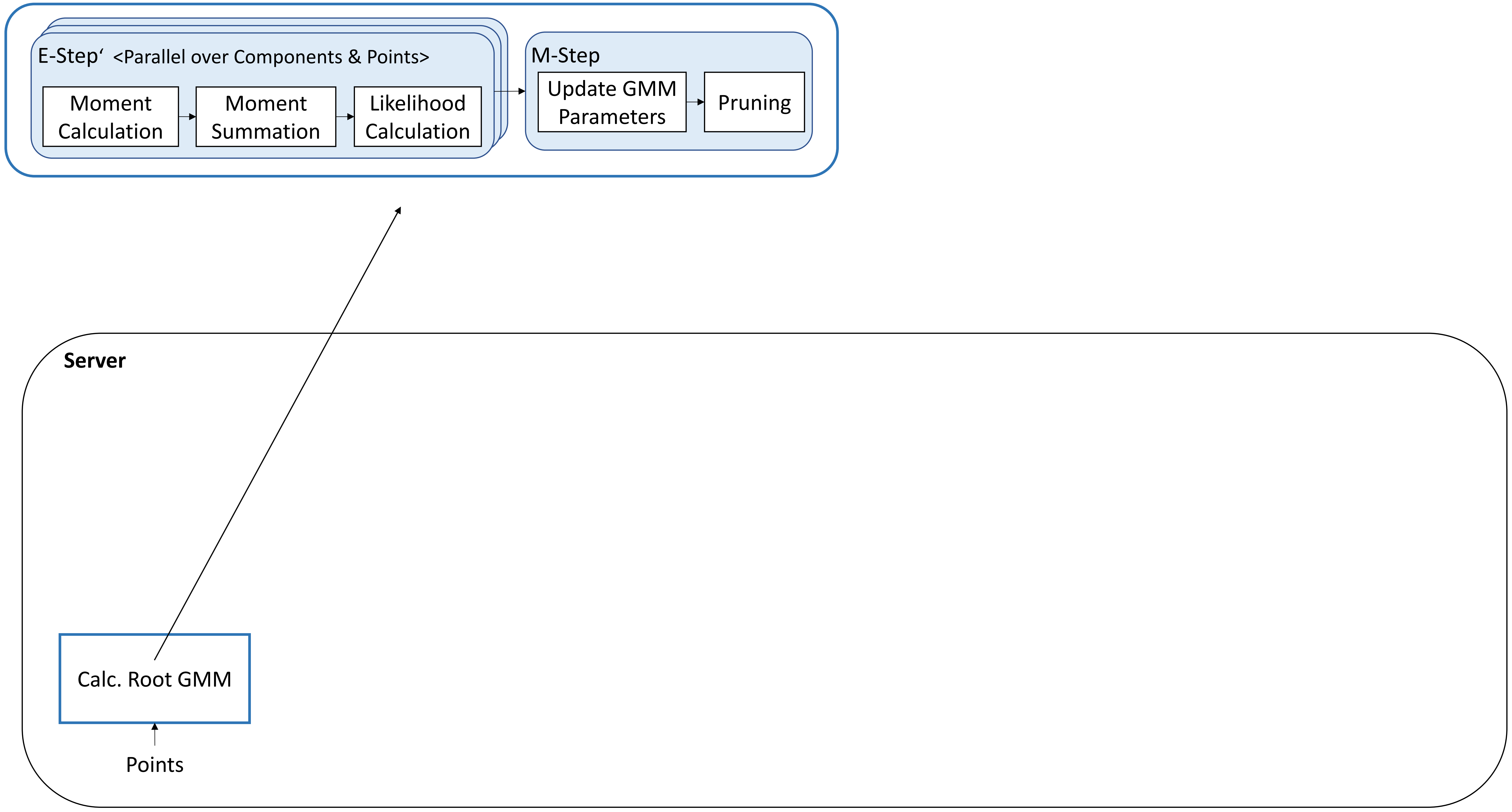

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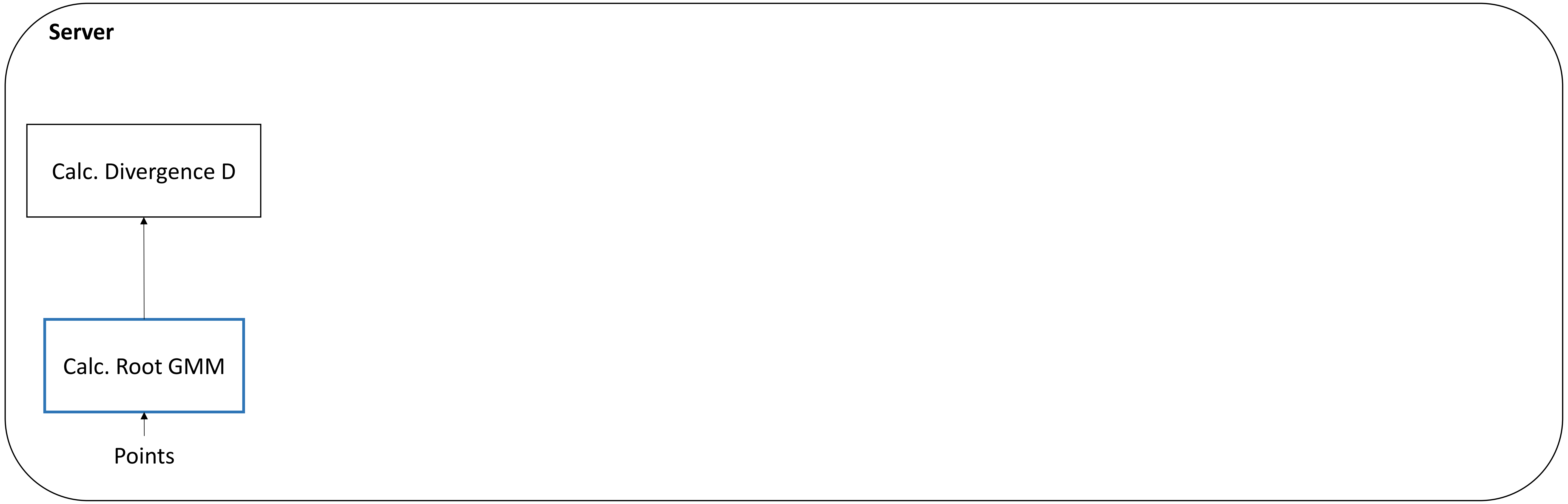

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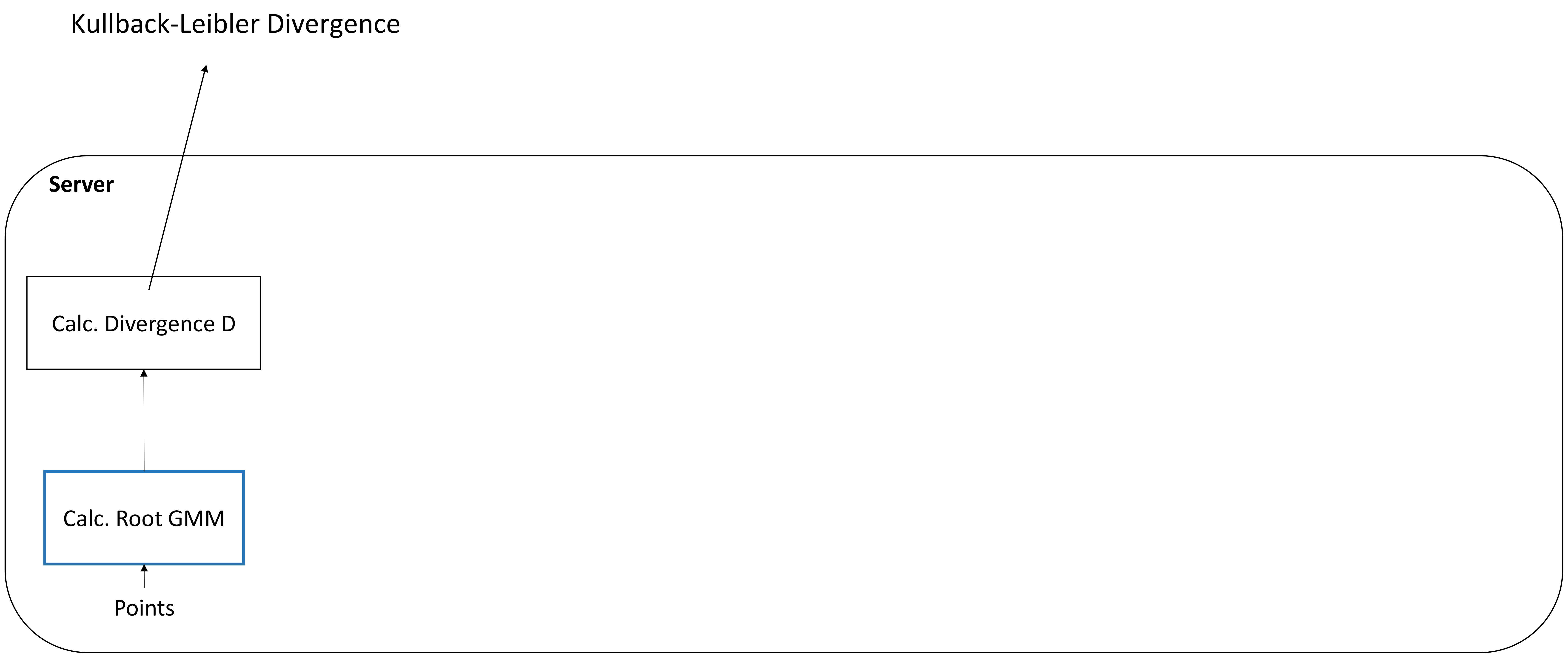

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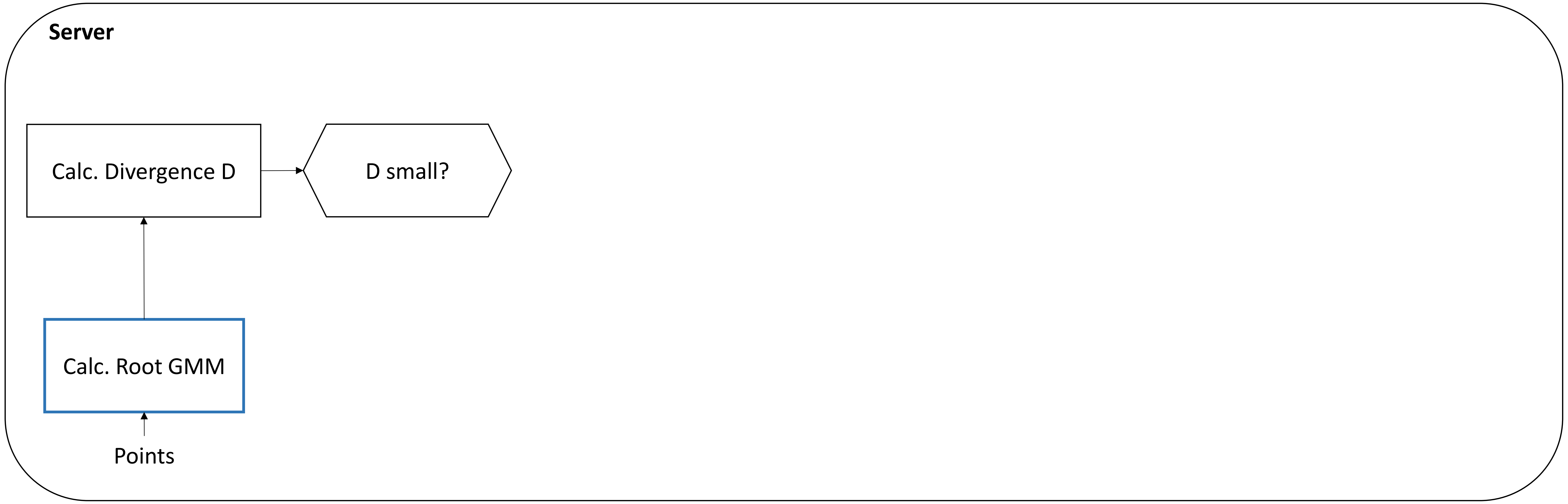

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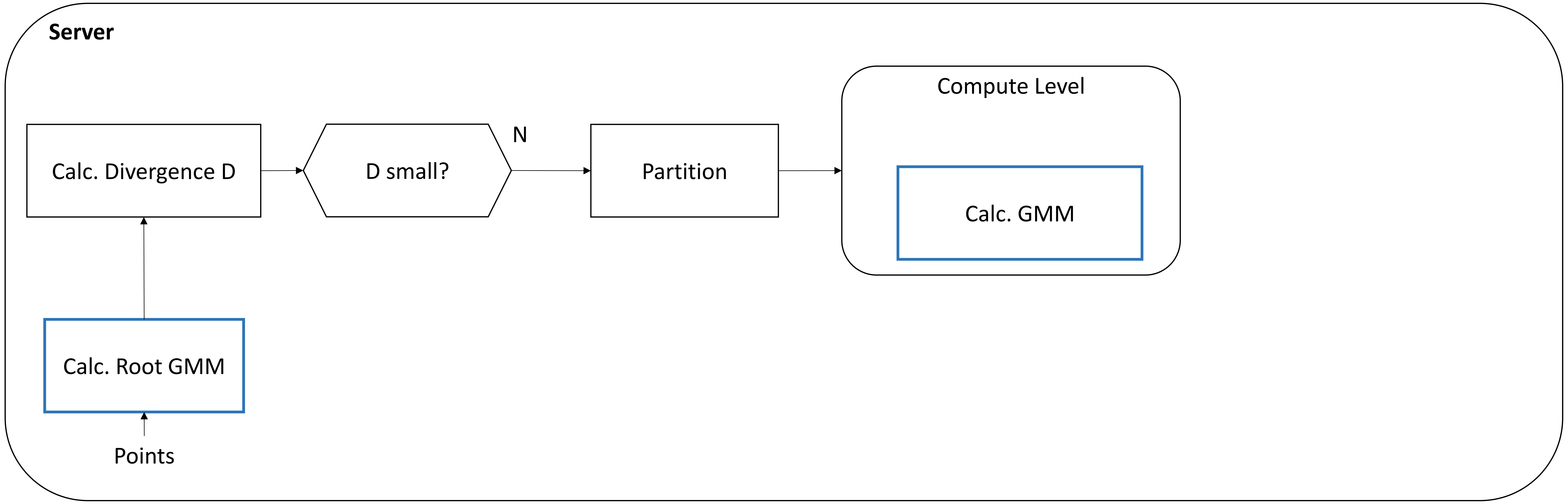

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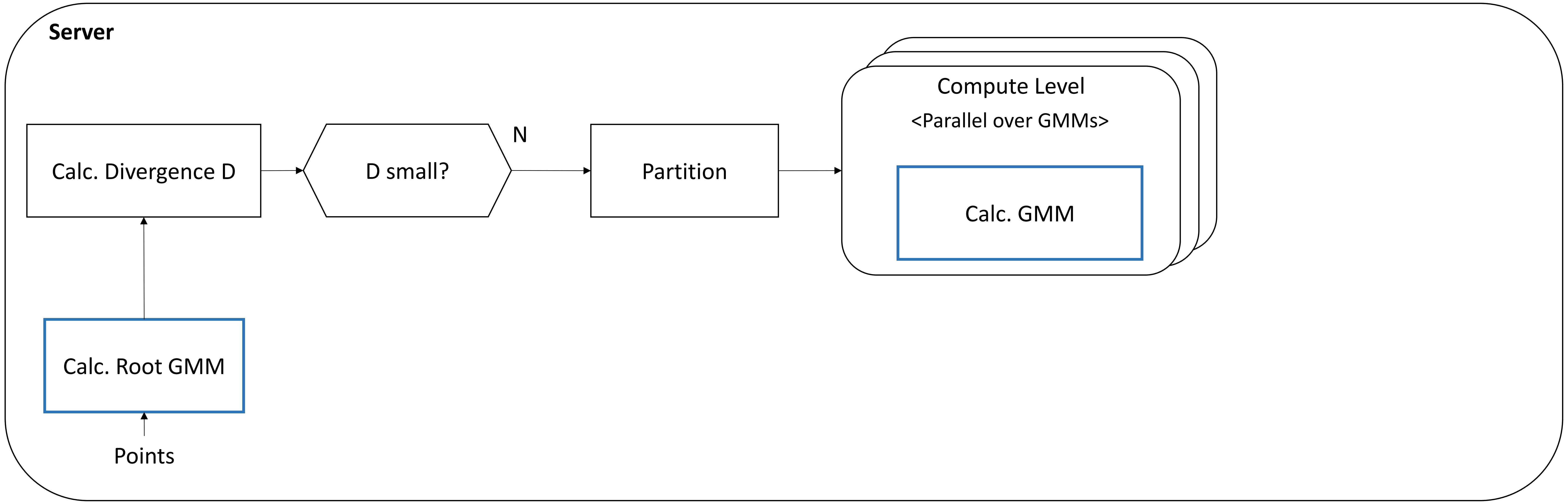

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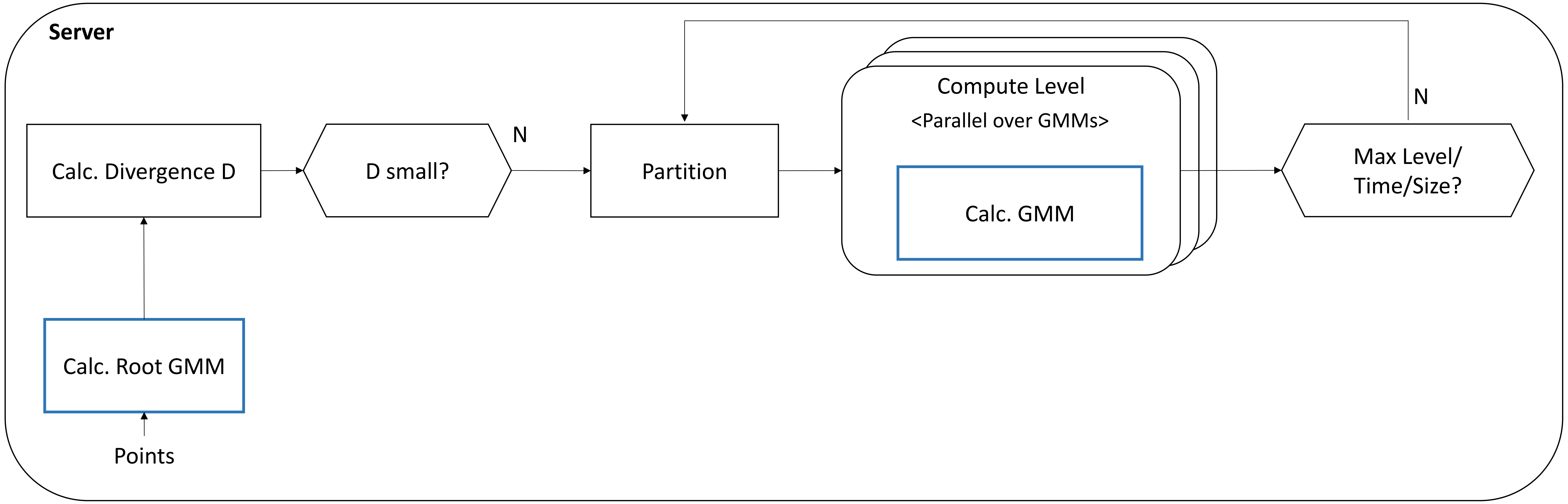

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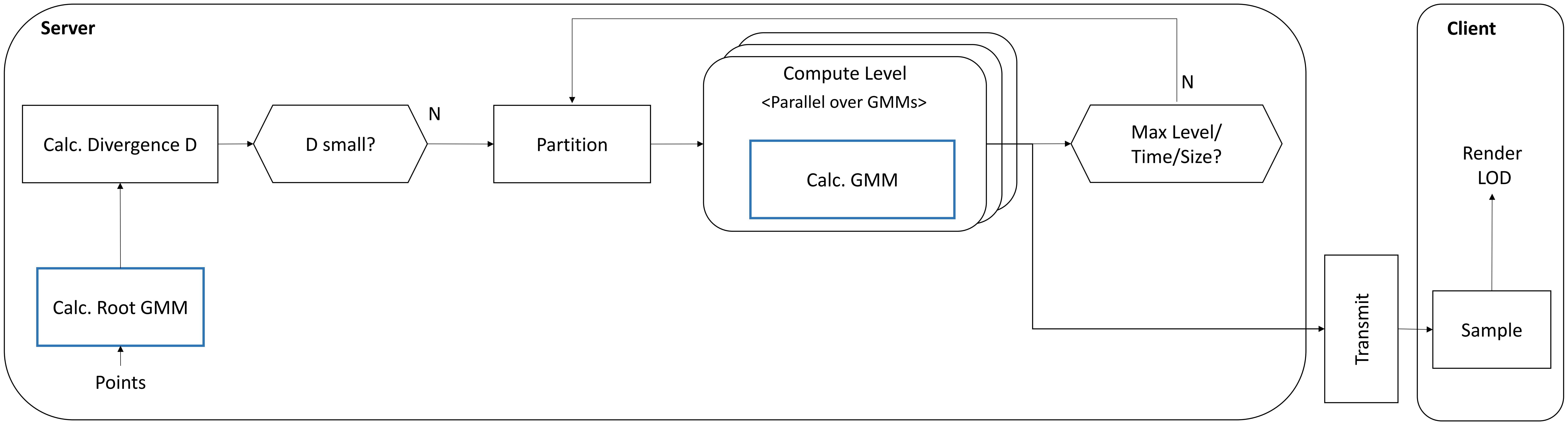

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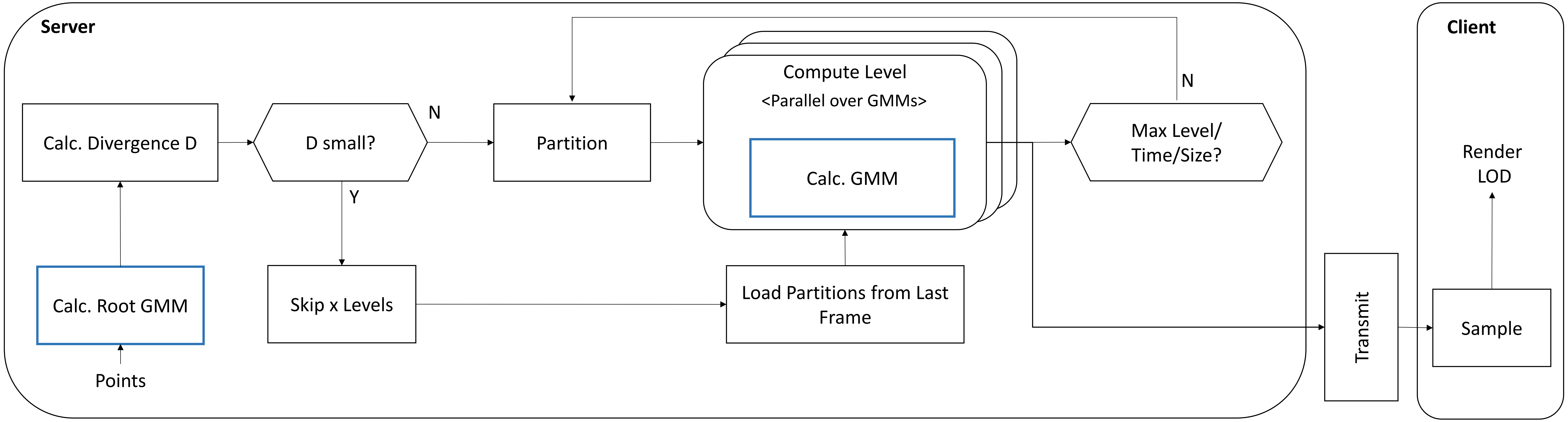
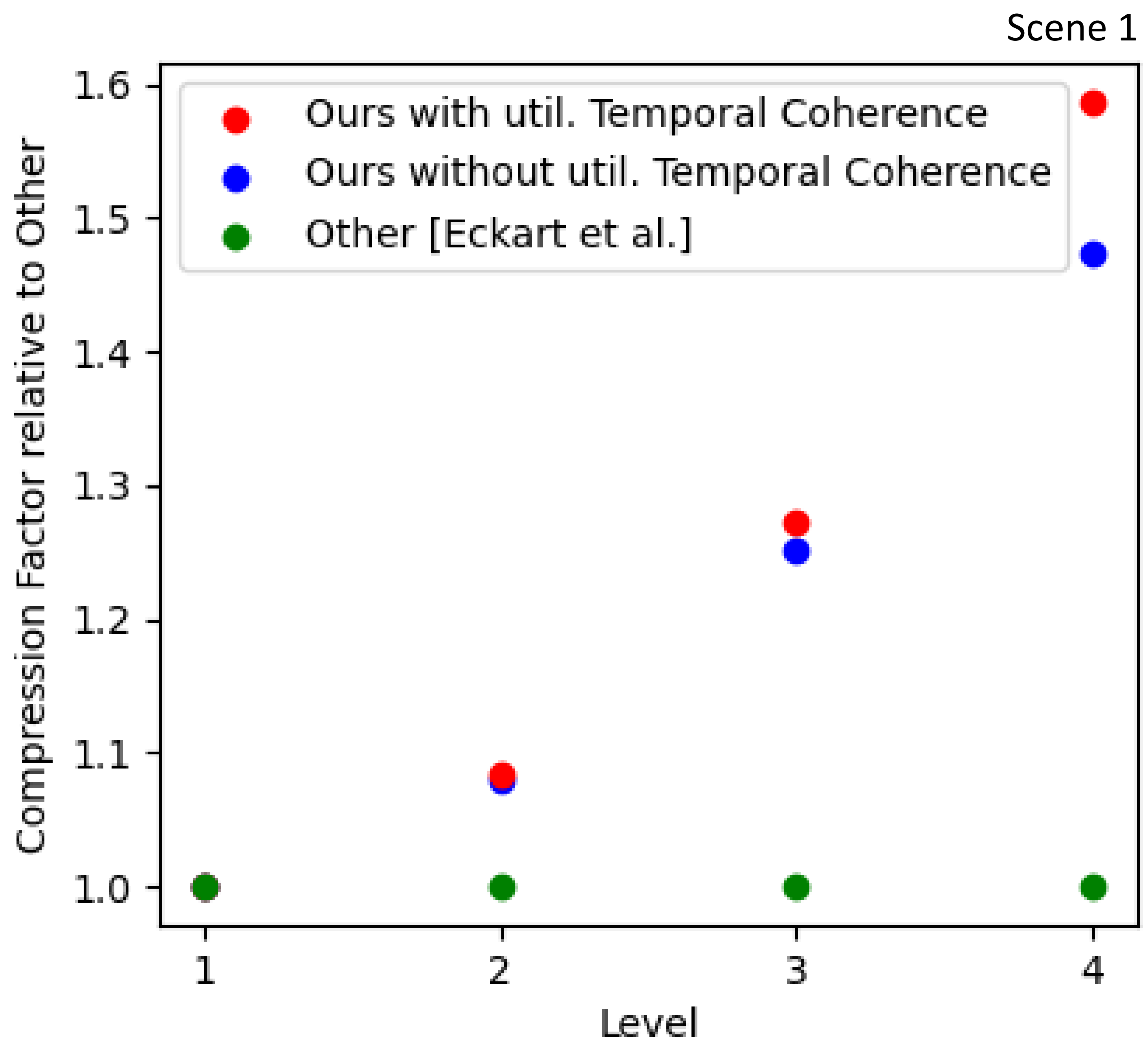


Results & Discussion: Size + Accuracy



All results with GPU: RTX 4090

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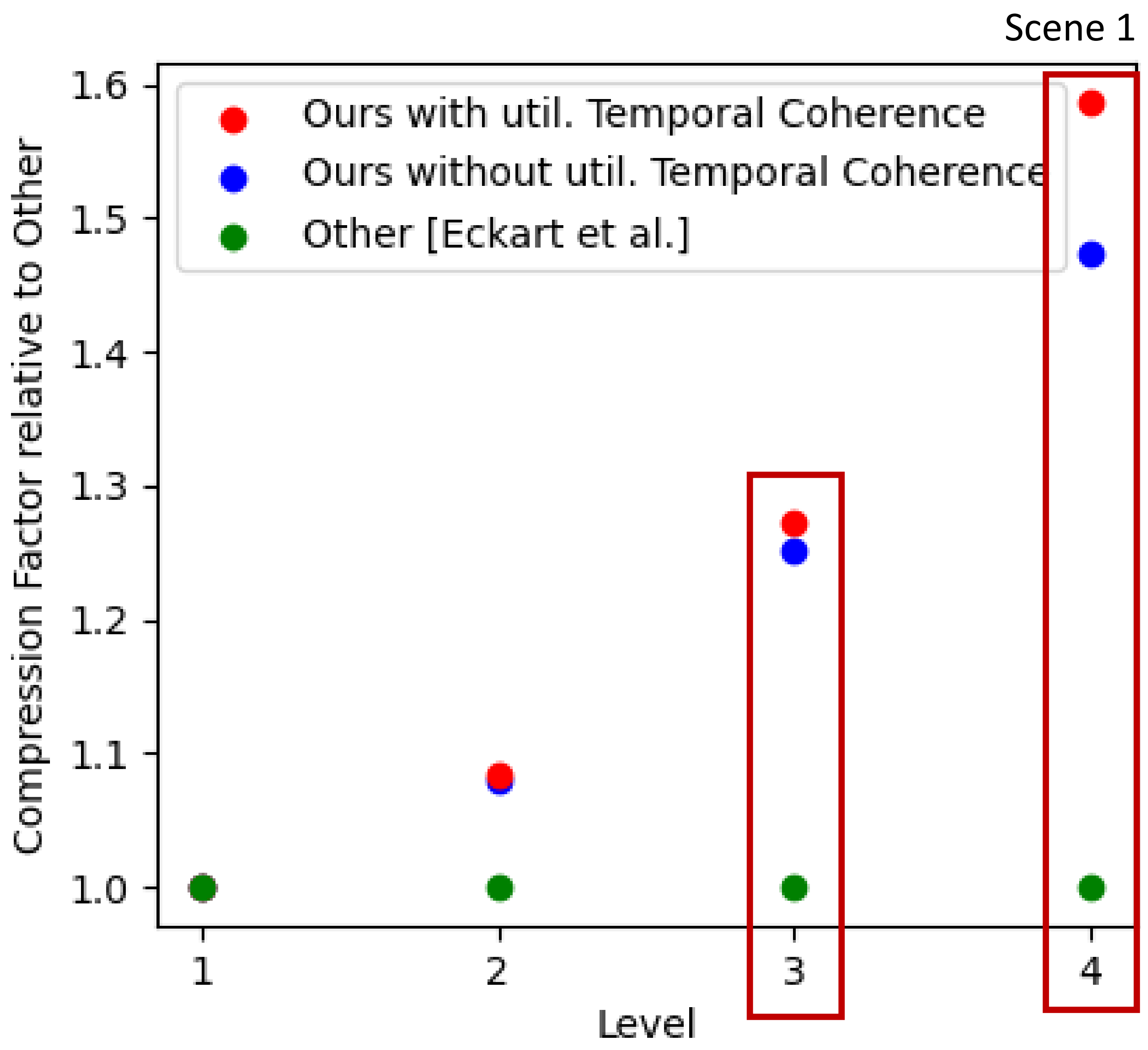

Significantly higher compression factors:
26.7@L3, 4.1@L4 (58.7% higher)

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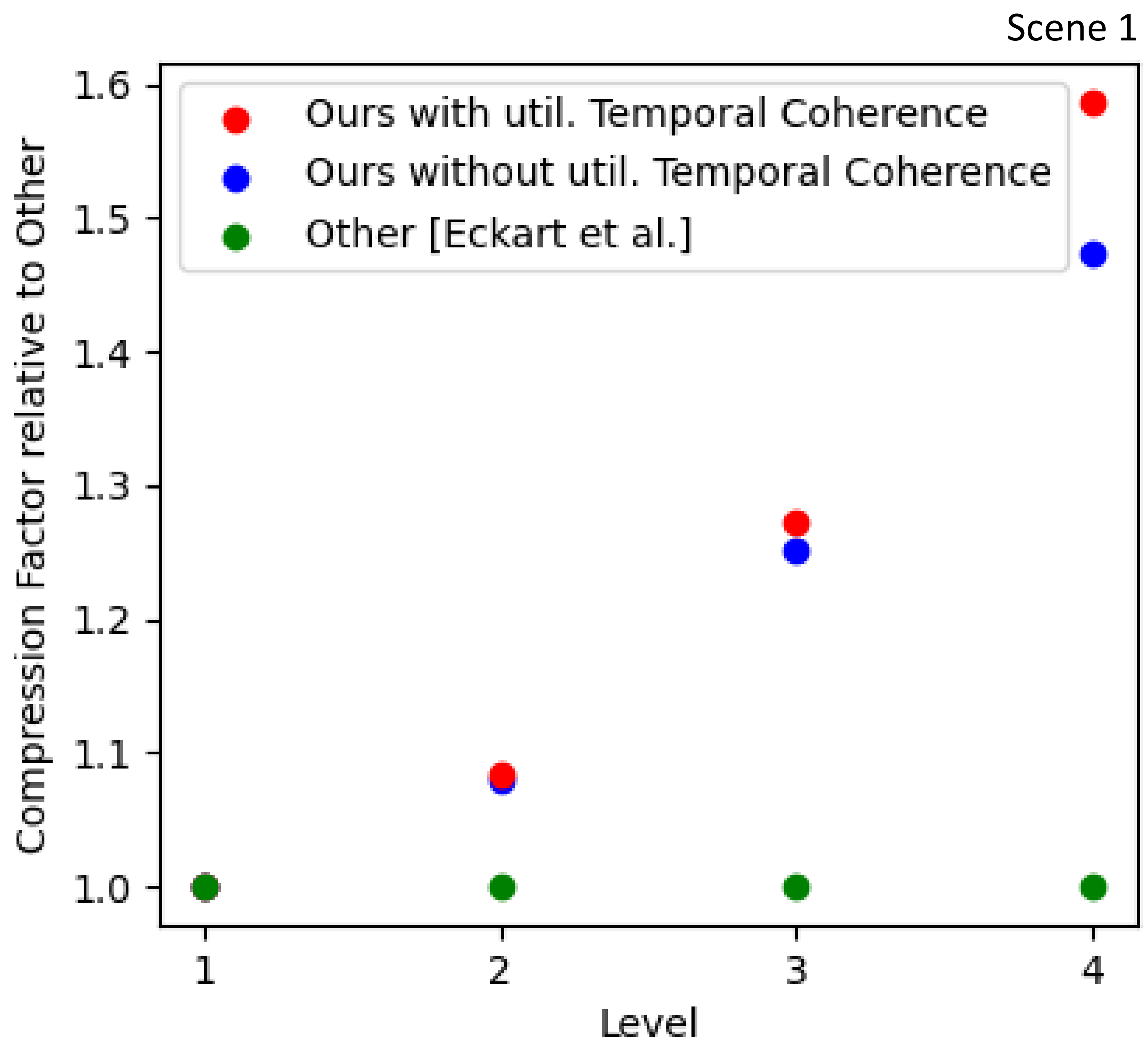

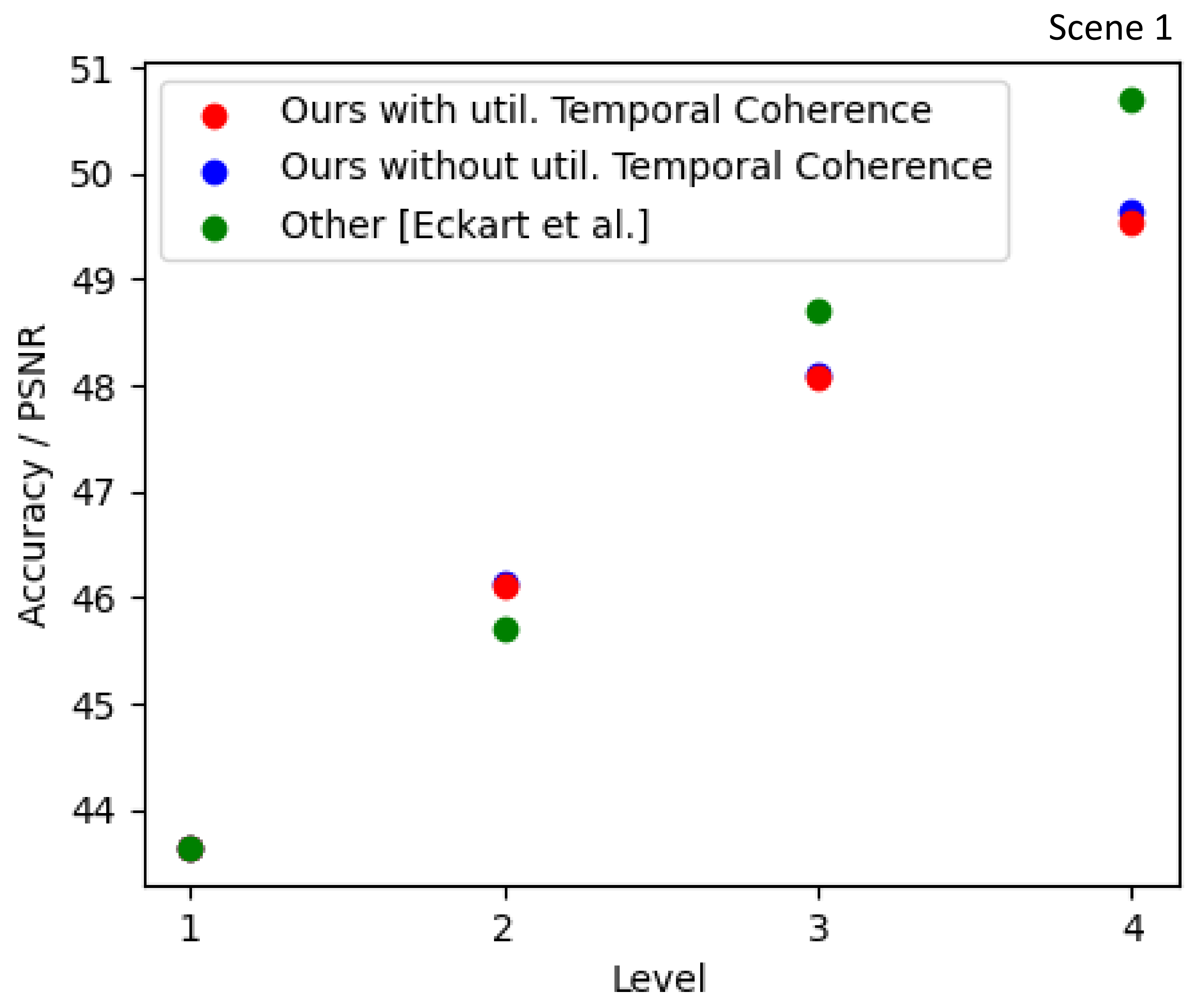

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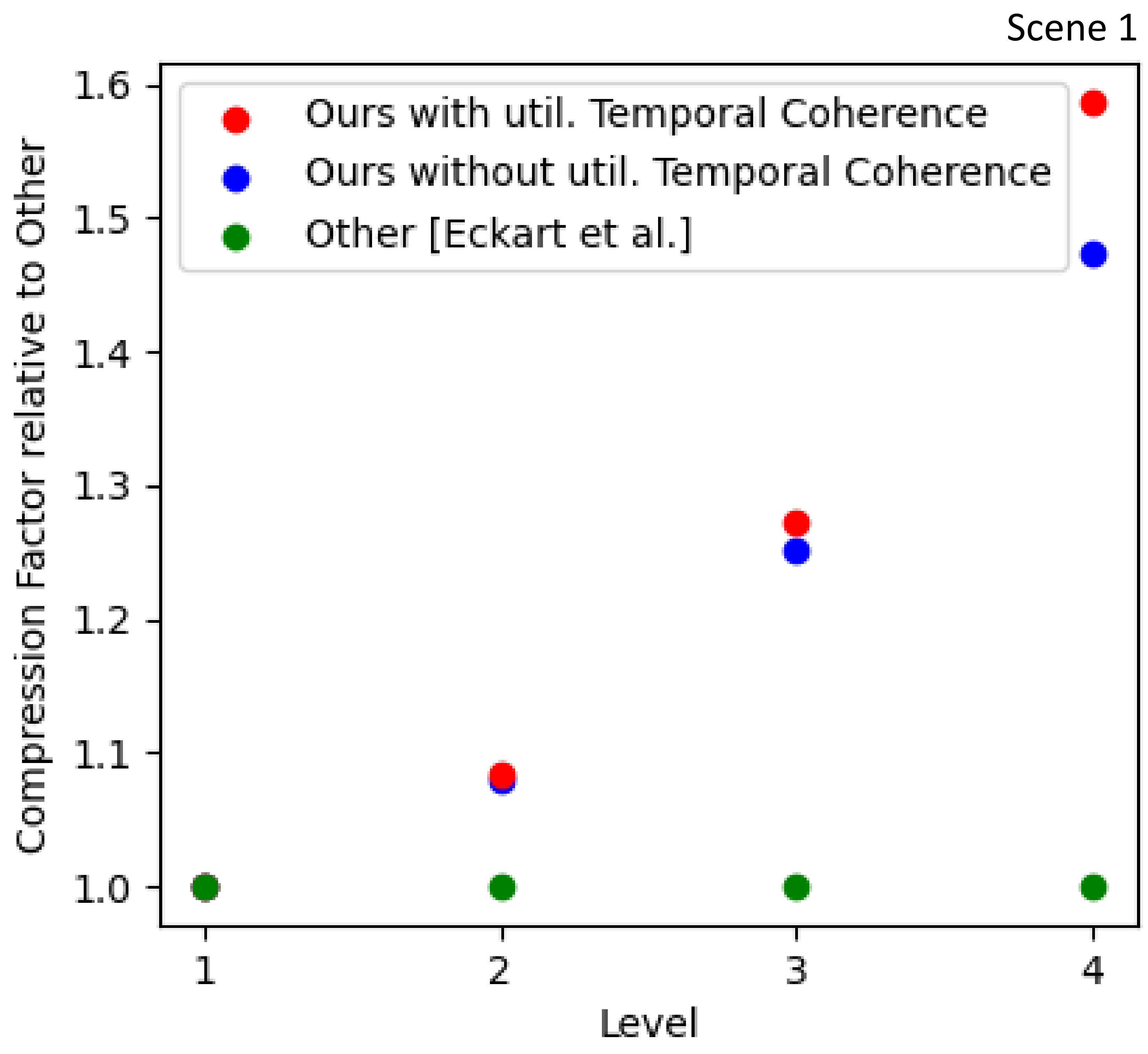
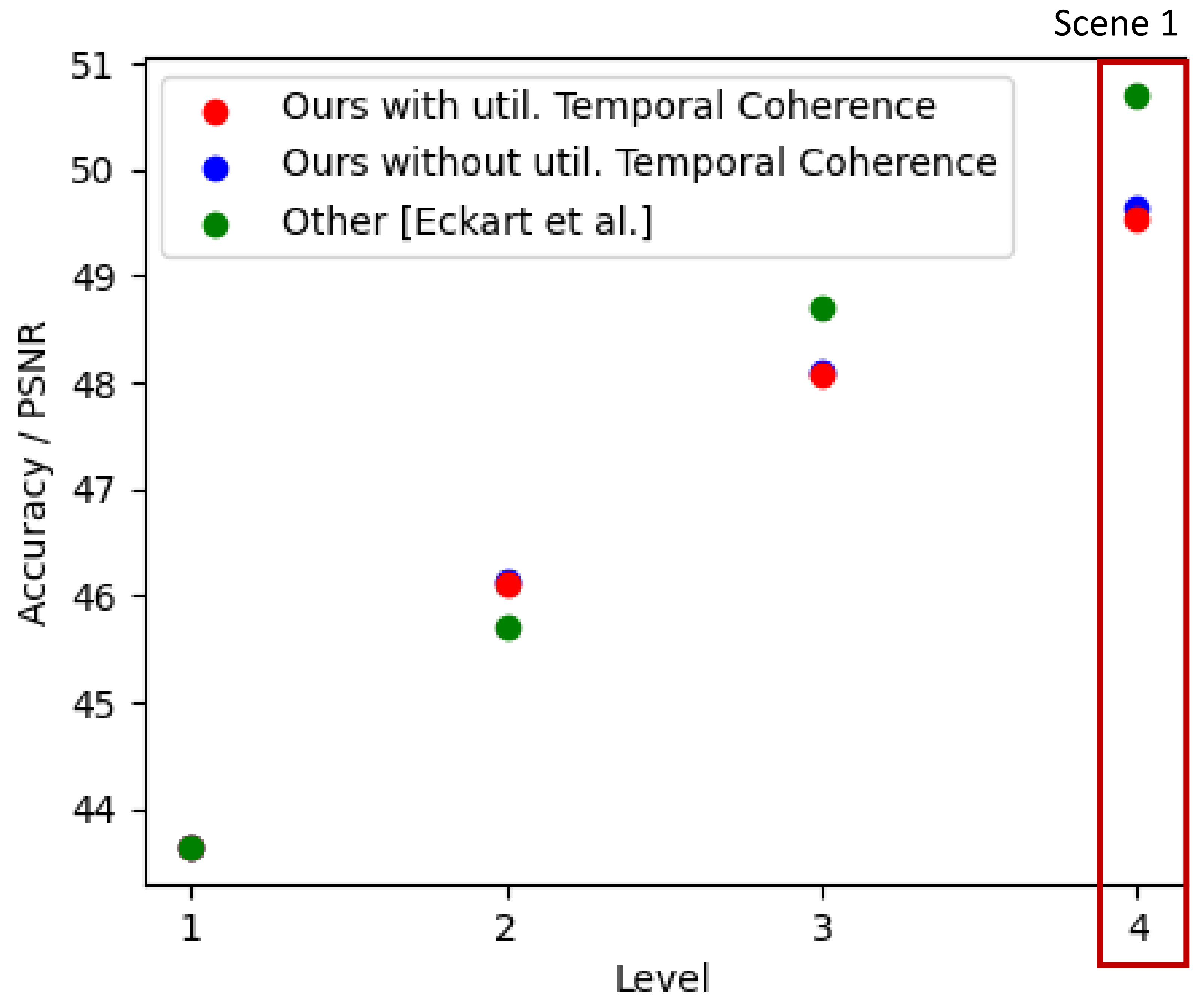
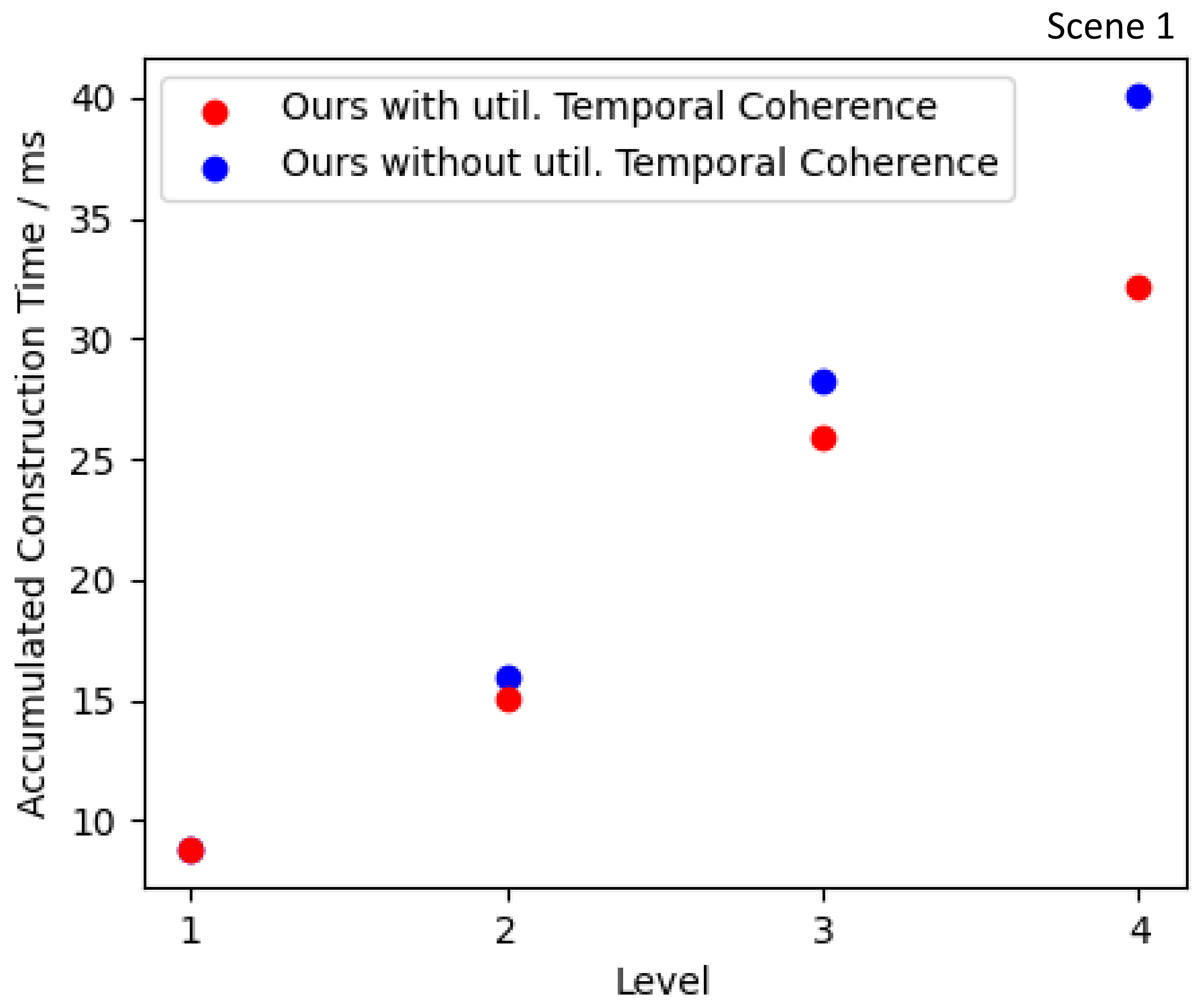




Only slightly lower PSNR (up to 2,3%)

All results with GPU: RTX 4090

Results & Discussion: Time



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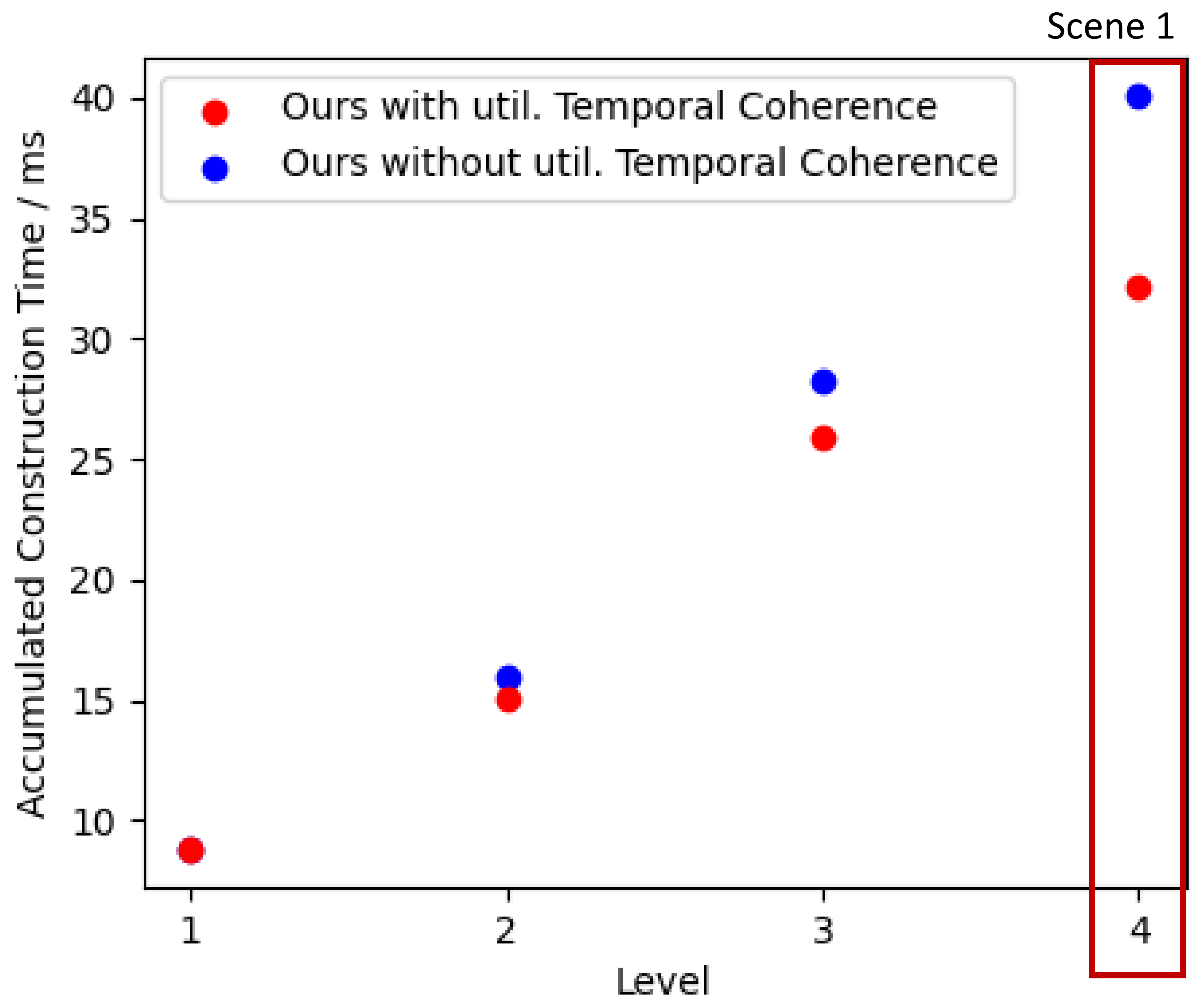

Temporal approach greatly accelerates construction, especially at higher LODs

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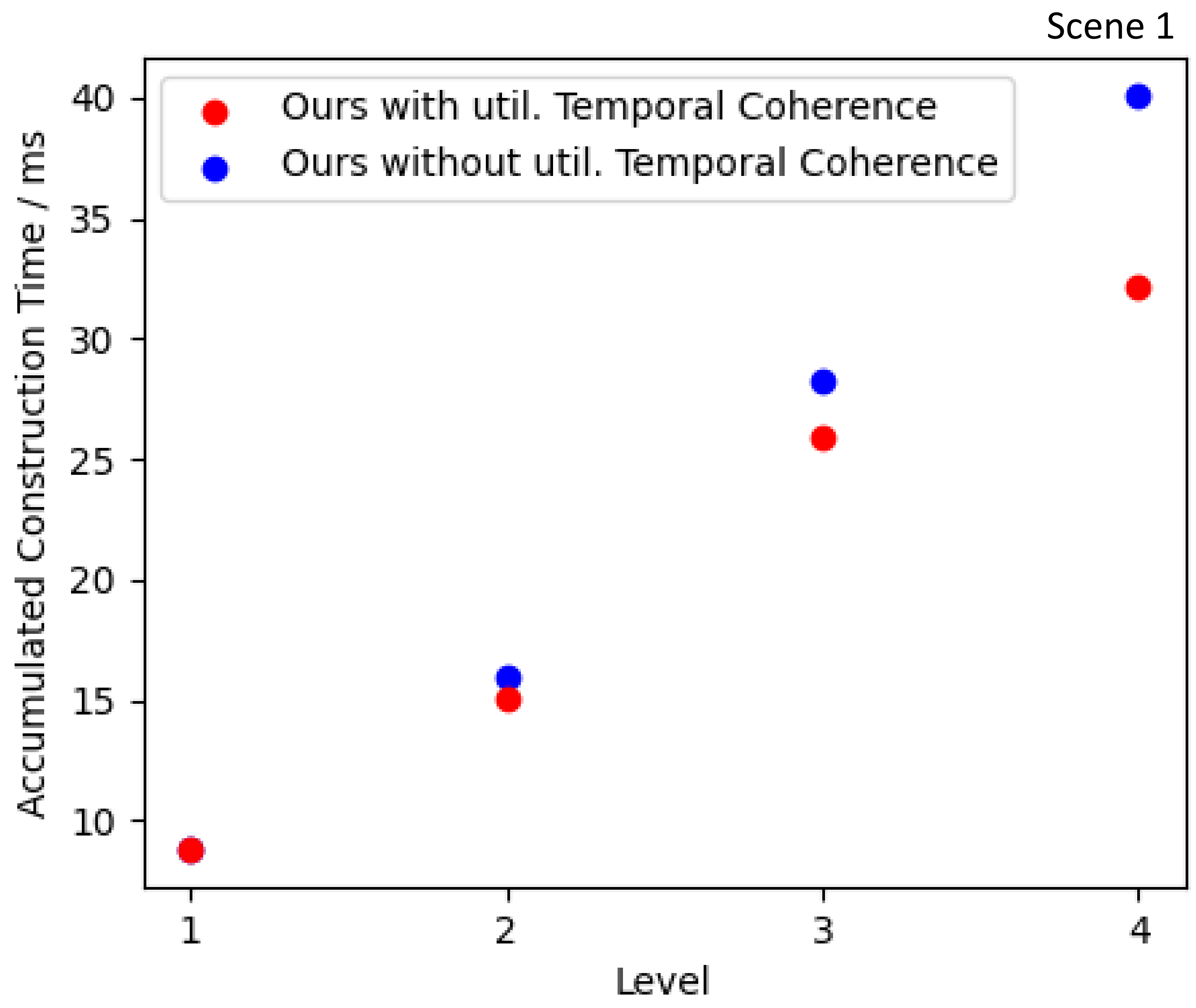

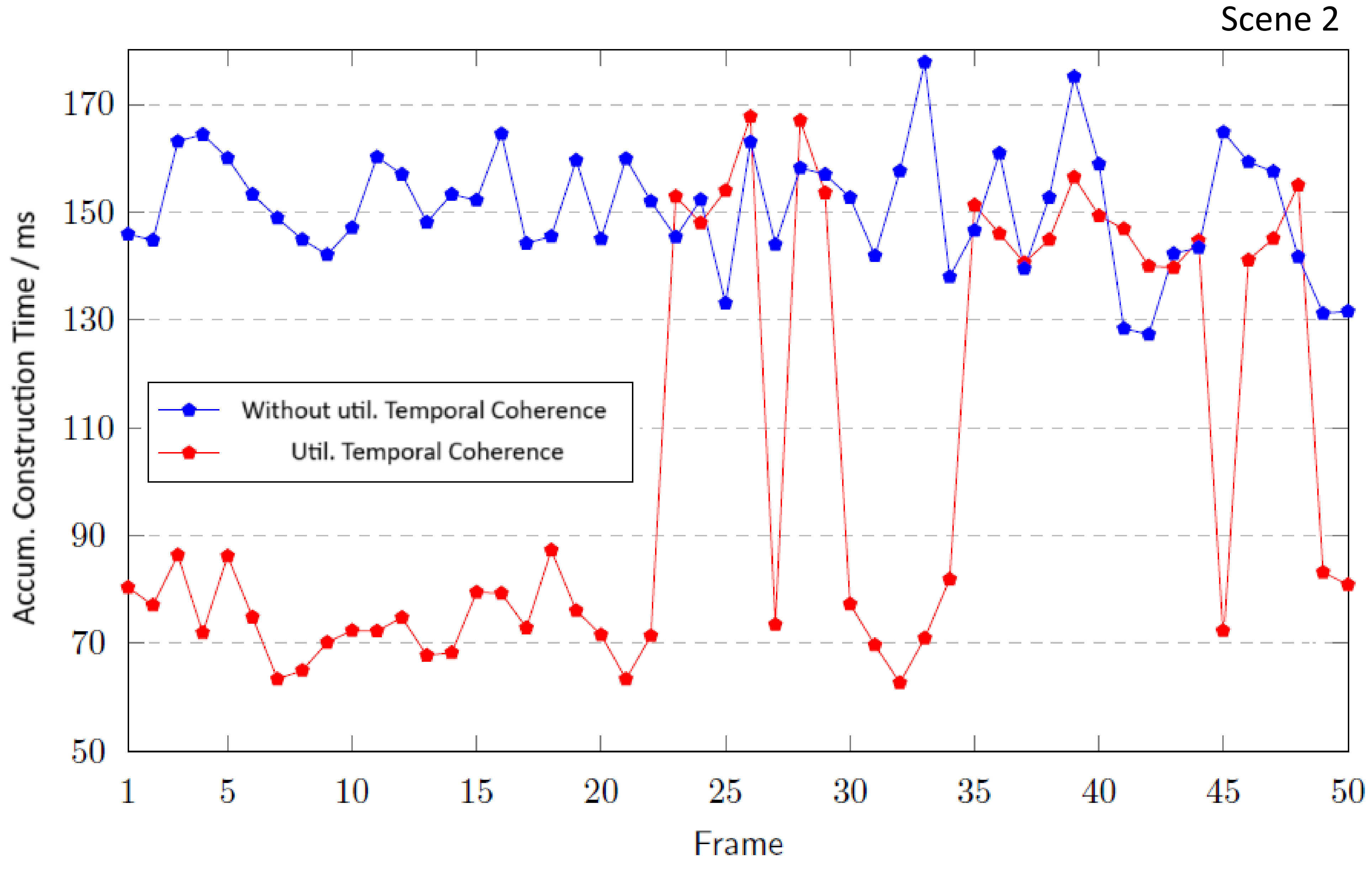

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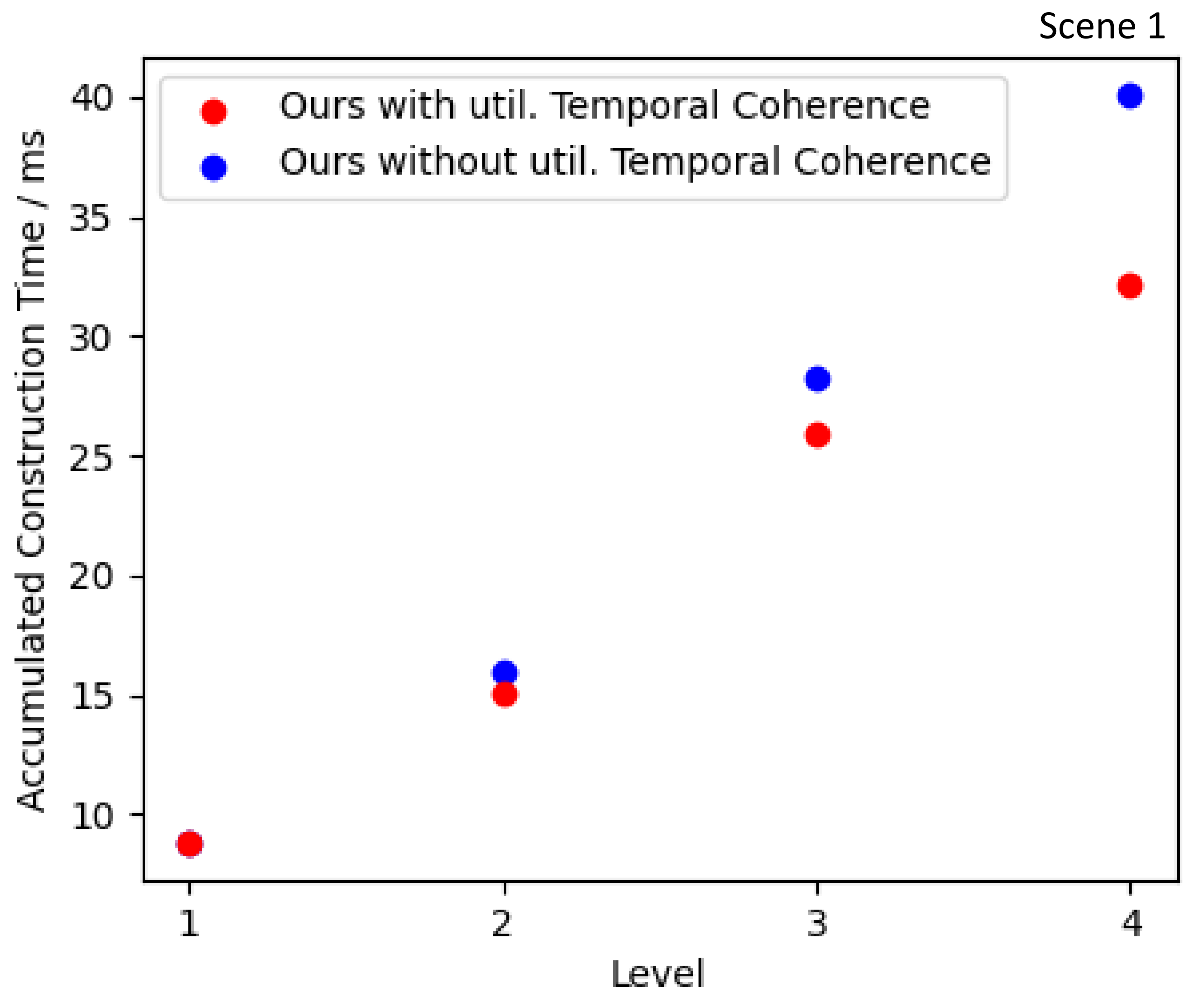
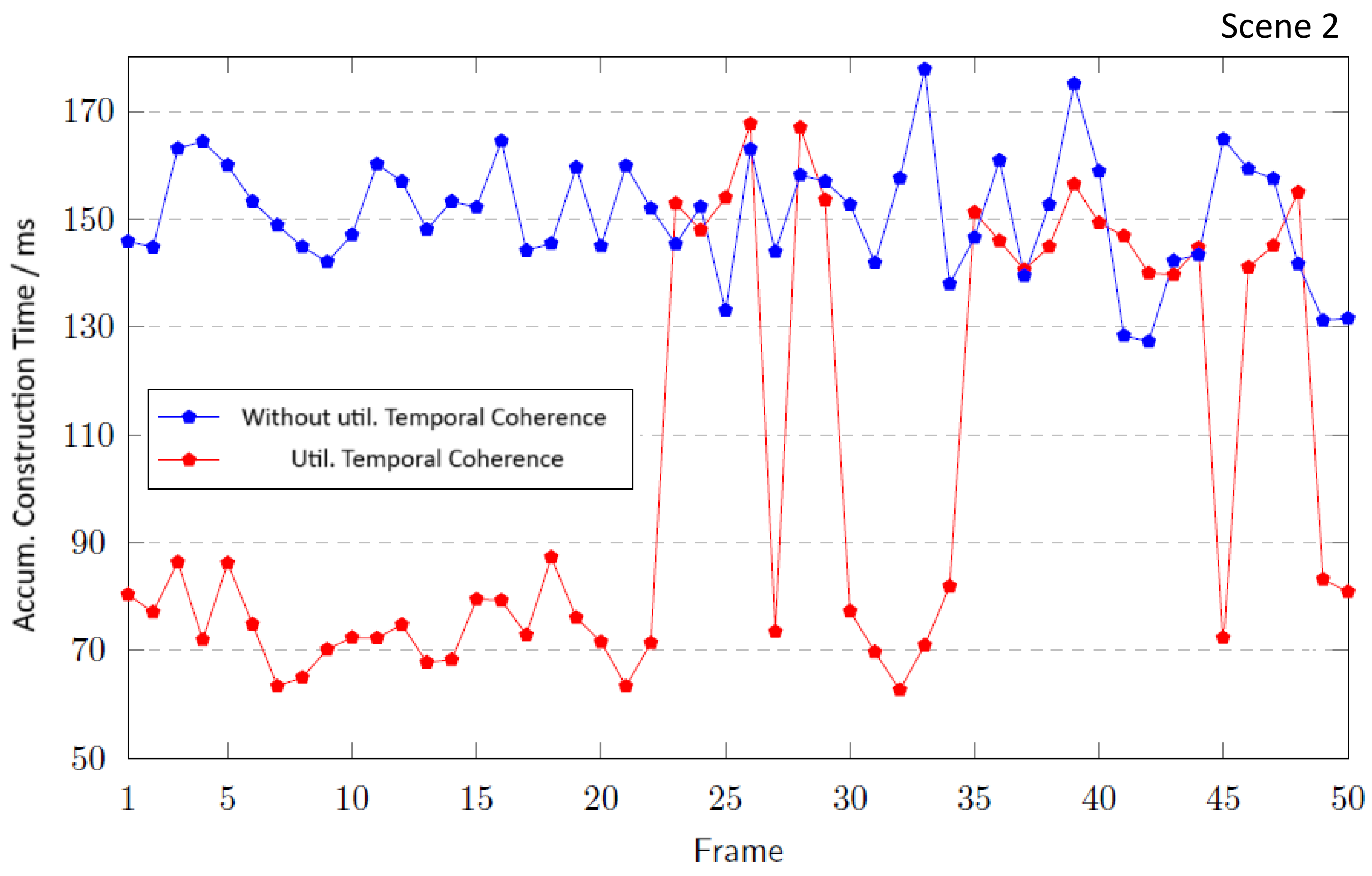
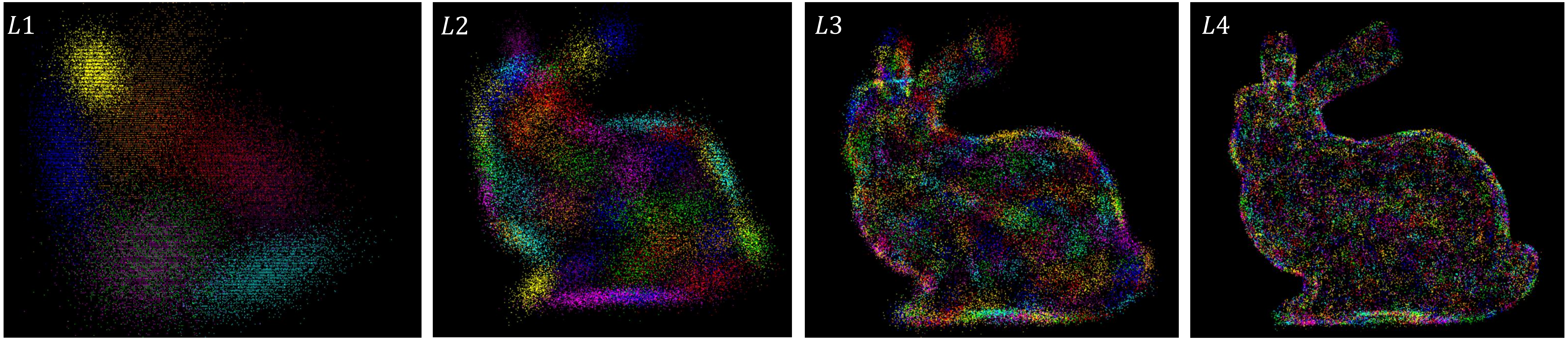




Temporal approach is very effective:
times cut in half for similar frames

Results & Discussion: Visuals

Scene 1
36k points



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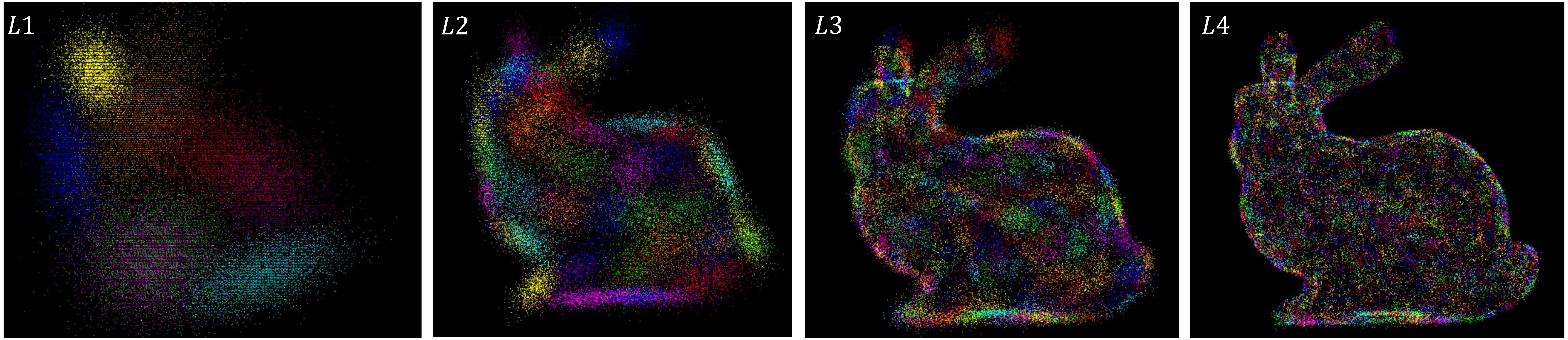
Already very accurate at L3/4



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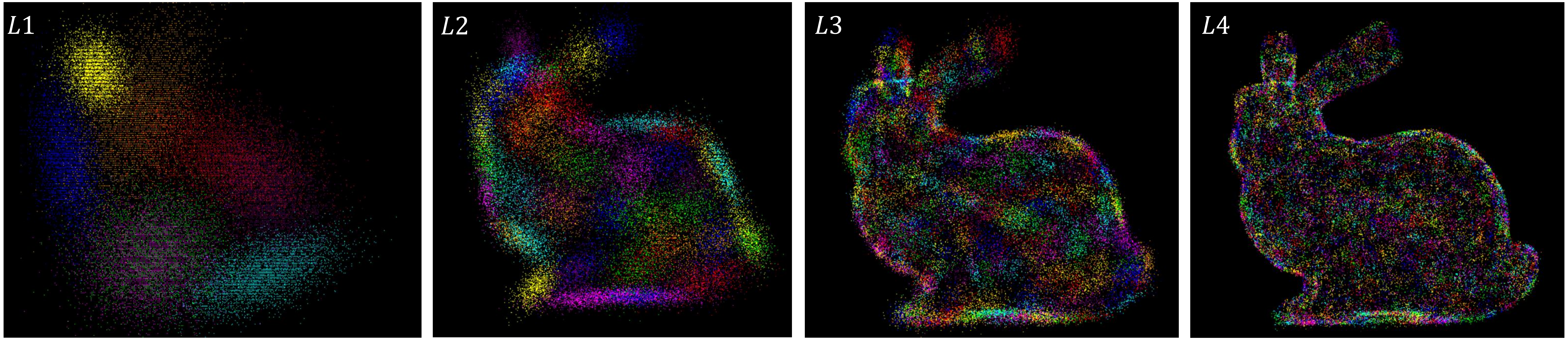
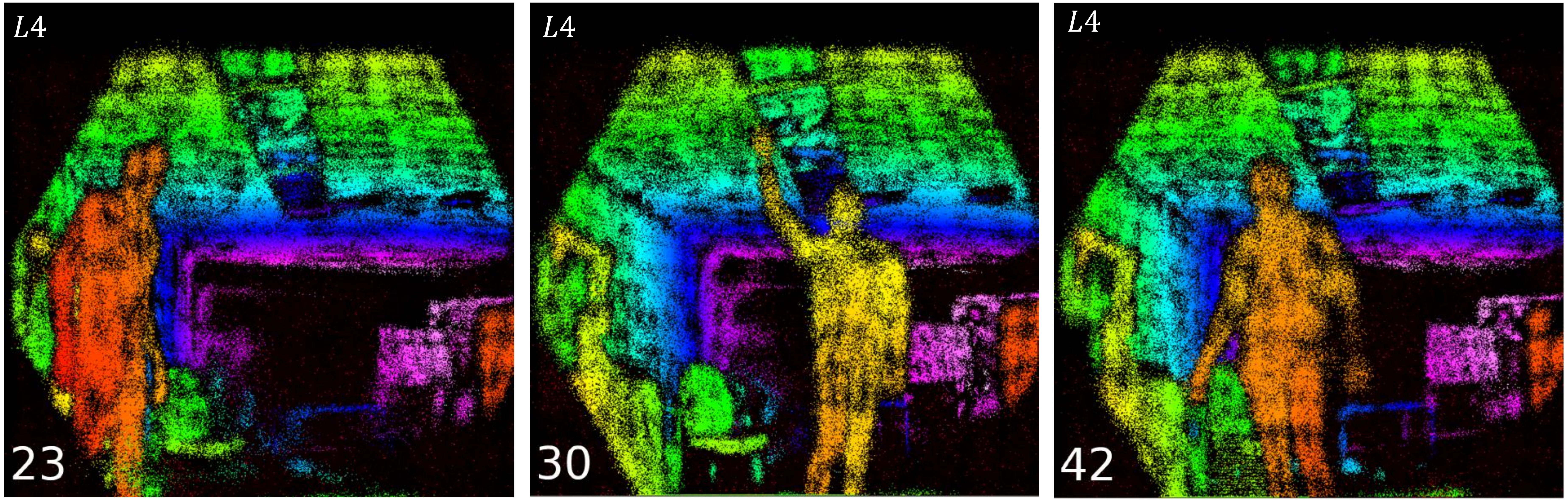


Scene 2
368k points



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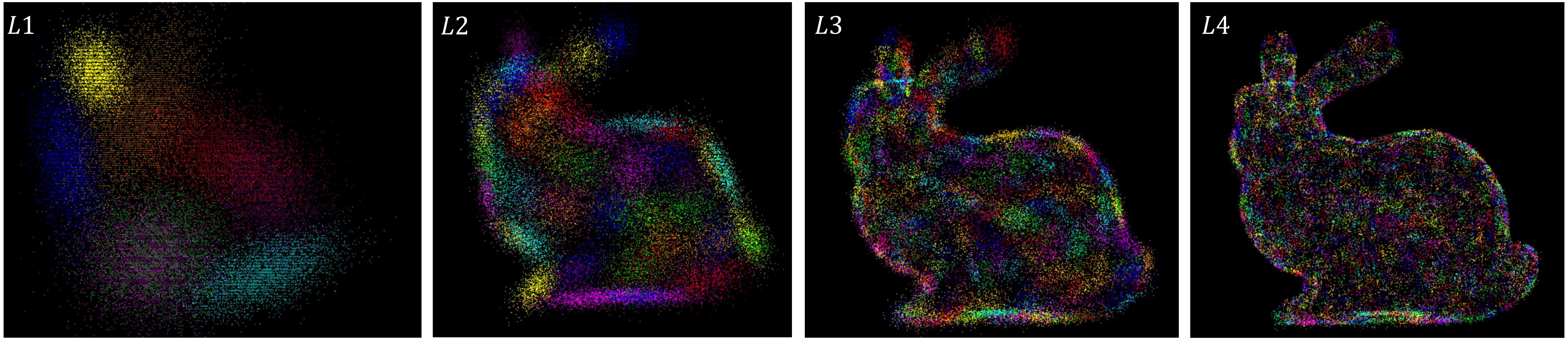

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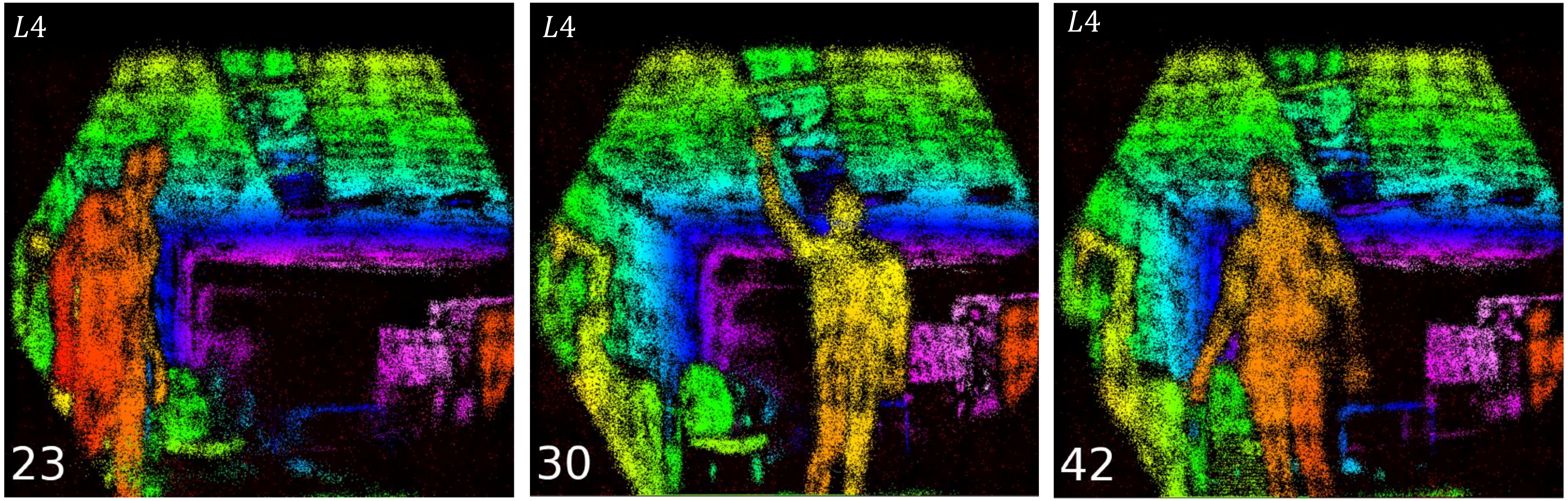

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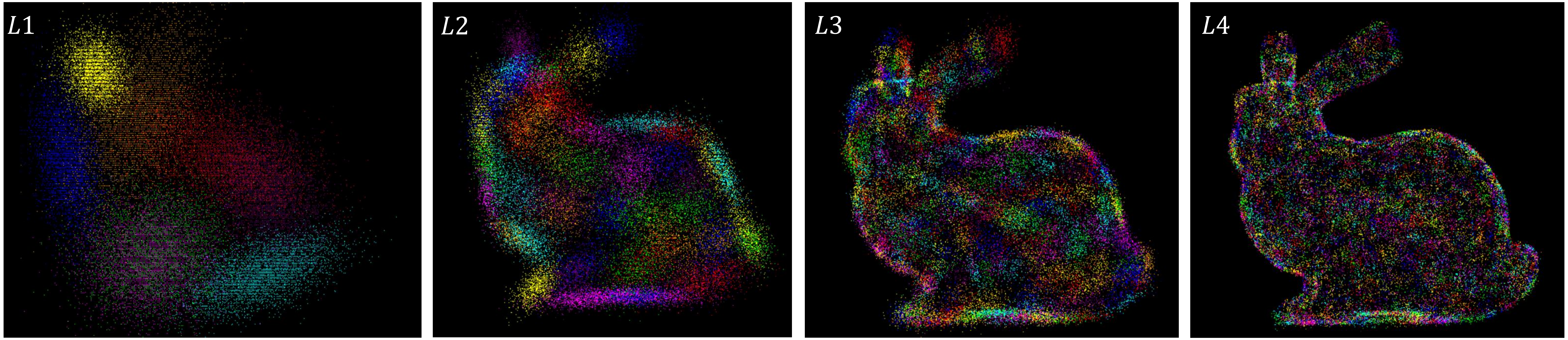

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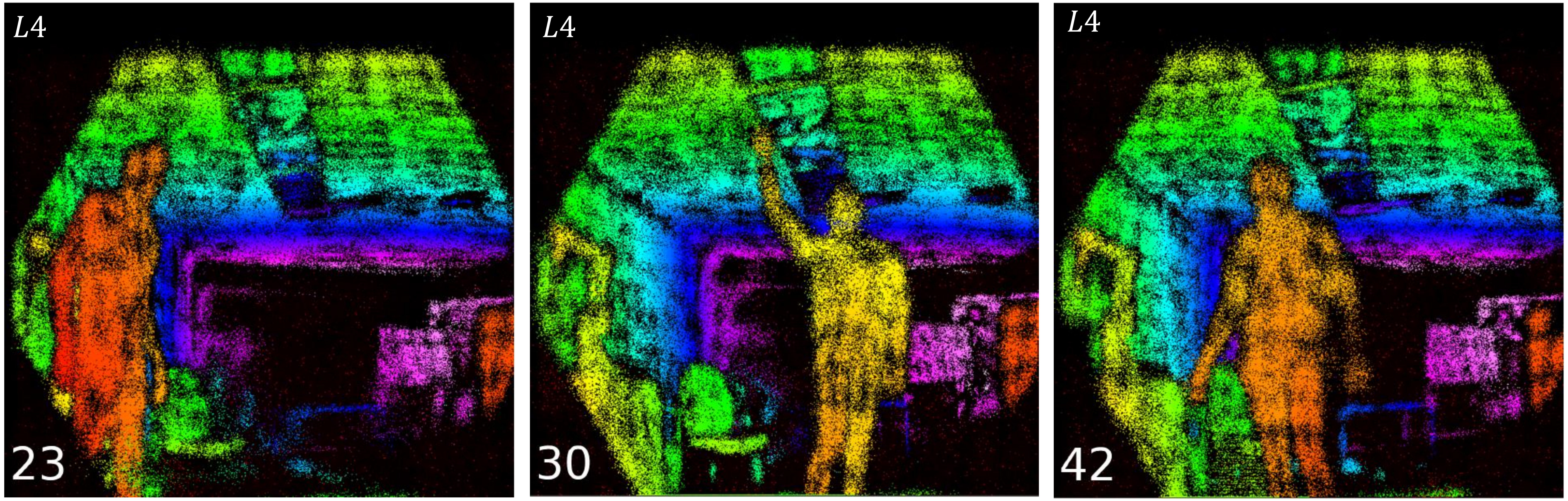

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Avg. Time: 103 ms

Conclusion

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  - Hierarchy of GMMs with level-by-level construction
  - Utilizing temporal coherence
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  - Dynamic, adaptive streaming of LODs
- Up to 59 % higher compression vs previous work (slightly lower accuracy)
- Temporal approach saves 20-32 % construction time on higher LODs

Future Work

- Encode color

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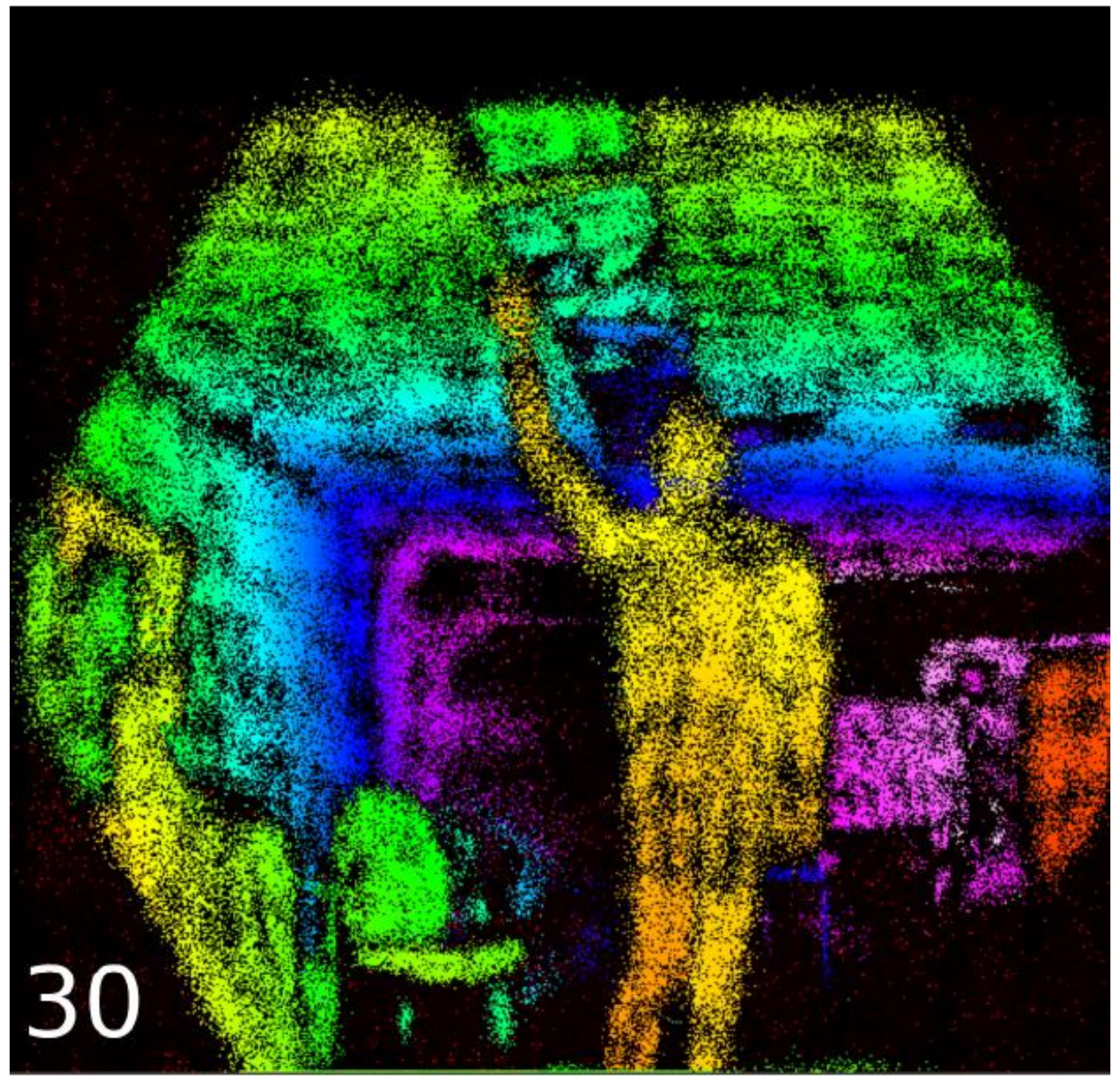
- Integrate Gaussian splatting
- Generalize for unstructured point clouds

Thank you for your attention!
Questions?



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