Scalable Surface Reconstruction from Point Clouds with Extreme Scale and Density Diversity

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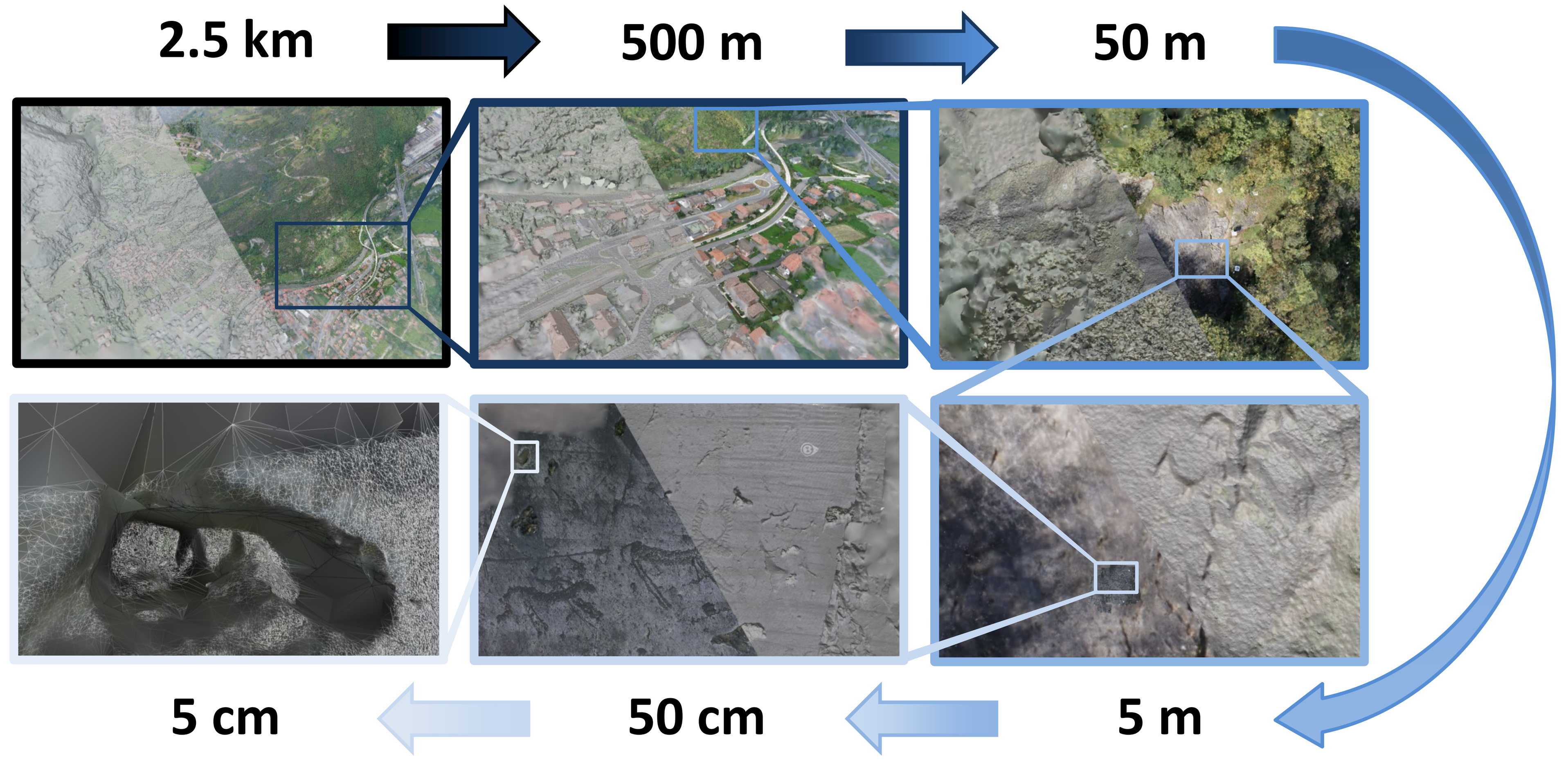
Abstract

From Kilometer to Micrometer – One Mesh

Our approach is capable to compute **a consistently connected mesh** even in the presence of vast point density changes, while at the same time keeping a **definable constant peak memory usage**. This enables a **scalable parallel execution** of our approach, where the memory consumption can be adjusted to the available set of computers. Here, we processed **2 billion points** with a ground sampling variation from **1m to 50µm** using less than **9GB of RAM** per process



Key Idea

Combination of octree data partitioning, local Delaunay tetrahedralization and graph cut optimization. Graph cut optimization is used twice, once to extract surface hypotheses from local Delaunay tetrahedralizations and once to merge overlapping surface hypotheses even when the local tetrahedralizations do not share the same topology.

State-of-the-art Performance

in terms of **accuracy, completeness and outlier resilience** on multiple public datasets, while being scalable and parallelizable with definable peak memory usage.

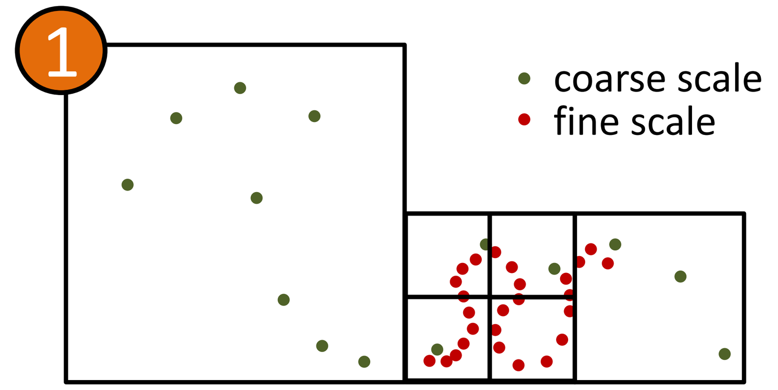
New Multi-Scale 3D Dataset Released

Cultural heritage site in Italy. **2 billion points** from 1500 high resolution images, area of 6 km², 4 registered scale levels, ground sampling distance from 1m to 50µm.

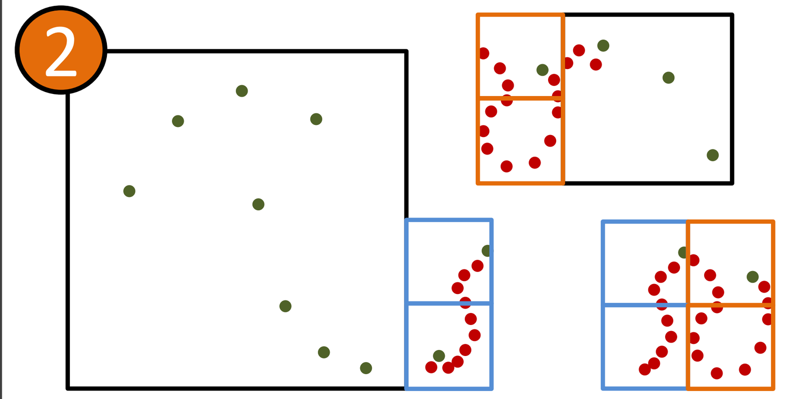
Method

Combination of Octree and Delaunay Space Division

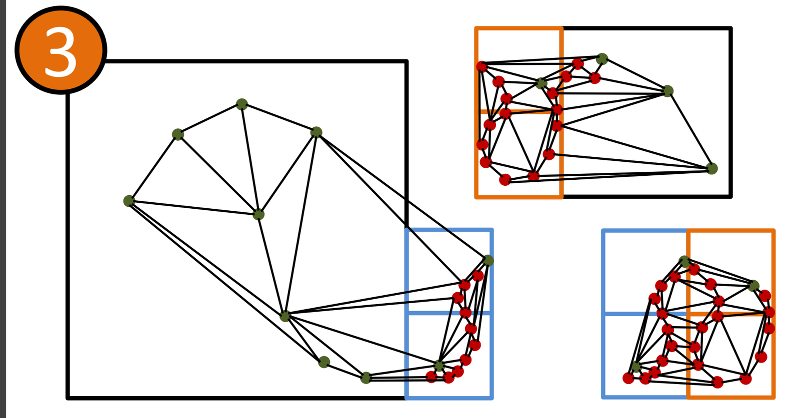
Here, we show a 2D slice through 3D data



Coarse **octree divides data** into managable pieces. Each leaf contains a maximum number of points (here 10, typically 128k)

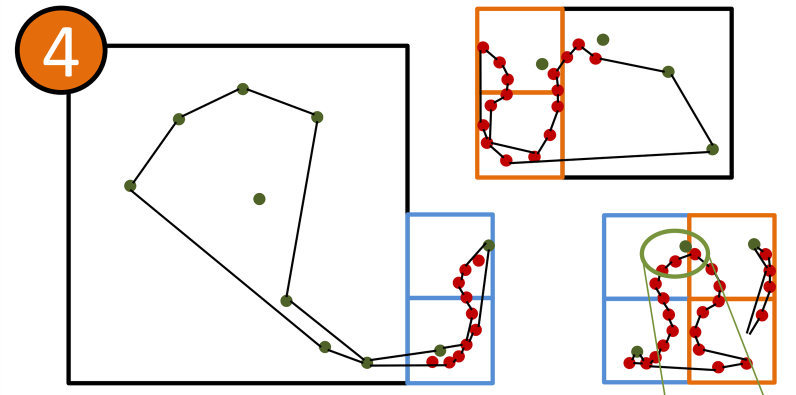


Overlapping neighborhoods are extracted (max. voxel number per neighborhood is 8)

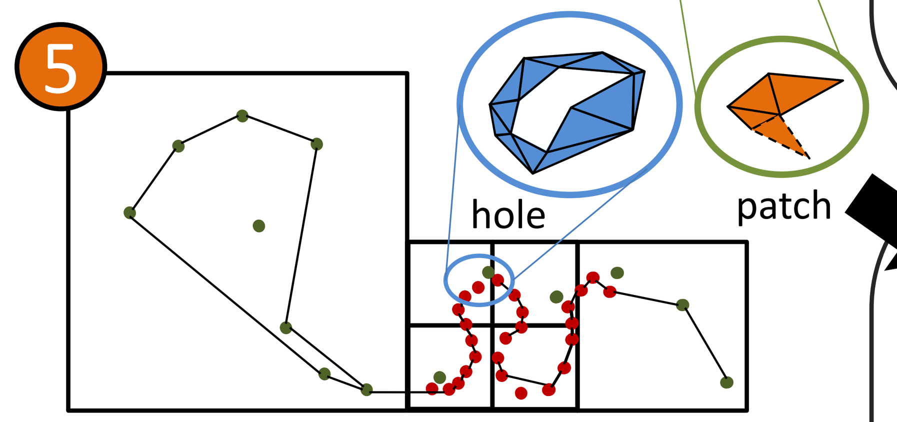


For each neighborhood we compute the **Delaunay tetrahedralization**

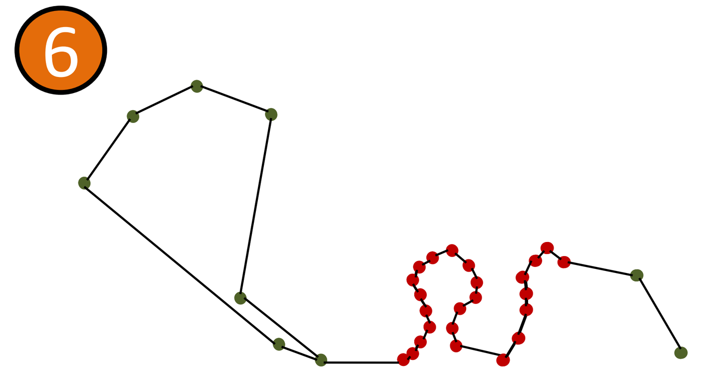
Building a consistent mesh



For each neighborhood **extract closed surface mesh** using graphcut [1]

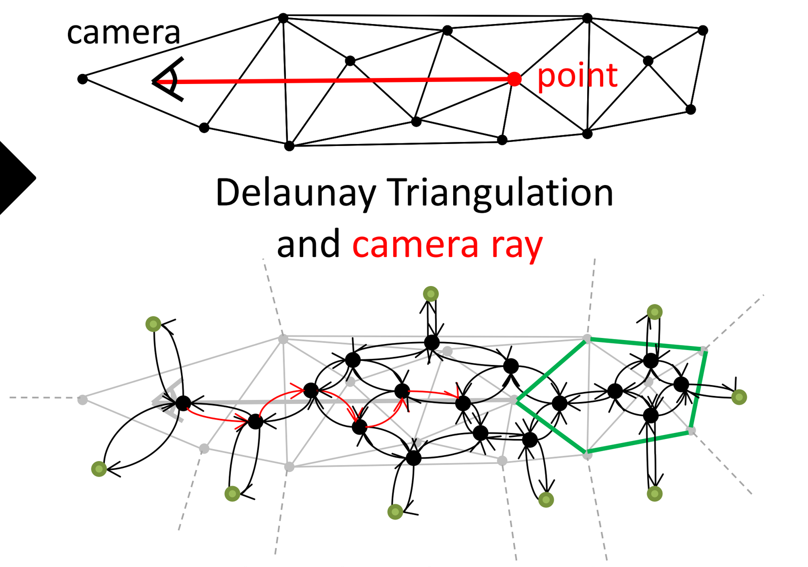


Collecting consistent faces



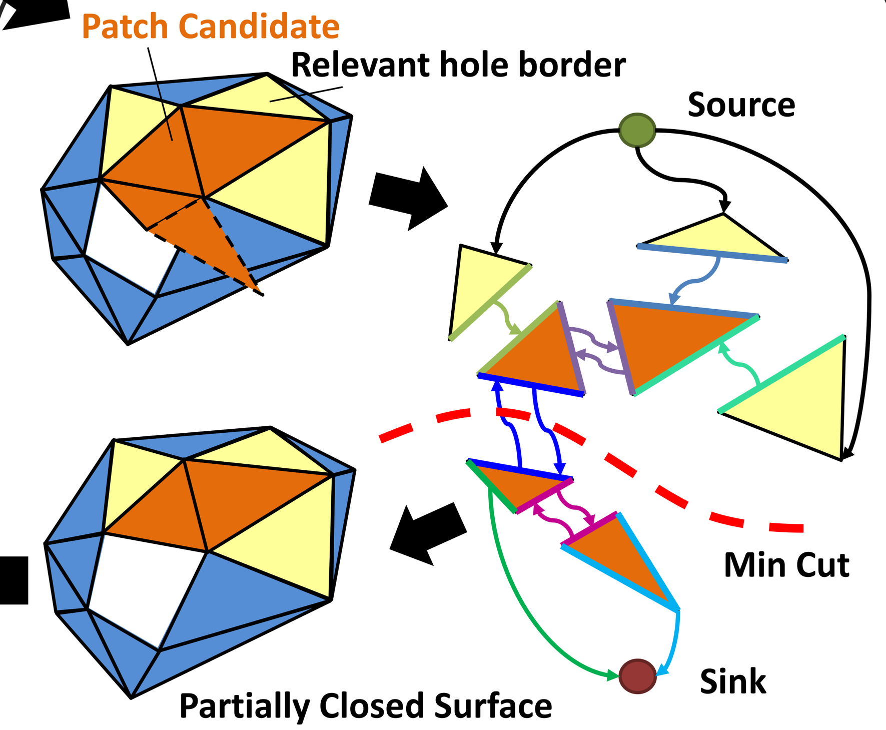
Closing holes with a second graph cut to obtain final mesh

Delaunay-based Graphcut [1]



Dual graph with minimal cut

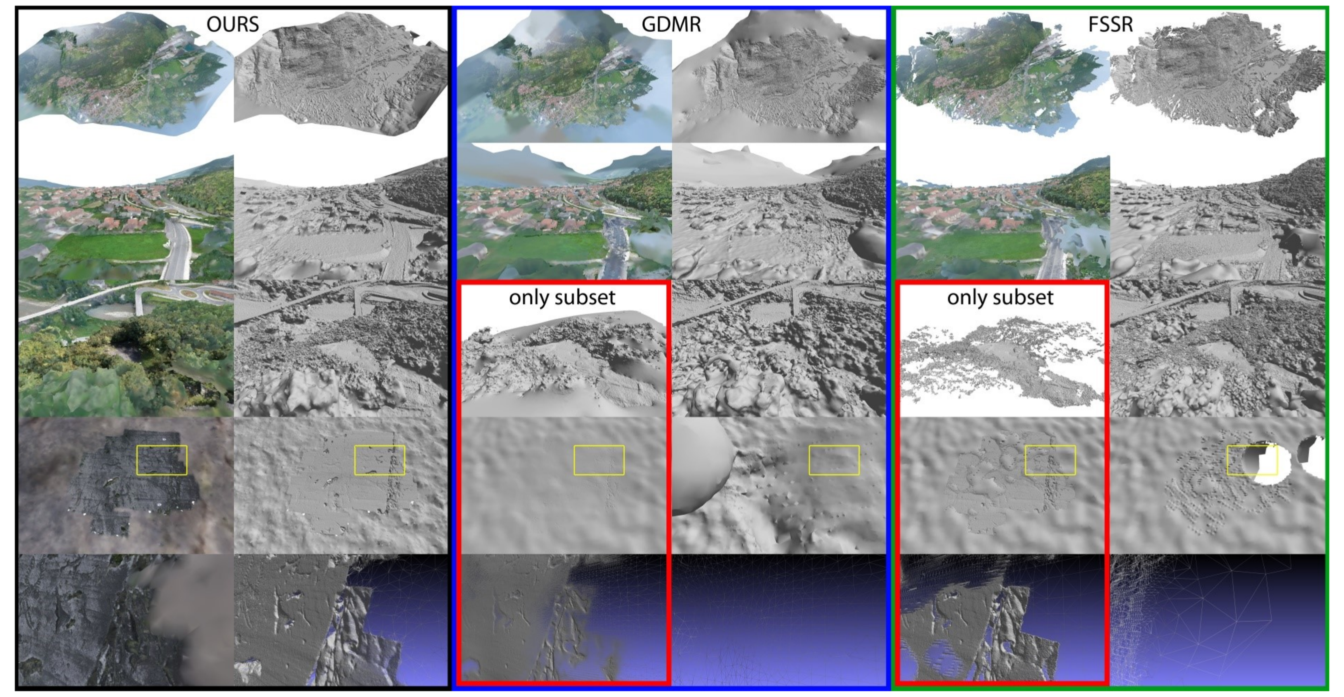
Hole Filling Graphcut



Weight of graph edges corresponds to triangle edge lengths

Results

Valley Dataset (NEW)



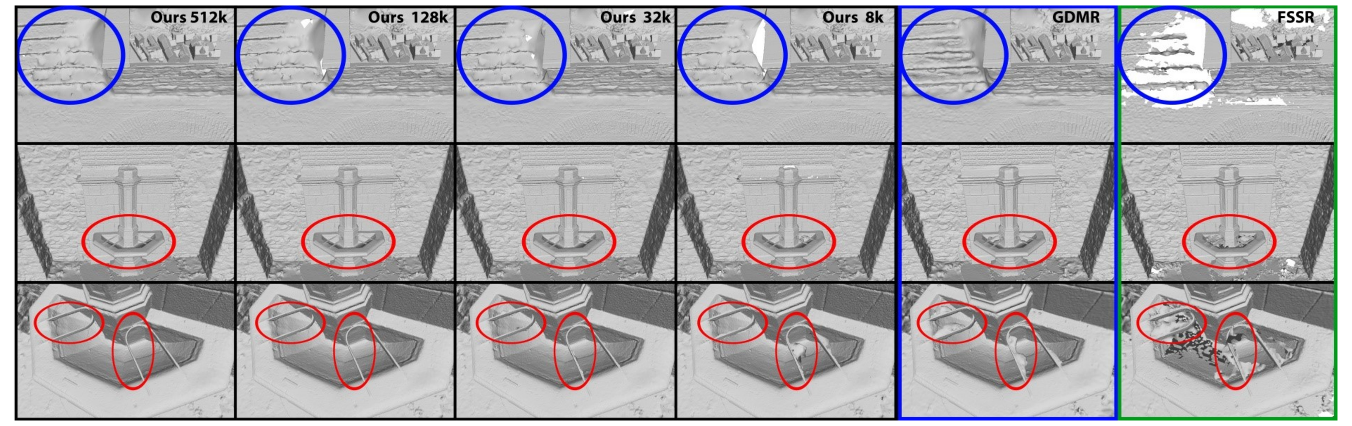
Our approach using less than 9GB RAM compared to GDMR [3] (150GB RAM) and FSSR [4] (170GB RAM) with four times increased point radius (otherwise [3,4] exceed available memory)

Valley Dataset Link

Dataset Properties:

- Point cloud with 2 billion points
- 6 km² area
- 4 scale levels
- GSD 1 mto 50µm
- 1500 images

Citywall Dataset [5]



Our approach with different leaf sizes compared to GDMR [3] and FSSR [4]

leaf size	512k	128k	32k	8k
Peak Mem [GB]	25.3	8.9	3.1	2.2

Influence of the octree leaf size on the peak memory usage

Middlebury Dataset [2]

Thr.	PSR [6]	SSD [7]	FSSR [4]	GDMR [3]	OURS
90%	0.36	0.38	0.40	0.42	**0.35**
97%	0.56	0.56	0.63	0.61	**0.54**
99%	0.84	0.75	0.84	0.78	**0.71**

Our approach has a better accuracy and completeness than all other approaches with same input. Here, we show accuracy (lower is better).

Conclusion

- Hybrid Octree-Delaunay Space Division
- Definable peak memory usage
- Scalable and parallelizable
- State-of-the-art accuracy and completeness

References:

[1] P. Labatut, J.-P. Pons, and R. Keriven. *Efficient multi-view reconstruction of large-scale scenes using interest points, delaunay triangulation and graph cuts*. ICCV'07.
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[6] M. Kazhdan, M. Bolitho, and H. Hoppe. *Poisson surface reconstruction*. Eurographics on Geometry processing, 2006.
[7] F. Calakli and G. Taubin. *SSD: Smooth signed distance surface reconstruction*. Computer Graphics Forum, 2011.