Distributed Path Compression for Piecewise Linear Morse-Smale Segmentations and Connected Components

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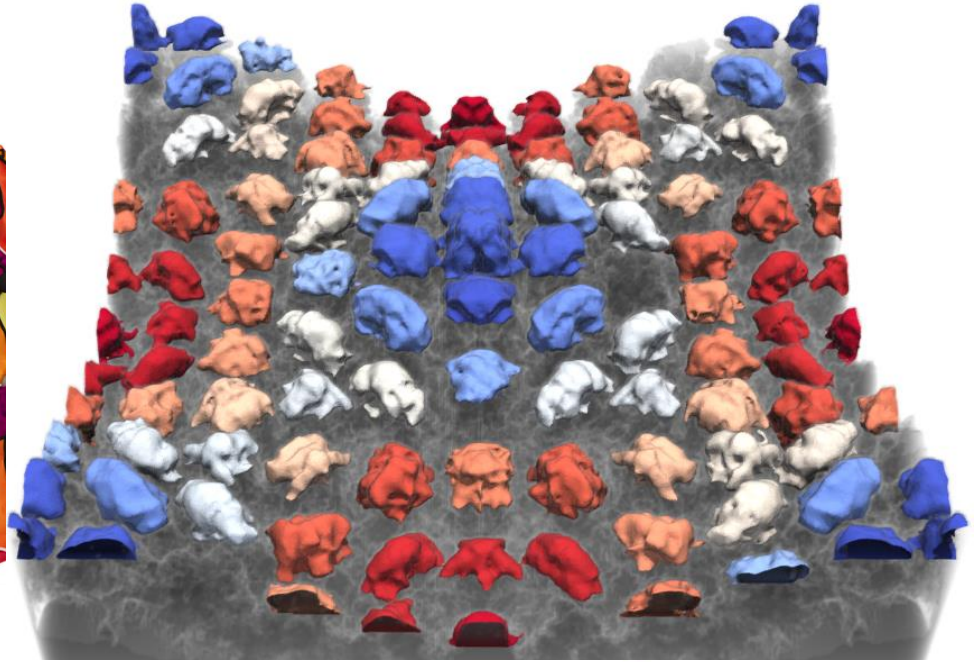

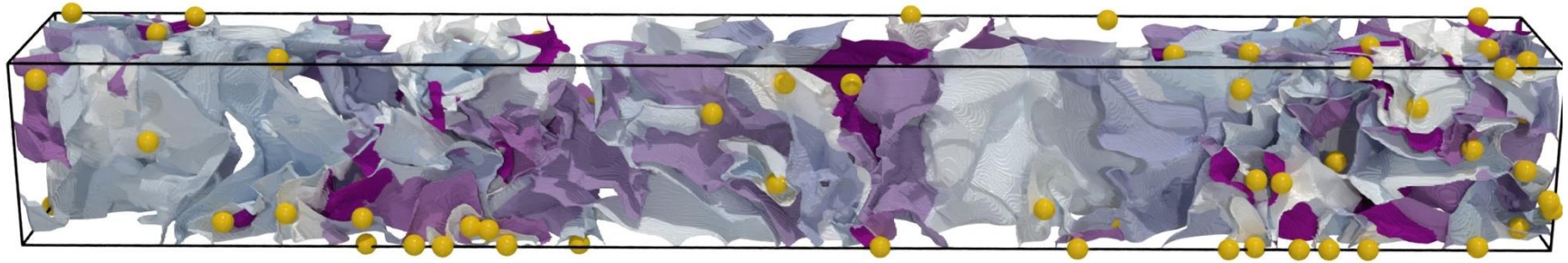

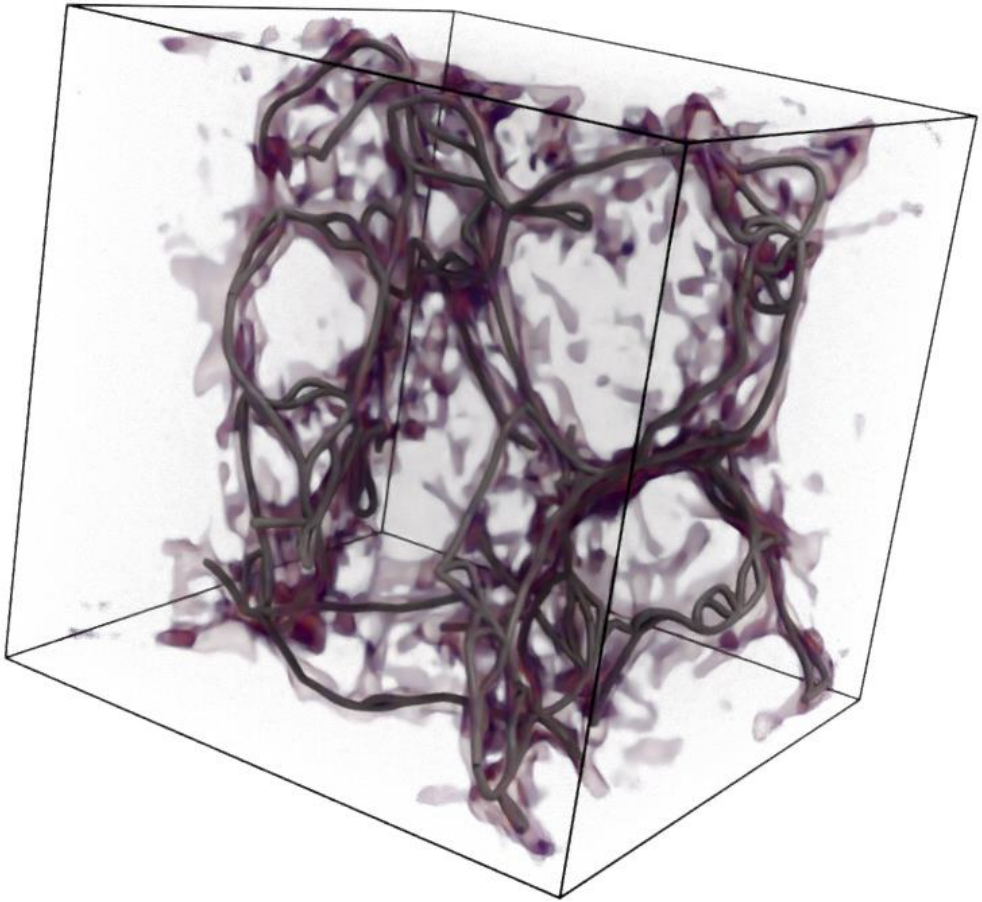

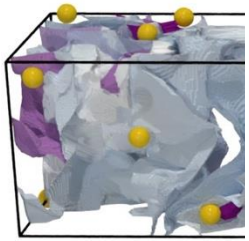

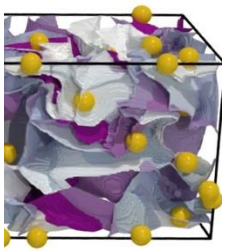

Ascending and Descending Segmentation

- piecewise linear Morse-Smale segmentation (PLMSS), presented by Maack et al. [1]
- computes the descending and ascending segmentation of the domain
  - assigns to each vertex the maximum reached by following the gradient along the steepest ascent and descent
- shown to be well-scaling in a shared memory setting
- not distributed parallel
- not a complete MS complex, but useful for many processing and visualization tasks

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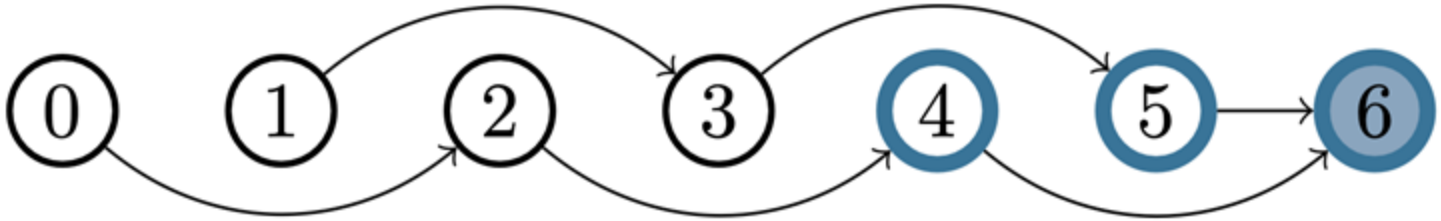

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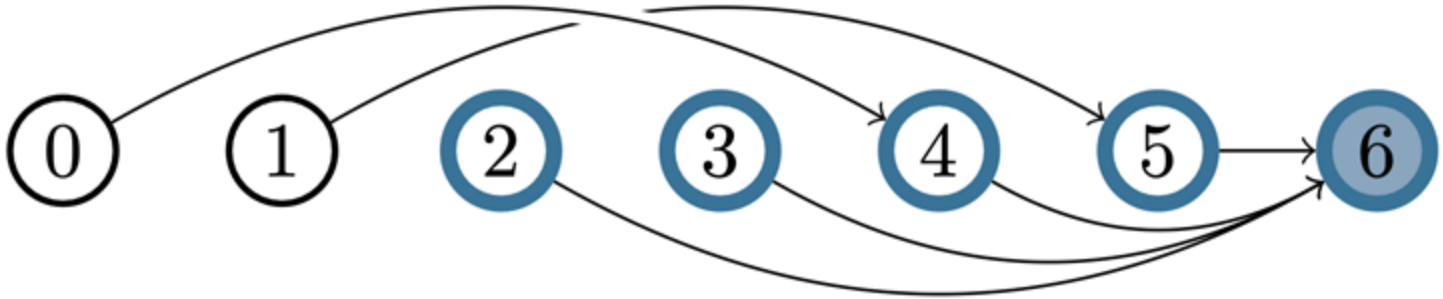

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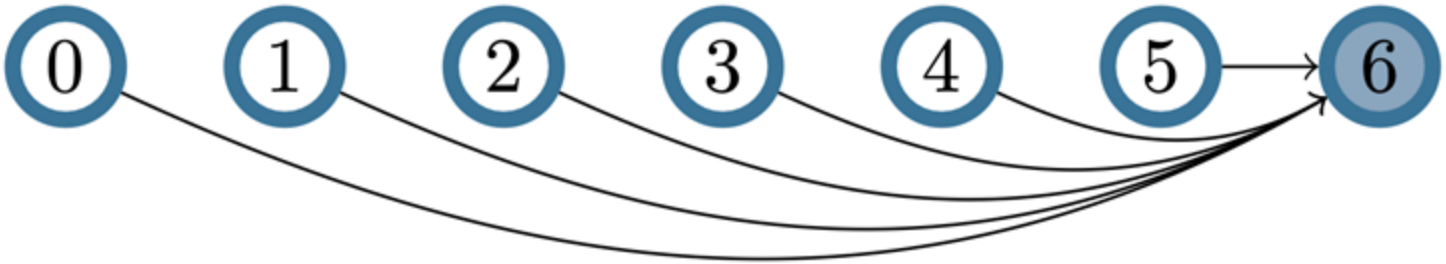
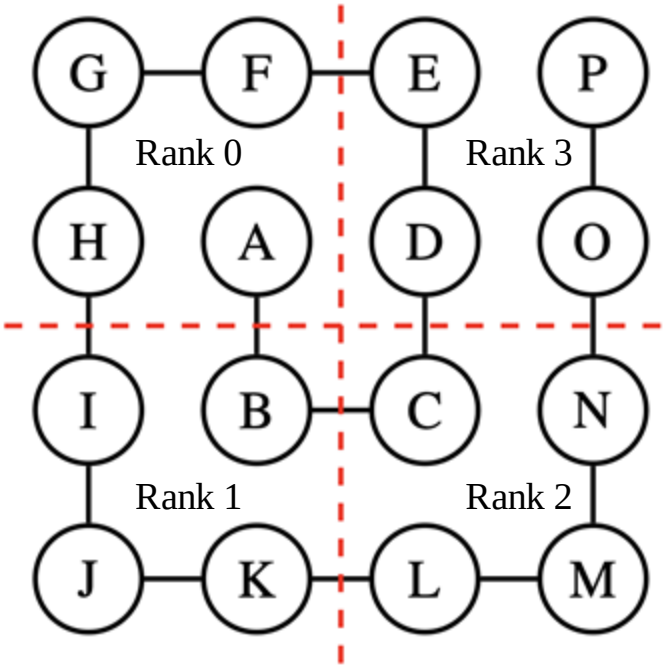


Distributed Path Compression (DPC)



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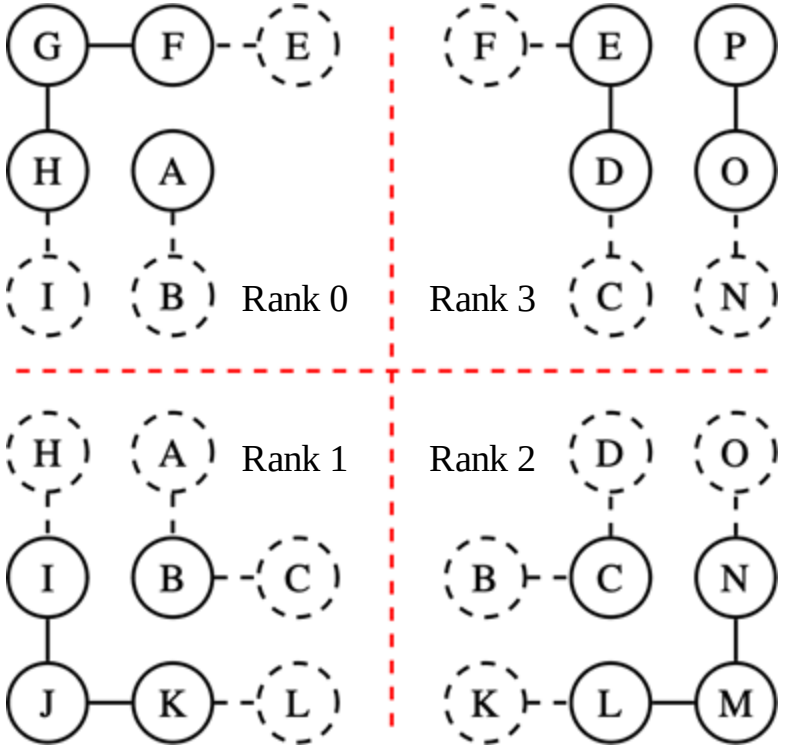

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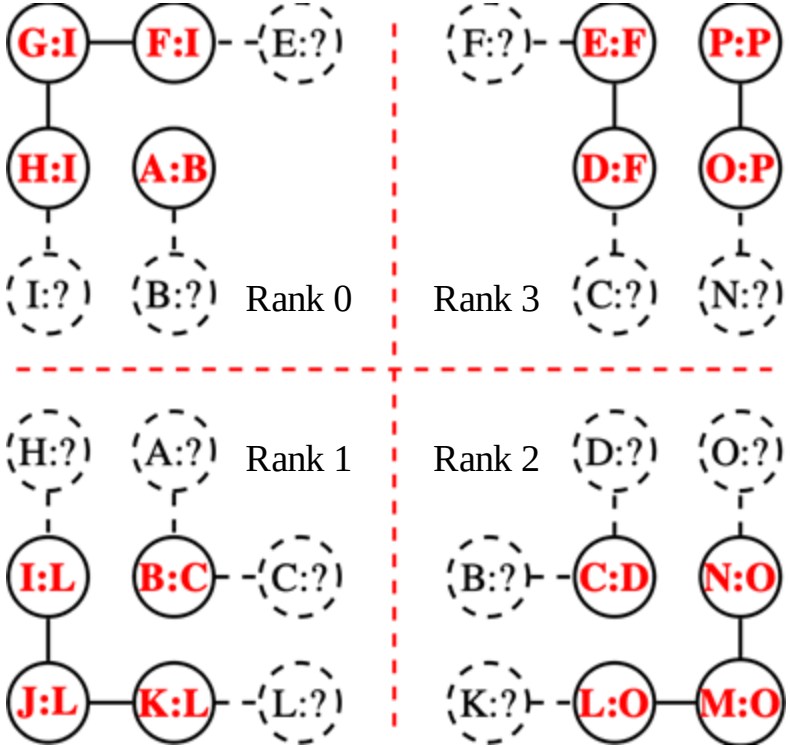
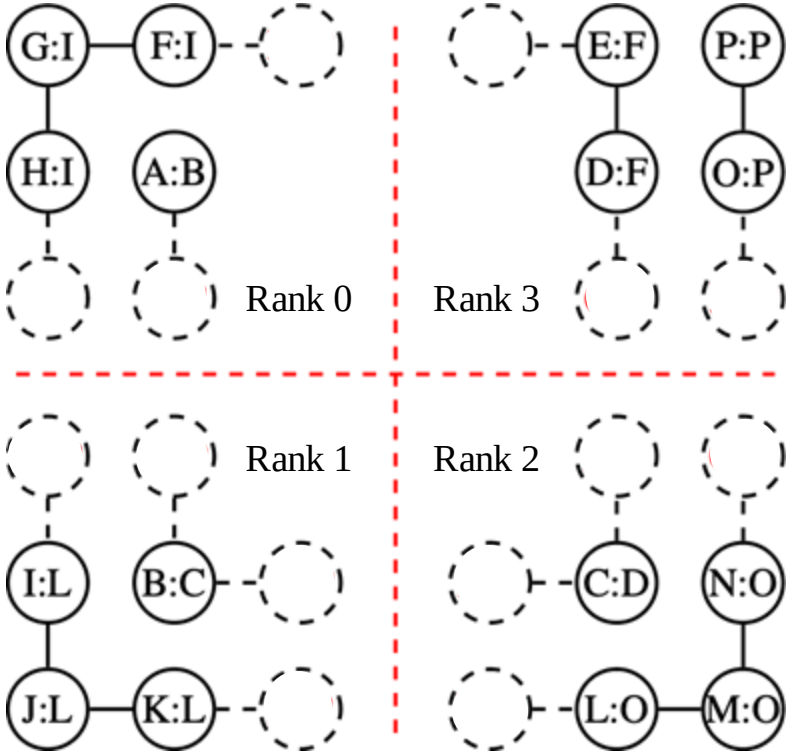


Distributed Path Compression

Vertex	P_0
A	B
B	C
C	D
D	F
E	F
F	I
H	I
I	L
K	L
L	O
N	O
O	P



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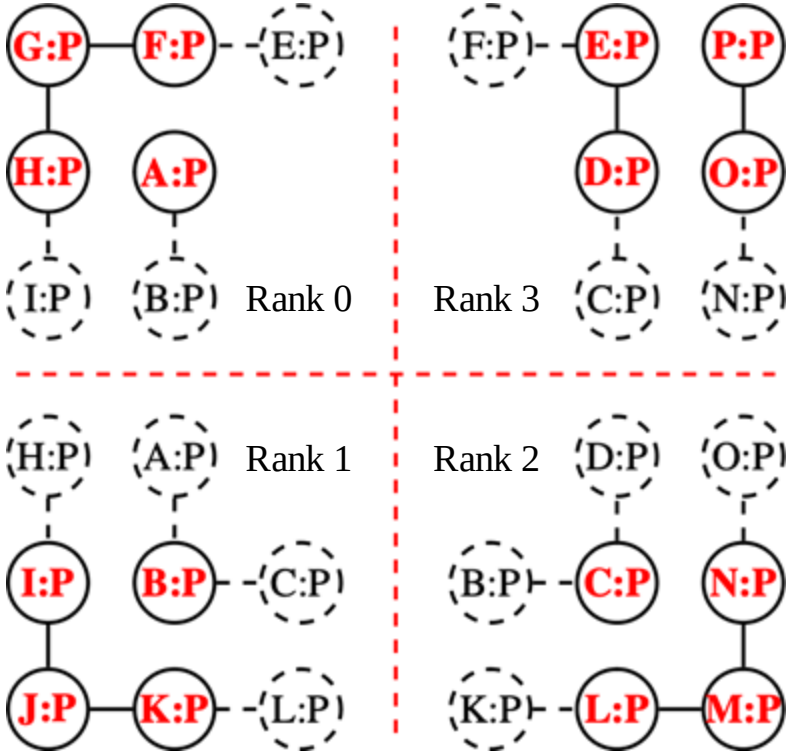
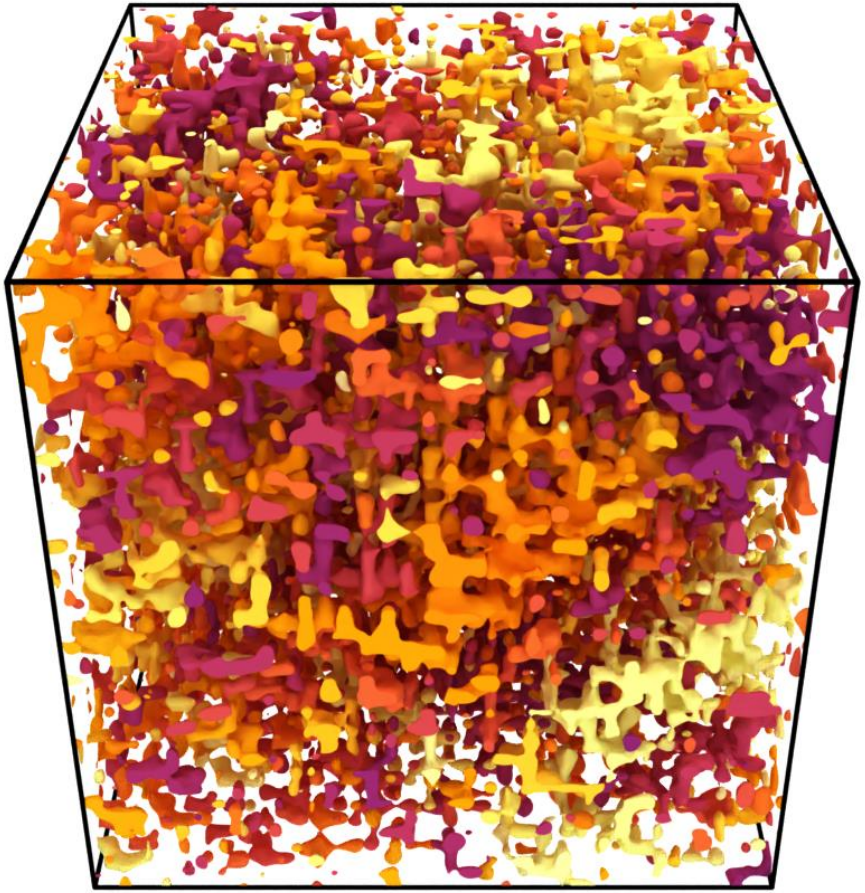
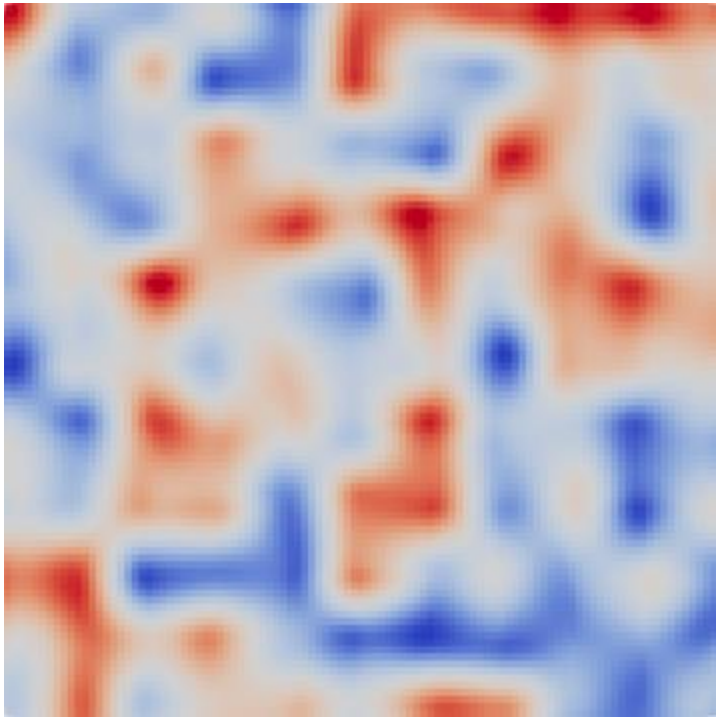




Connected Components



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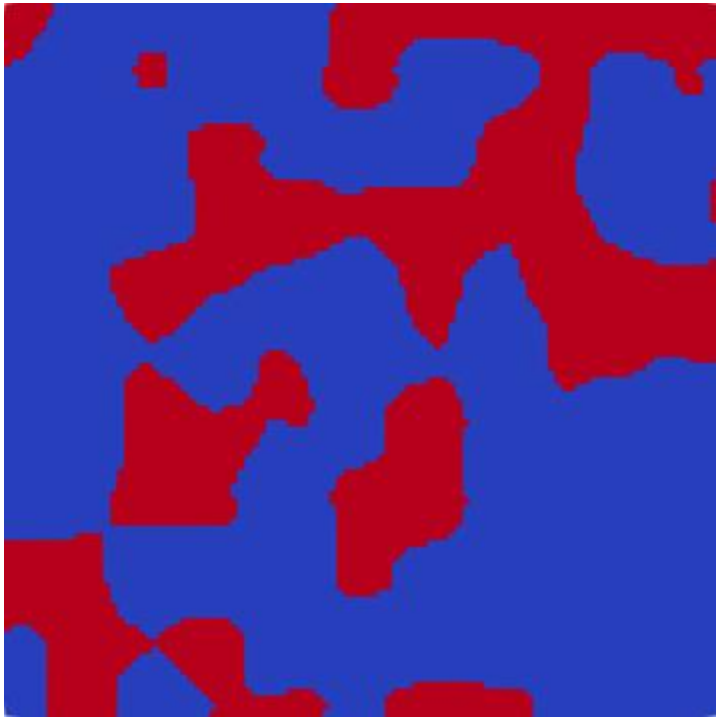

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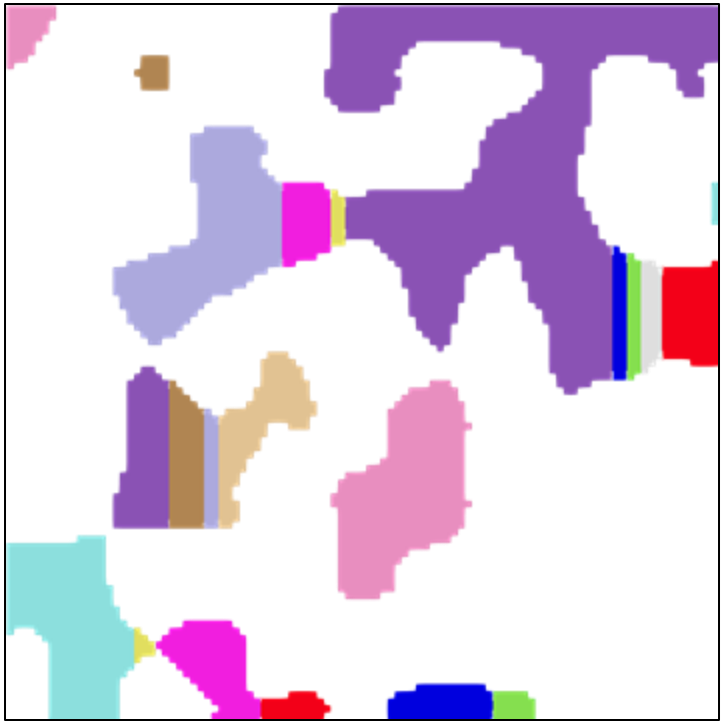

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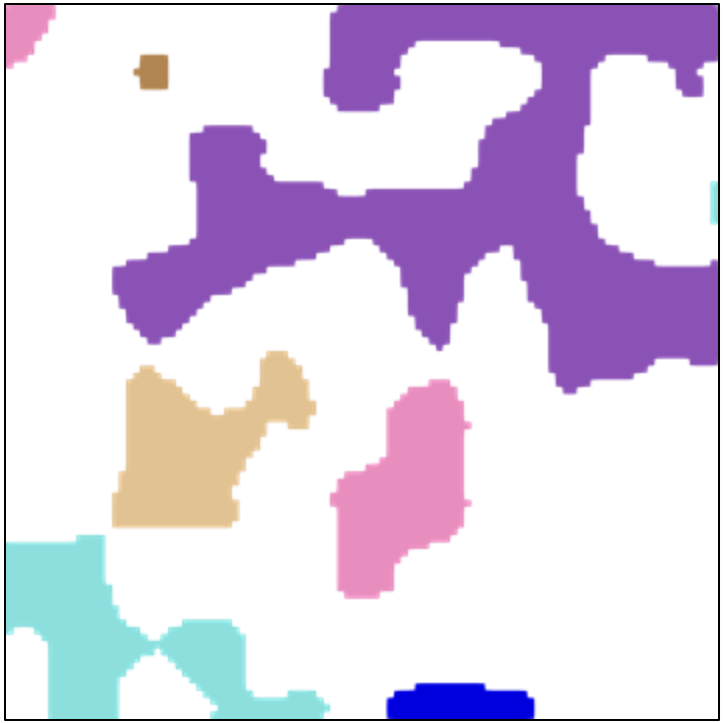
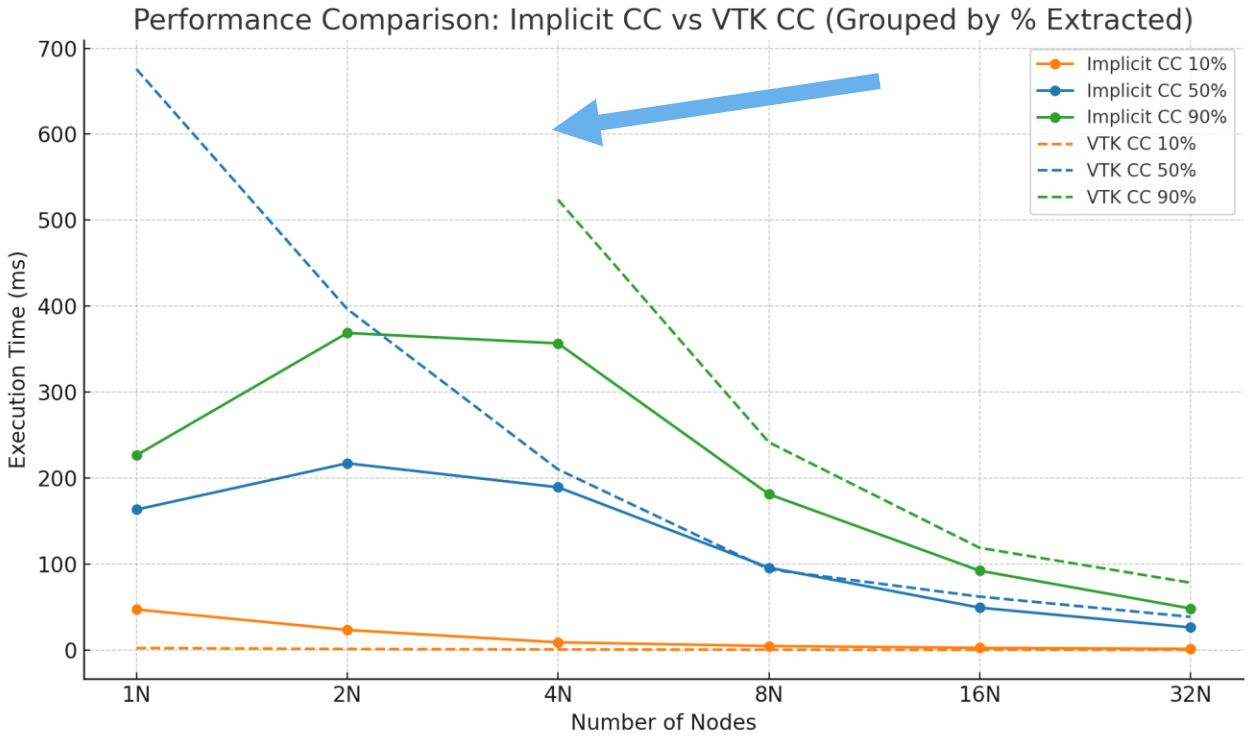


Running Times for different grid sizes

Size in #Vertices	Algorithm	1N	2N	4N	8N	16N	32N	64N
512^3	Segmentation	11.291	20.629	1.468	2.440	3.687	4.875	6.785
1024^3	Segmentation	86.044	167.134	17.417	13.010	16.148	20.046	25.103
2048^3	Segmentation	905.872	2165.203	215.517	106.430	91.730	-	-
512^3	DPC CC	5.973	4.994	1.835	0.950	0.718	0.592	0.847
	VTK CC	6.898	3.323	1.836	0.969	0.595	0.379	0.226
1024^3	DPC CC	44.750	41.451	17.683	8.023	3.640	1.908	1.446
	VTK CC	64.692	43.553	18.686	7.086	3.756	2.131	1.367
2048^3	DPC CC	237.242	402.772	111.073	68.752	29.125	15.188	8.912
	VTK CC	671.906	349.608	174.838	88.756	45.556	24.410	13.350
4096^3	DPC CC	-	-	-	-	277.634	129.562	73.757
	VTK CC	-	-	-	-	372.957	198.001	109.066

Running Times for different extraction sizes



Conclusion

Contributions:

- adaption of a well-scaling parallel algorithm for computing Morse-Smale segmentations to a distributed setting
- extending it to compute Connected Components, implicitly and explicitly
- open-source implementation in the Topology ToolKit

Future Work:

- investigating efficiency of one global vs multiple local communication steps
- using distributed MS segmentations for further algorithms e.g. distributed merge trees, distributed topological simplification

References

[1] Parallel Computation of Piecewise Linear Morse-Smale Segmentations. / Maack, Robin G.C.; Lukasczyk, Jonas; Tierny, Julien et al.
In: IEEE Transactions on Visualization and Computer Graphics, Vol. 30, No. 4, 01.04.2024, p. 1942-1955.

(a) PLMSS

(b) MS complex