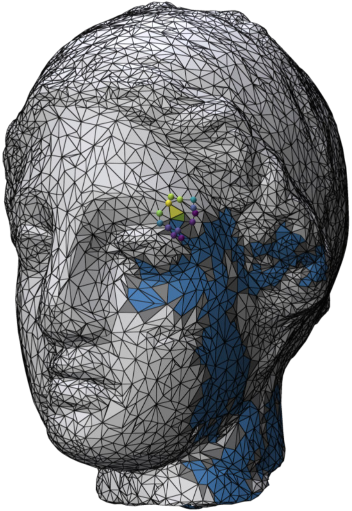
Priority-based encoding of triangle mesh connectivity for a known geometry

(and beyond)



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Pilsen, Czech Republic

May 19, 2023

Connectivity compression with known geometry

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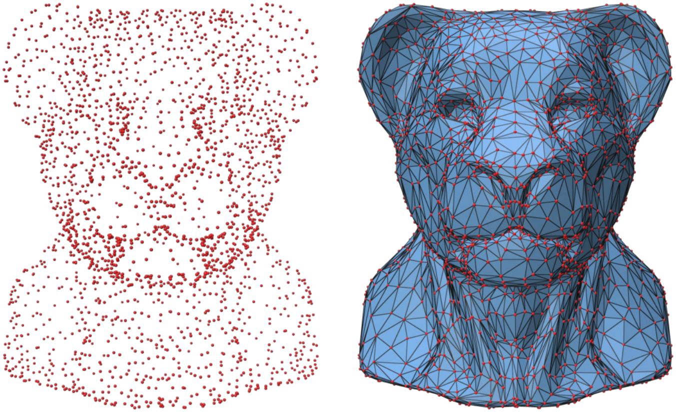
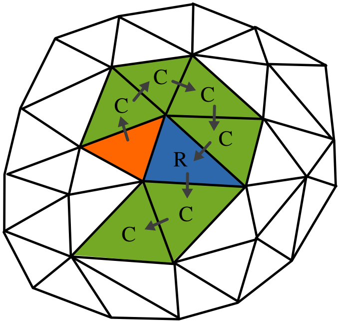
Geometry encoded first

- Temporal prediction
- Predictable spatial structure
- Multiple-rate compression



Conventional connectivity coding

Simple, does not require geometry information



< 2 bpf

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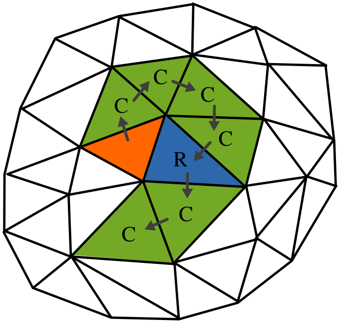


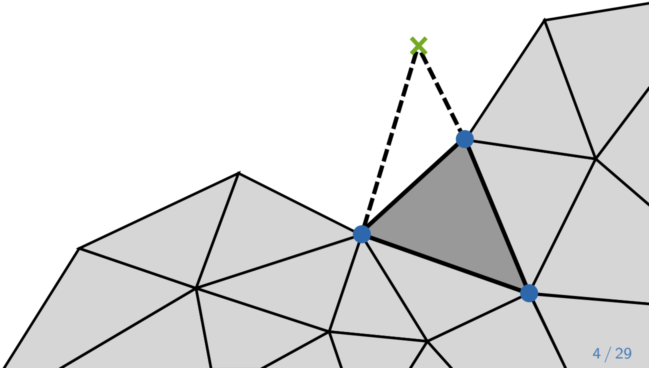
< 2 bpf

Causes reordering!

Permutation map: $\frac{1}{F}\log_2(V!)$ bpf

Distance-ranked coding

- Marais et al. 2007
- Fixed connectivity traversal through edges



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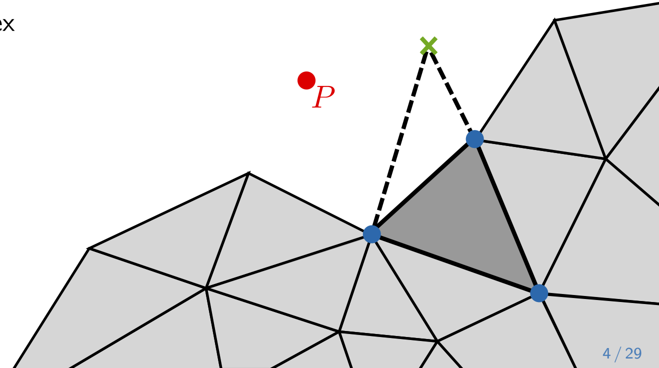

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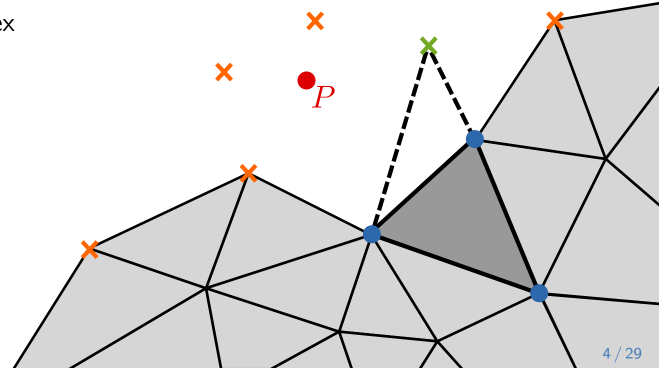

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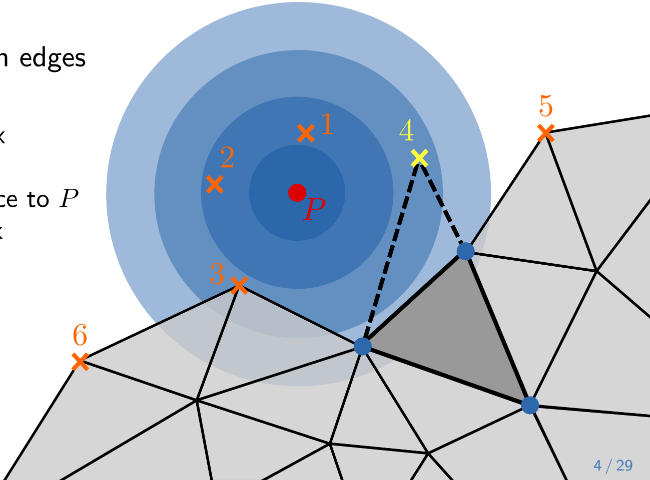

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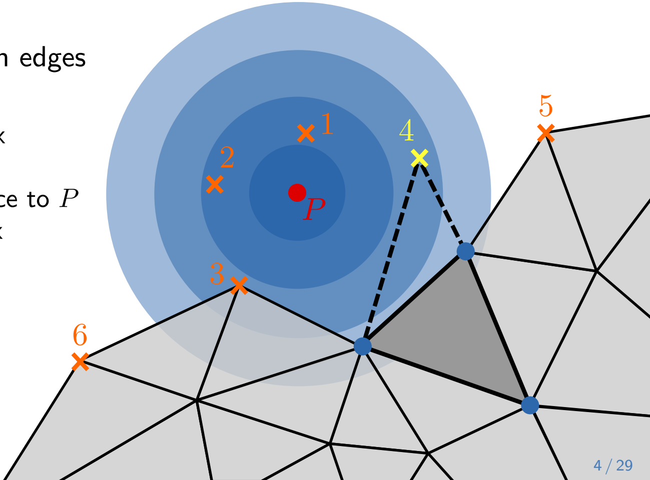
- Symbol **0** reserved for boundary



Our method

- Directly built upon Distance-ranked algorithm

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Priority-driven traversal

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Triangles where encoder most certain processed first

$$p = q_{\max} - q_{\max2}$$

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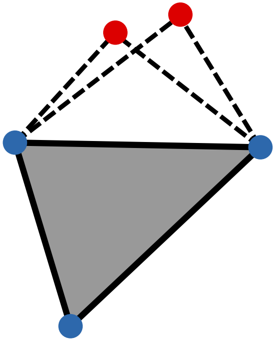
- More feasible situation in future



Priority-driven traversal

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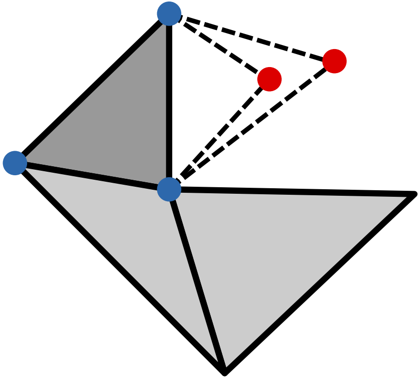

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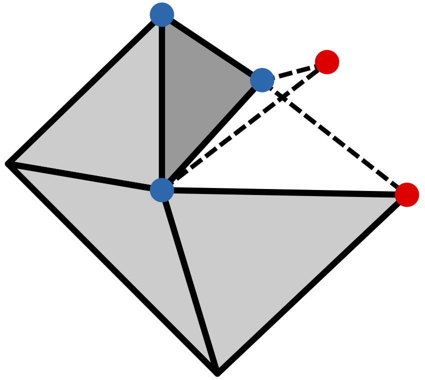

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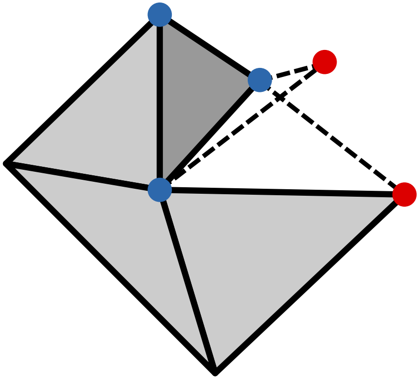
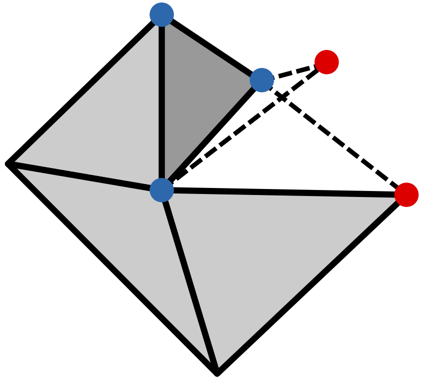


Priority-driven traversal

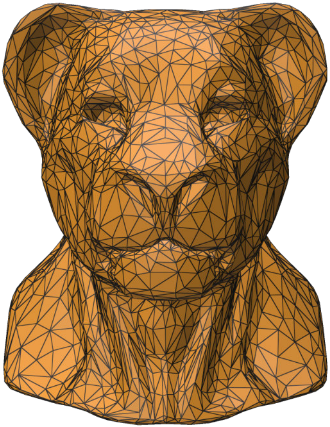
Triangles where encoder most certain processed first

$$p = q_{\max} - q_{\max 2}$$

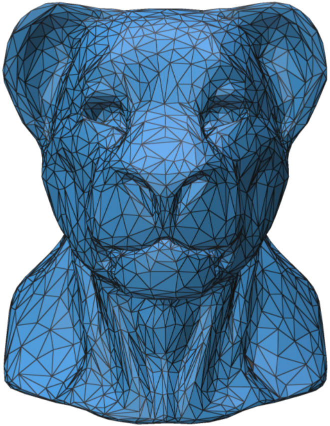
- More feasible situation in future
- Exponential distribution expected
- exp-Golomb code + CABAC
- Benefits when smaller values are encoded first



Fixed vs. Priority-driven traversal



Distance-ranked



Priority-driven

Fixed vs. Priority-driven traversal

Distance-ranked

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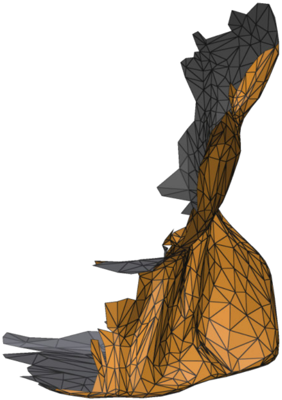

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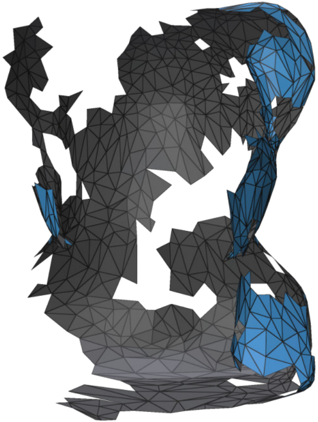

Priority-driven

Candidate vertex quality

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$$q = \theta - w_1 \cdot \bar{d} + w_2 \cdot \phi + w_3 \cdot S$$

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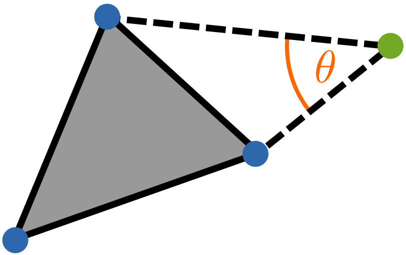
- Optimally - regular planar triangulation

Inner angle

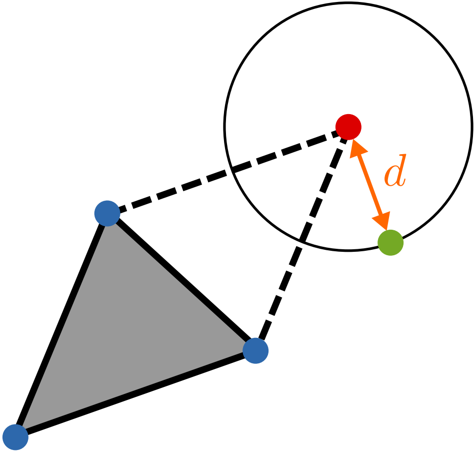
Penalize long triangles



Best value: π

Distance from parallelogram prediction

Planarity, similar properties (area, edge length, inner angles)



$$\bar{d} = \frac{d}{l_{\text{avg}}}$$

Best value: 0

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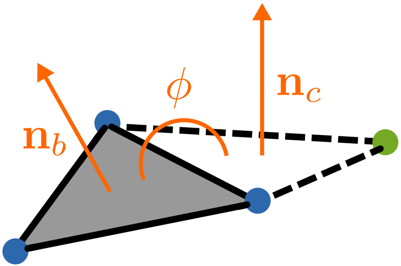
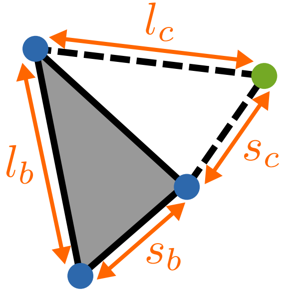
Planarity



$$\phi = \pi - \arccos(\mathbf{n}_b \cdot \mathbf{n}_c)$$

Best value: π

Alternative to parallelogram rule without enforced planarity



$$r_s = s_b/s_v, \quad r_l = l_b/l_c$$
$$r = (r_s + r_l)/2$$
$$S = -(|r - r_s| + |r - r_l|)/2.$$

Best value: 0

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To prevent ranking mismatch, the candidate list must be identical at both the encoder and decoder.

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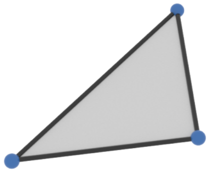
Still can be evaluated by radial search, the search area can be deduced by plugging optimal values into the equation for evaluating q.

Search area

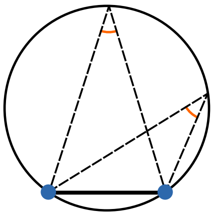
$$q = \theta - w_1 \cdot \bar{d} + w_2 \cdot \phi + w_3 \cdot S$$

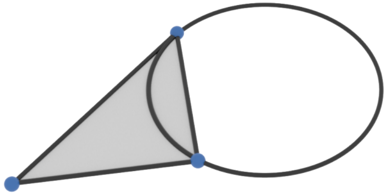


Search area

$$q_c = \theta_{\text{min}} - w_1 \cdot 0 + w_2 \cdot \pi + w_3 \cdot 0$$

$$\theta_{\text{min}} = q_c - w_2 \cdot \pi$$





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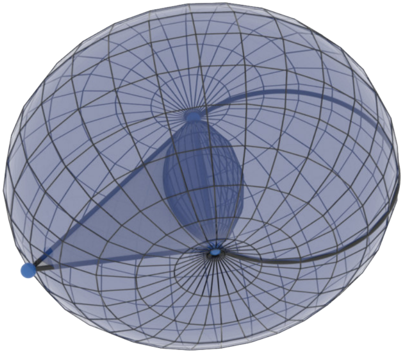

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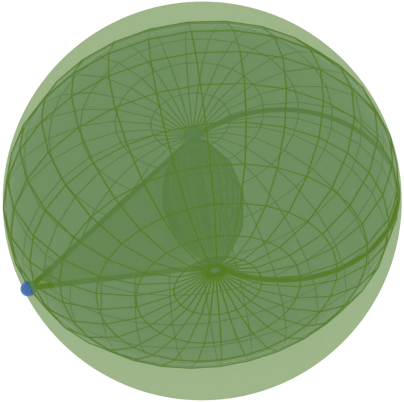

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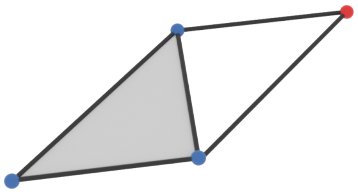
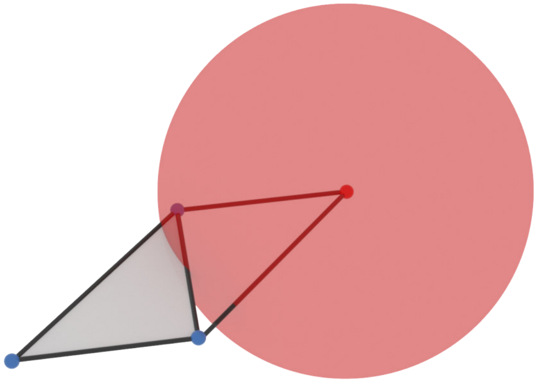


Search area

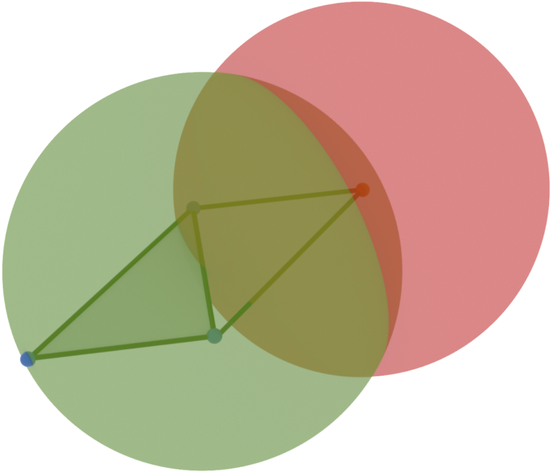
$$q_c = \pi - w_1 \cdot \bar{d}_{\max} + w_2 \cdot \pi + w_3 \cdot 0$$

$$d_{\max} = \frac{(w_2 \cdot \pi + \pi - q_c) \cdot l_{\text{avg}}}{w_1}$$



Search area

All vertices with $q \geq q_c$ lie within $\mathcal{B}_d \cap \mathcal{B}_\theta$



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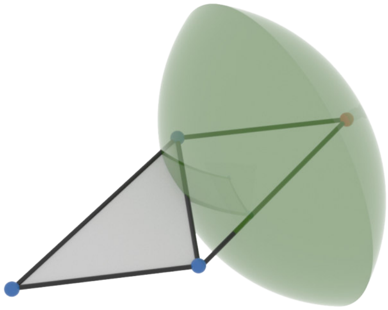

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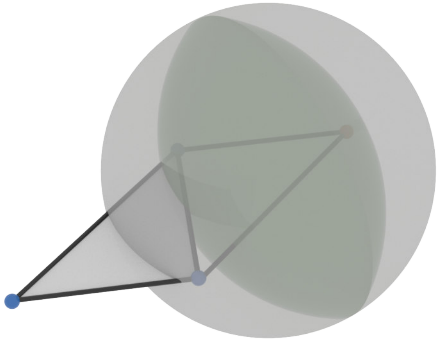

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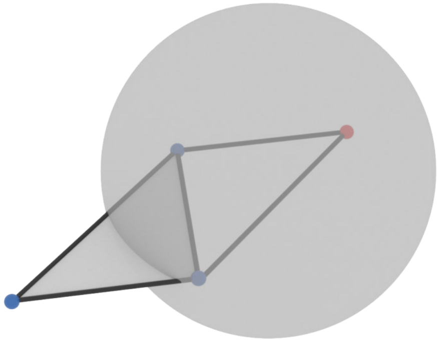

Boundary edge prediction

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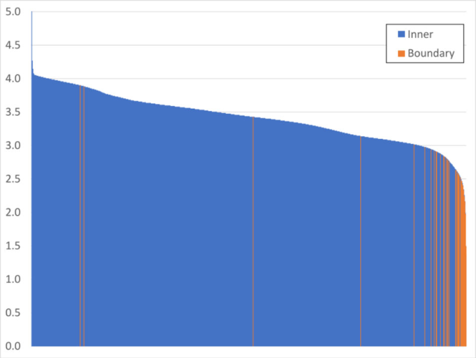
Assumption

The boundary edge usually has no candidate vertex of high quality.



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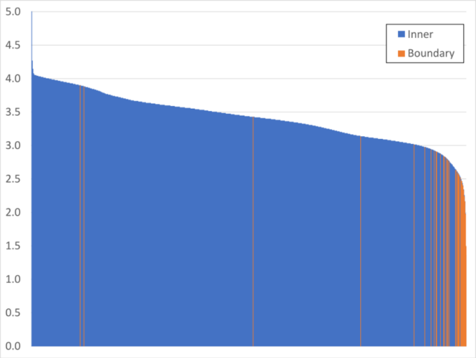
- Evaluate $q_{\max}$ of each edge



Boundary edge prediction

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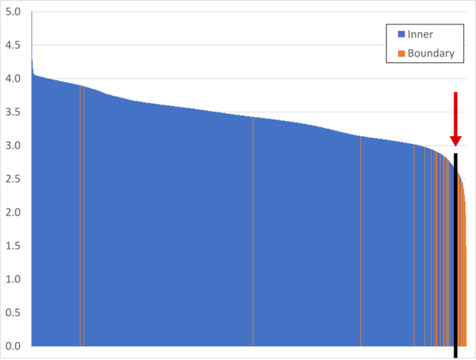
- Evaluate $q_{\max}$ of each edge
- Find q_t which best separates $q_{\max}$ of inner/boundary edges



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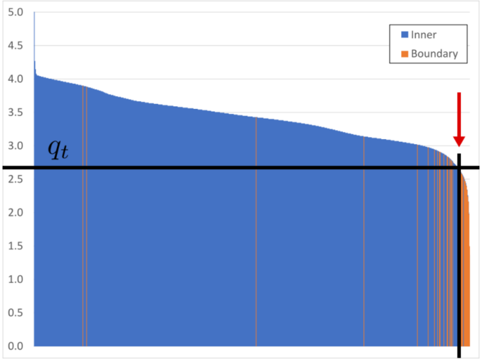

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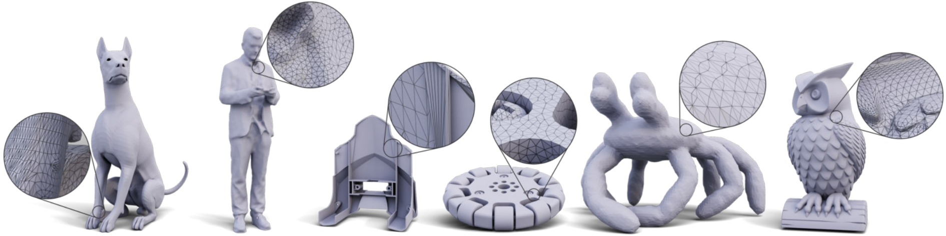
- Evaluate $q_{\max}$ of each edge
- Find q_t which best separates $q_{\max}$ of inner/boundary edges
- Predict boundary if $q_{\max} < q_t$

Prediction	Actual	Symbol
Inner	Inner	i
Boundary	Boundary	0
Boundary	Inner	$i+1$
Inner	Boundary	$\max(i)+1$

Experimental results

Main experiment



# meshes	80	546	10000	10000	458	8133

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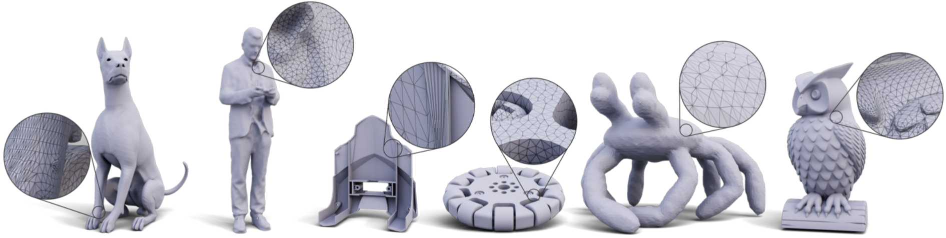

Proposed	1.112 bpf $H = 1.247$	0.152 bpf $H = 0.171$	1.050 bpf $H = 1.195$	0.181 bpf $H = 0.282$	0.448 bpf $H = 0.521$	0.919 bpf $H = 1.079$

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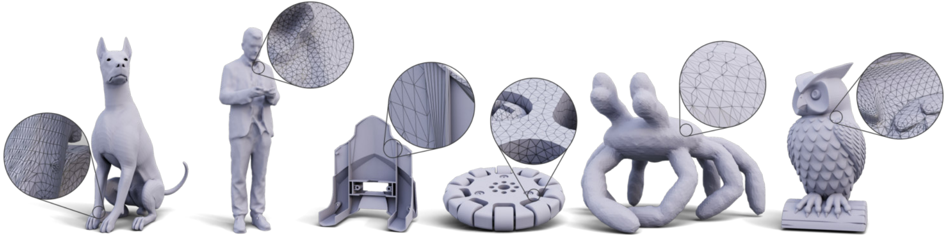

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Distance-ranked	1.343 bpf $H = 1.317$	0.264 bpf $H = 0.232$	2.261 bpf $H = 2.324$	0.331 bpf $H = 0.381$	0.708 bpf $H = 0.693$	1.523 bpf $H = 1.552$

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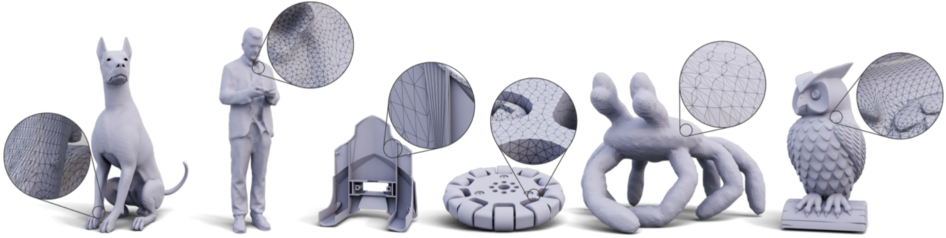

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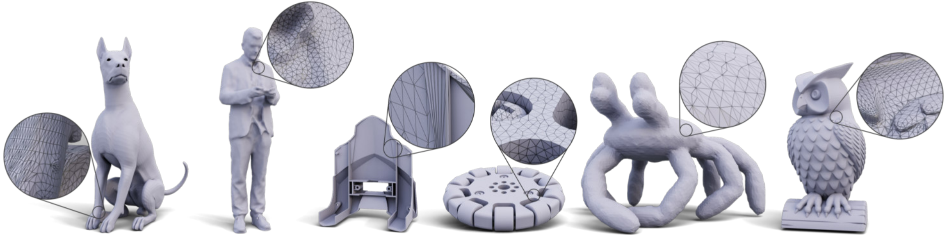
The Distance-ranked algorithm does not achieve a consistently lower data rate than H.

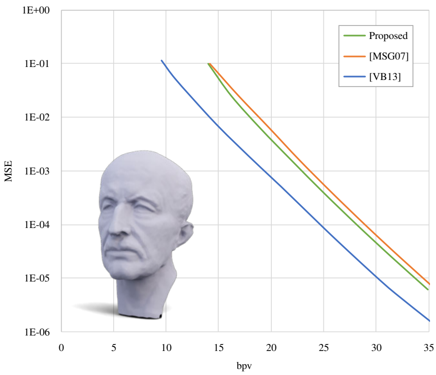
Main experiment

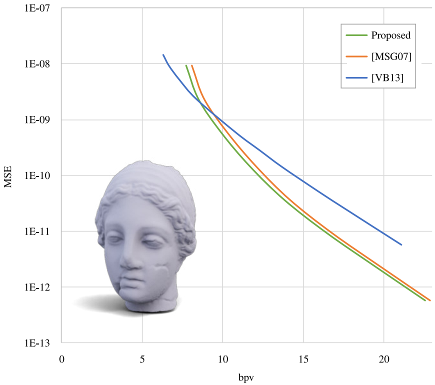


Improvement	17.17%	42.62%	53.54%	45.26%	36.68%	39.66%

Mesh compression

Combined with PC codec [Merry et al. 2006] vs. Weighted parallelogram [Váša-Brunnett 2013]





Limitations & Future Work

PAC-MAN configuration ᗧ···

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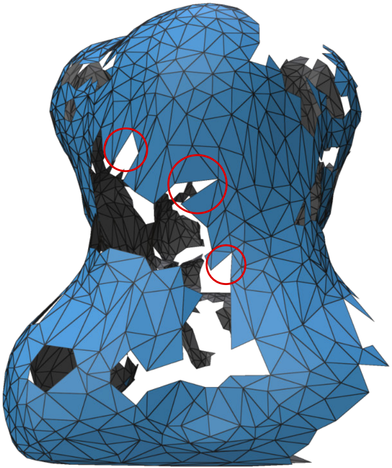
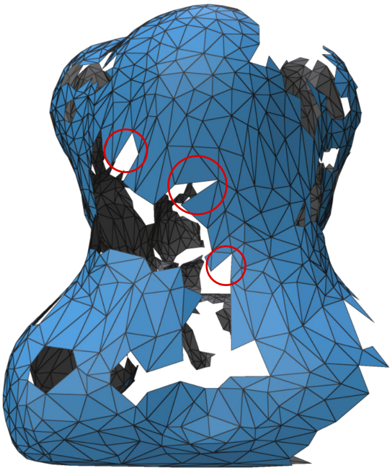
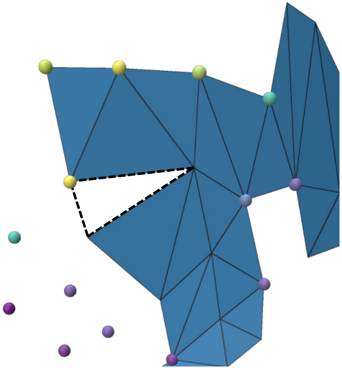


PAC-MAN configuration





PAC-MAN configuration ···

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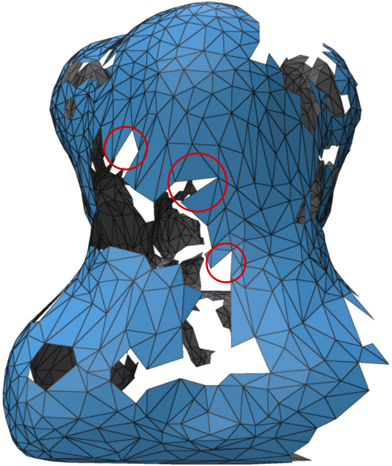
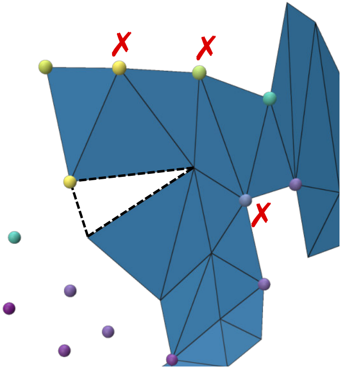
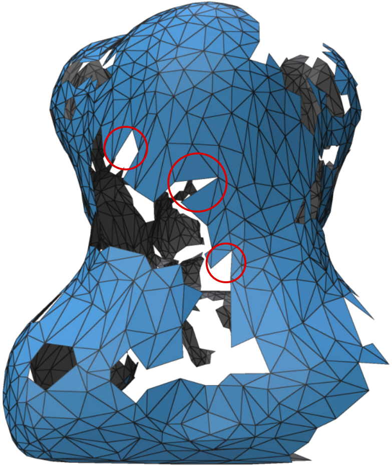
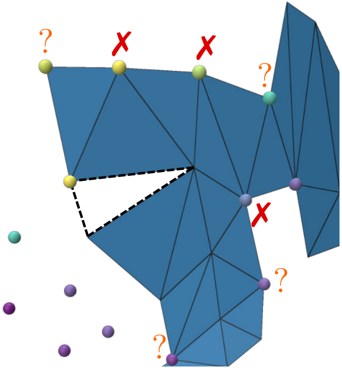




PAC-MAN configuration





Optimal parameters

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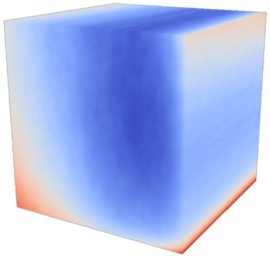
Difficult to find optimal w_1, w_2, w_3 for a certain model.

- Global trend towards a region of satisfactory rates

$$bpf(w_1, w_2, w_3)$$



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- Exhaustive search
- Simulated annealing
- Still no guarantee of finding the global minimum

In experiments:

- Default parameters vs. Fine-tuned for each dataset
- Estimated on a subset
- Default parameters still better than Distance-ranked
- No significant improvement for irregular data

Connection to mesh properties

- Obtain fine-tuned weights for various models

Connection to mesh properties

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- Compare mesh properties
  - Mean and Gaussian curvatures
  - Vertex degrees
  - Inner angles
  - Edge lengths
  - ...

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So complex, there might not be any.

Local-frame-based optimization

- Local frame optimization
  - Maximize tip vertex quality
  - Minimize quality of all other vertices

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1. Optimize over all gates and encode weights
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Does not consider all the aspects (e.g., priority).

Quality function for CAD models

Model-based compression of Time-varying meshes

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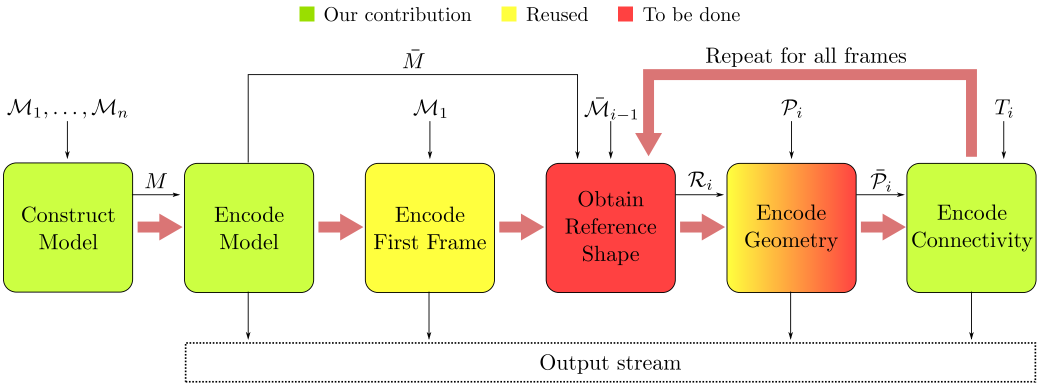

Thank you

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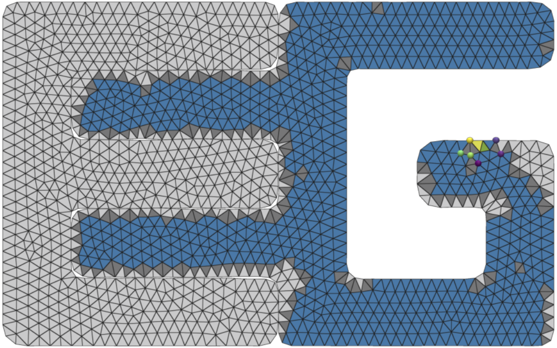
https://gitlab.kiv.zcu.cz/jdvorak/priority-based-connectivity-coding



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