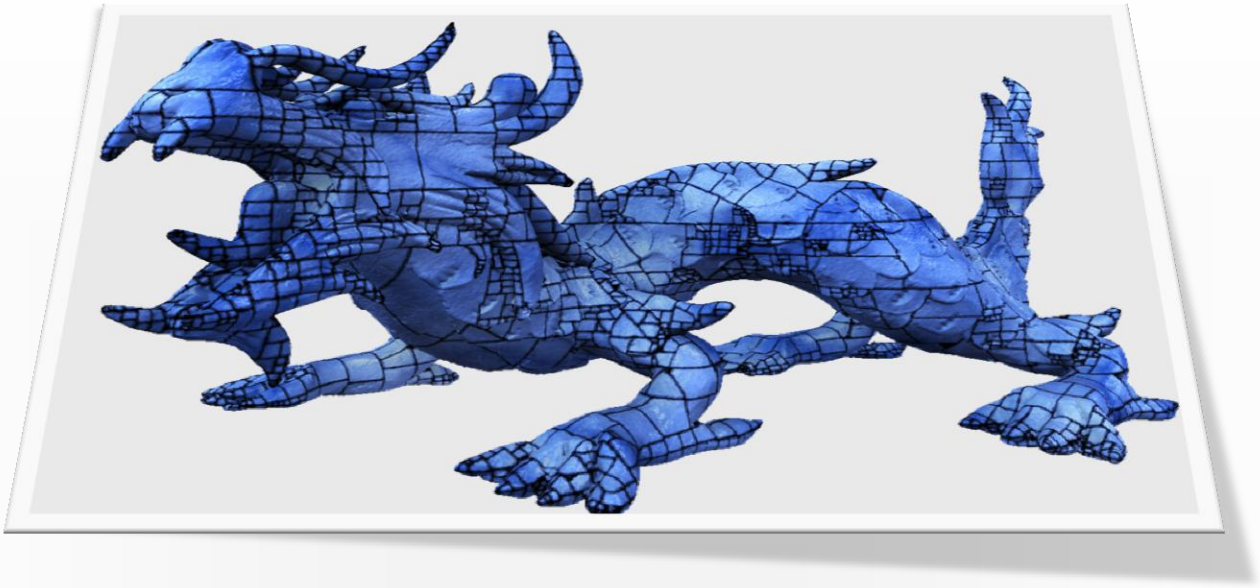


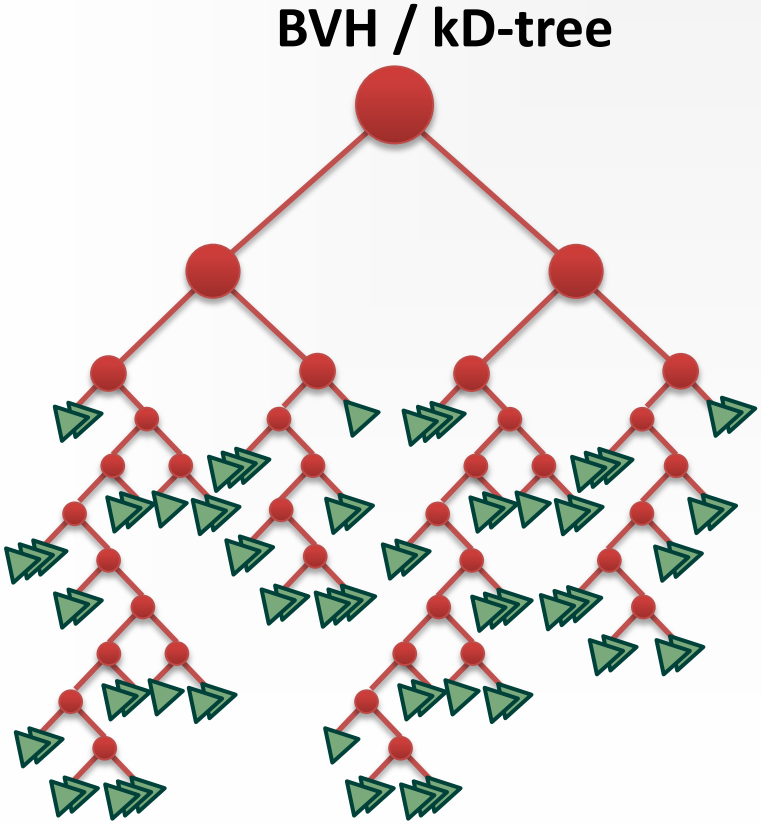
Rasterized Bounding Volume Hierarchies

Jan Novák and Carsten Dachsbacher

Computer Graphics Group
Karlsruhe Institute of Technology

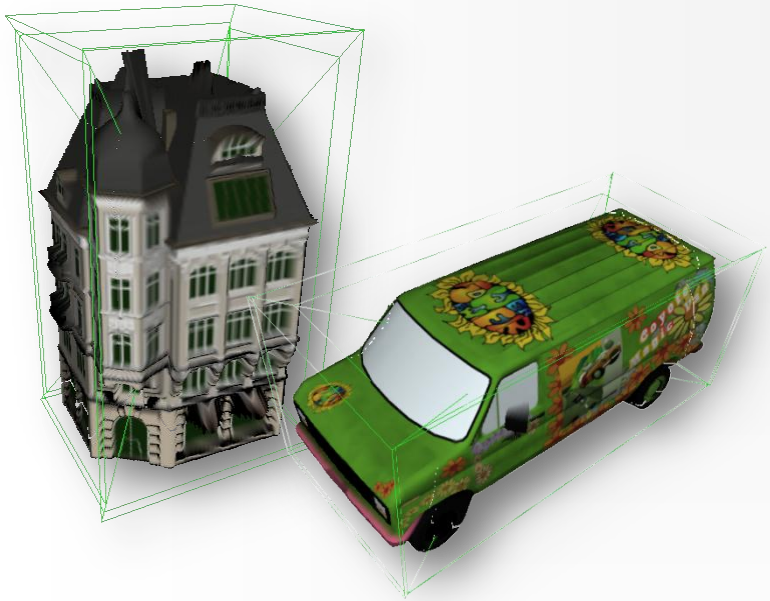
EUROGRAPHICS 2012

MOTIVATION (Previous Work)

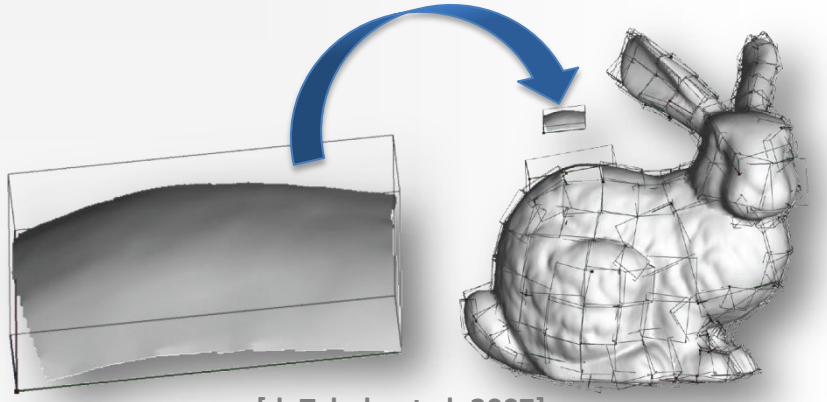


[Havran 2000]
[Ernst and Greiner 2007]
[Damnertz and Keller 2008]
[Popov et al. 2009]
[Aila and Laine 2009]
[Lauterbach et al. 2009]

MOTIVATION (Previous Work)

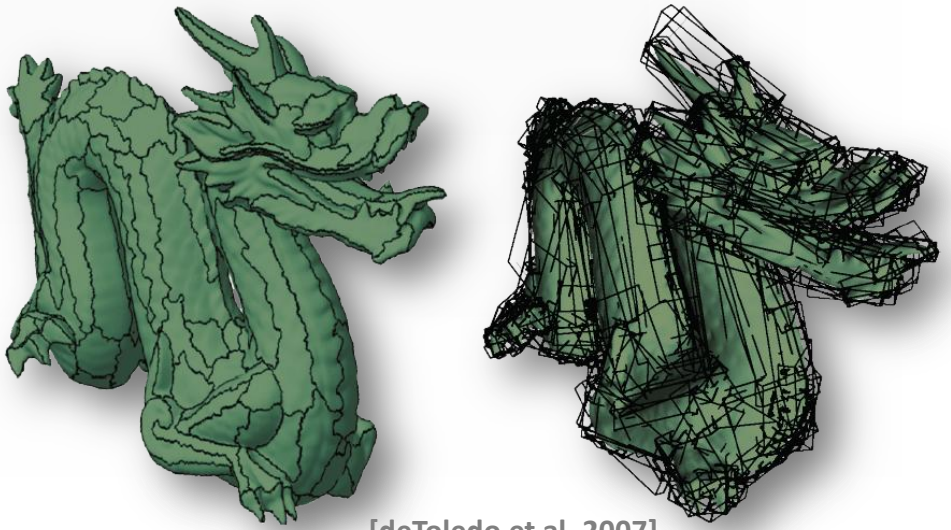


[Baboud and Decoret 2006]



[deToledo et al. 2007]

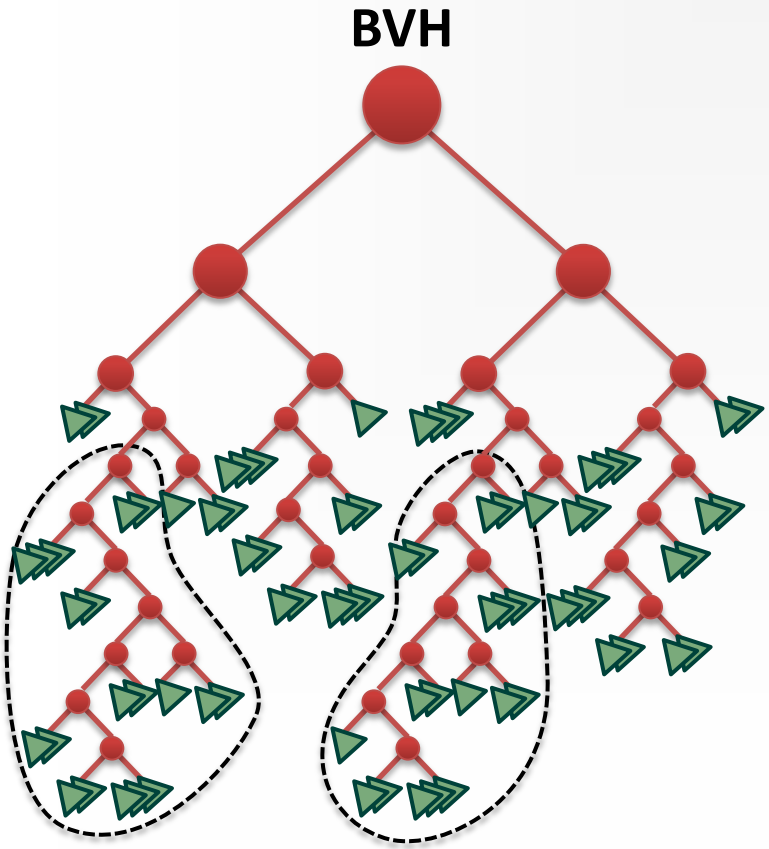
[Baboud and Decoret 2006]
[Carr et al. 2006]
[Szirmay-Kalos et al. 2005]
[deToledo et al. 2007]
[Boubekeur et al. 2006]

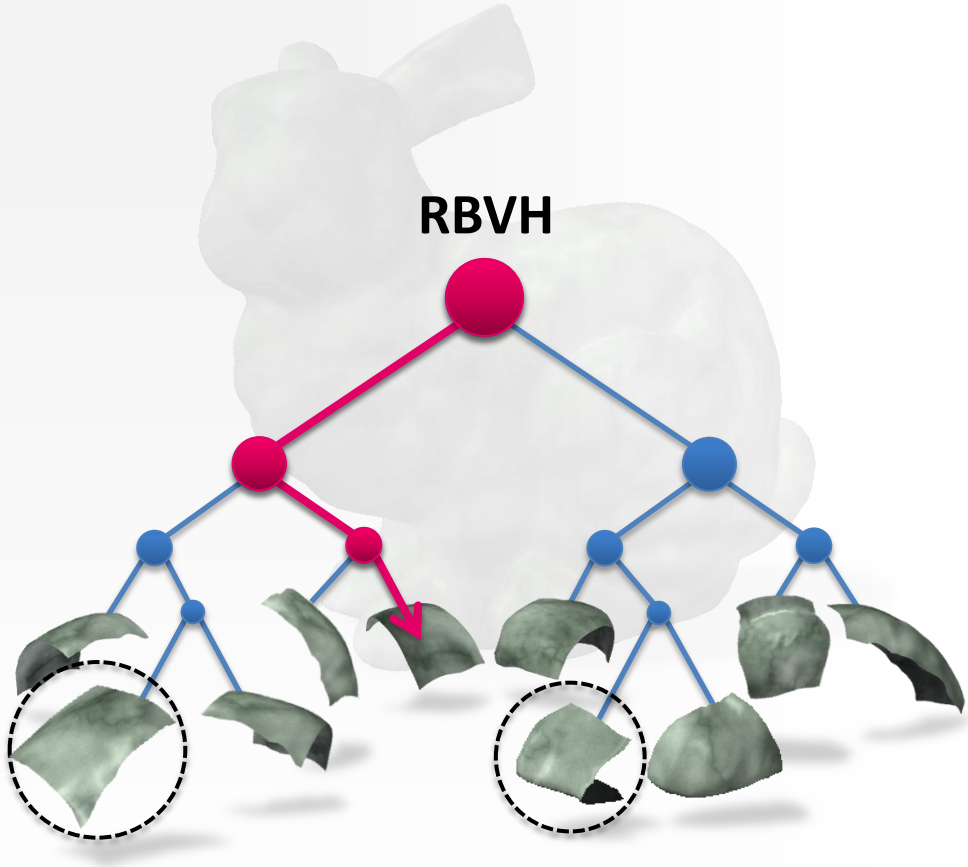


[deToledo et al. 2007]

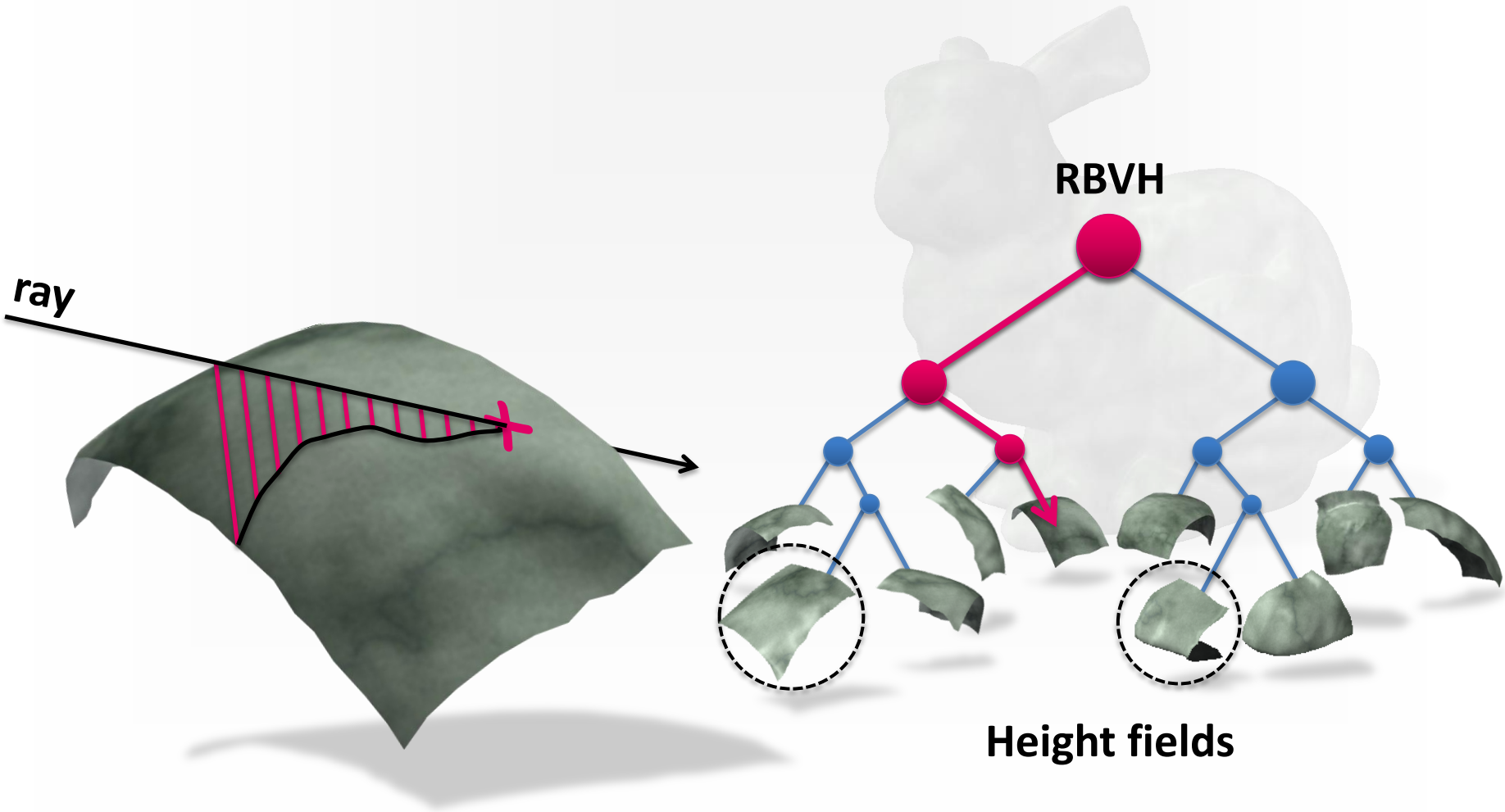
OVERVIEW

OVERVIEW

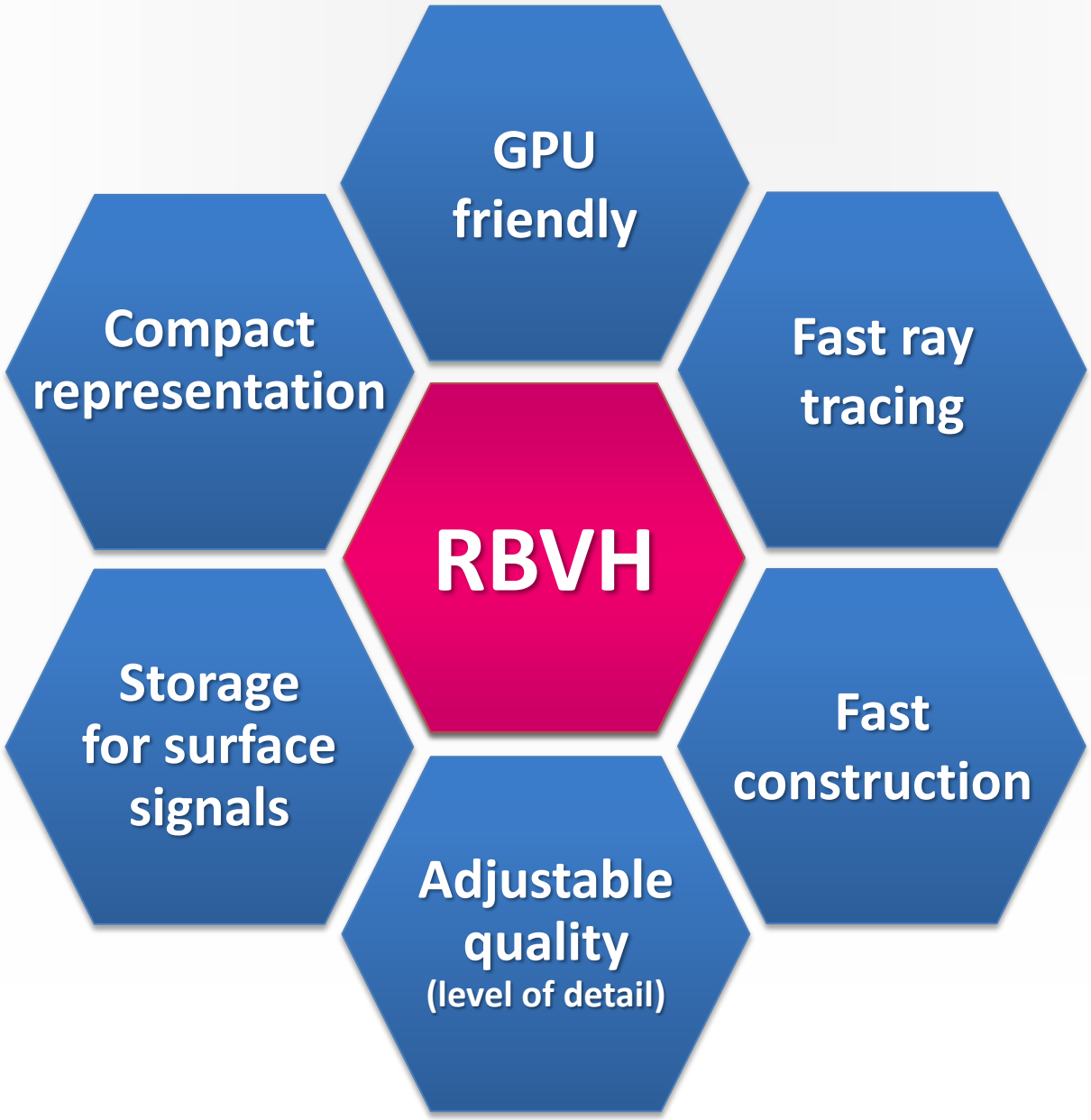




OVERVIEW

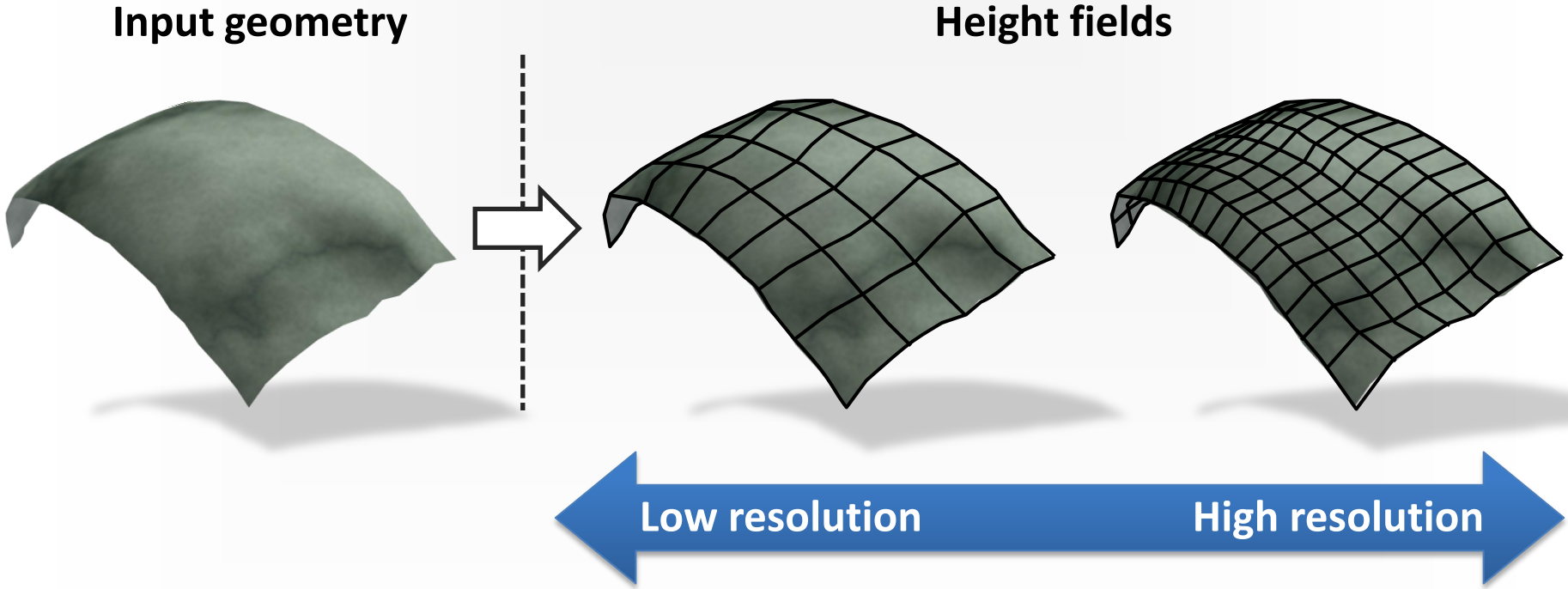


WISHLIST


GPU friendly
Compact representation
Fast ray tracing
RBVH
Storage for surface signals
Fast construction
Adjustable quality
(level of detail)

SAMPLING RATE

RBVH decouple from input geometry:



SAMPLING RATE

"number of pixels per unit area"
(defined by user)

affects: 1) quality of the representation
2) memory requirements

Construction: OVERVIEW

⇨ Construct RBVH (surfaces):

if (surfaces *cannot be represented by a single height field*) **then**

Split surfaces into two sets A and B

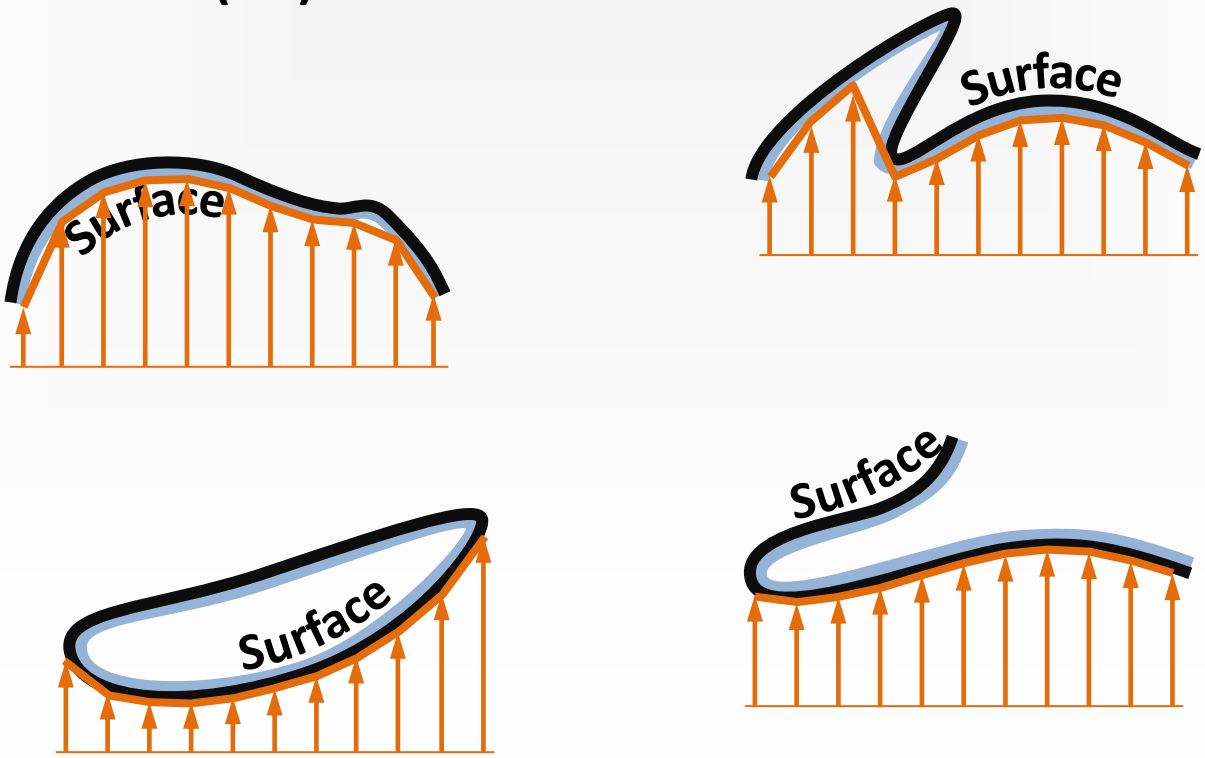
Construct RBVH (A)
Construct RBVH (B)

else

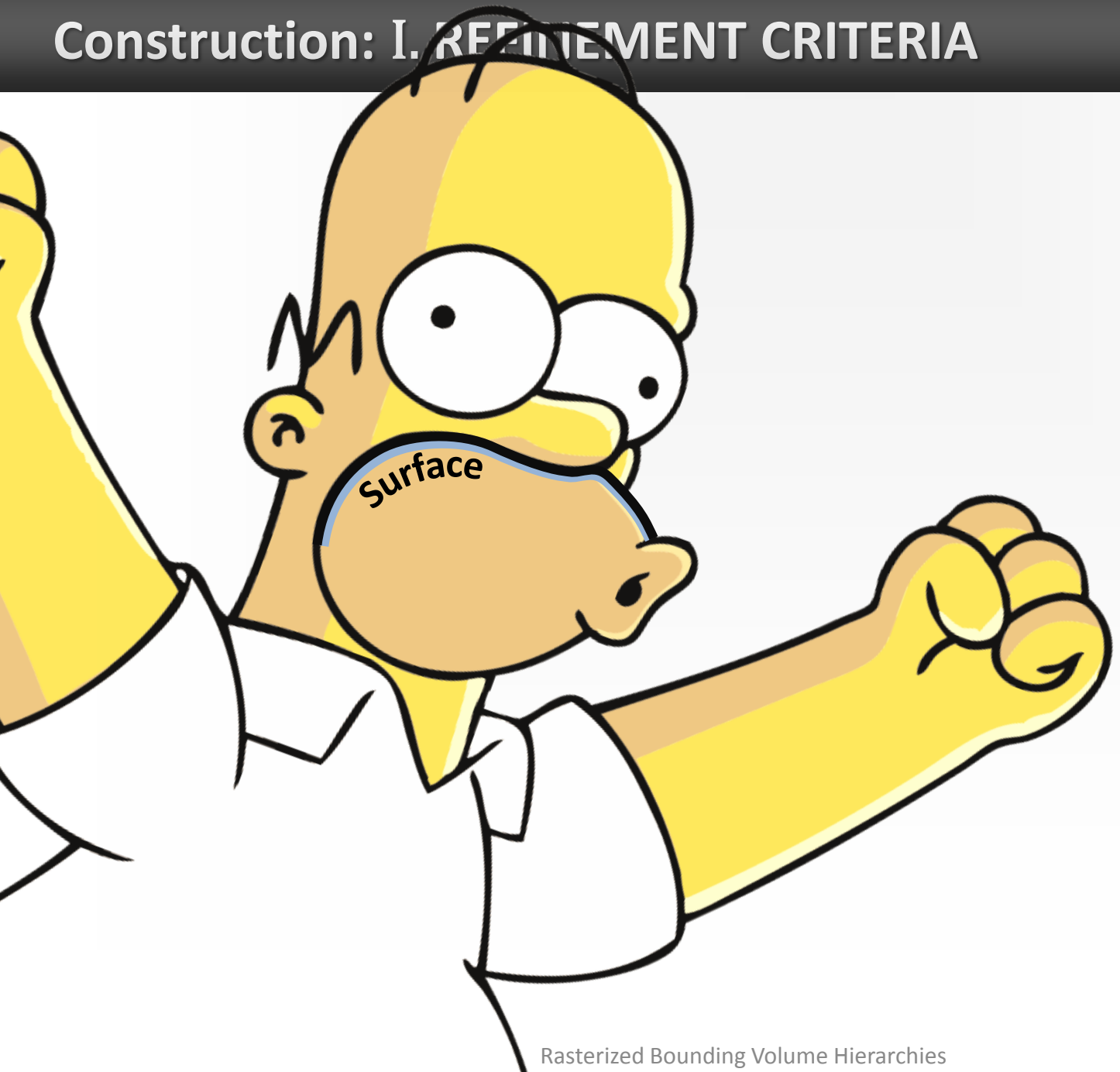
Rasterize surfaces into texture atlas

Construction: I. REFINEMENT CRITERIA

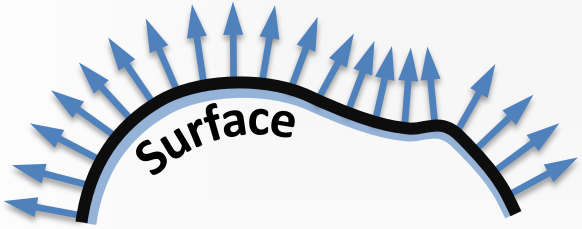
Example surfaces (2D):

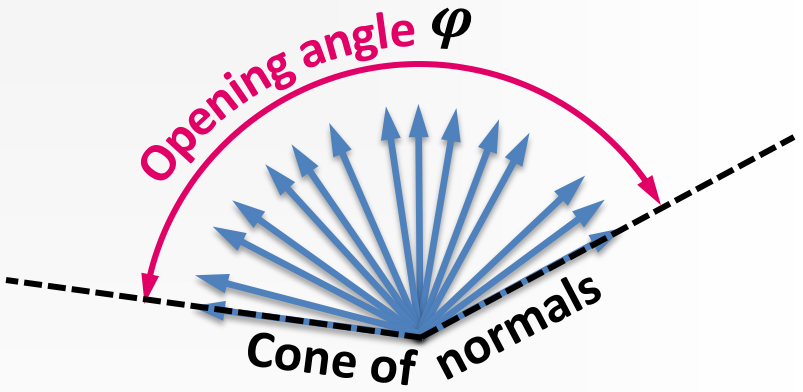


Construction: I. REFINEMENT CRITERIA



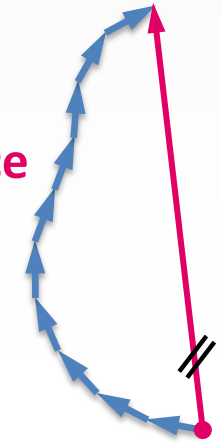
Construction: I. REFINEMENT CRITERIA

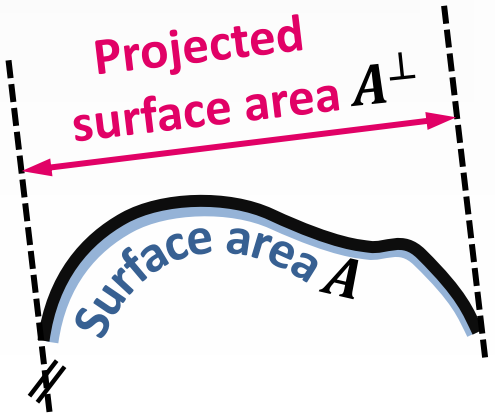




Average surface orientation

$$\sum \vec{\mathbf{n}}_i \, A_i$$



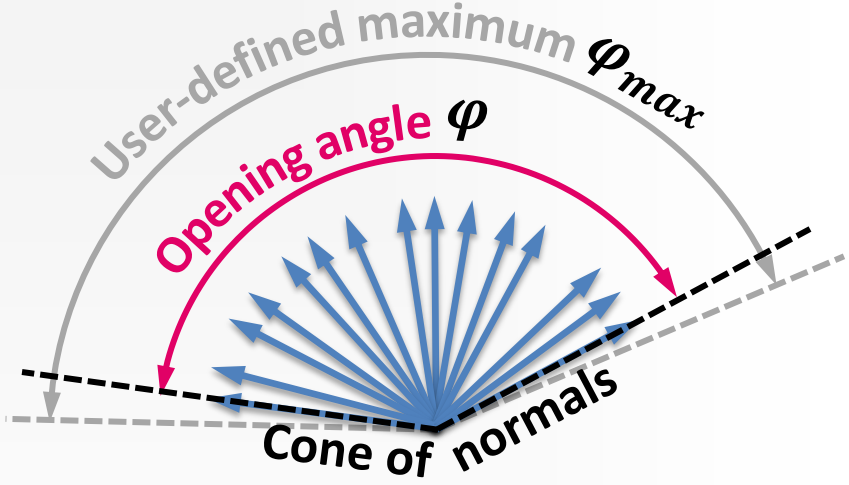


Construction: I. REFINEMENT CRITERIA

1) Cone of normals:

rasterize if $\varphi < \varphi_{max}$

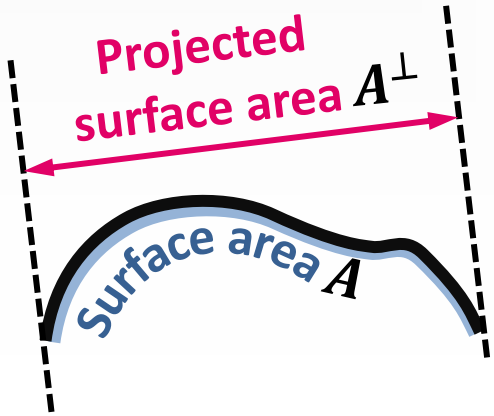
good for subdivision surfaces



2) Projected surface area:

rasterize if area ratio $\frac{A^{\perp}}{A} > a$

good for scanned (noisy) data



Construction: OVERVIEW

Construct RBVH (surfaces):

if (surfaces *cannot be represented by a single height field*) **then**

Split surfaces into two sets A and B

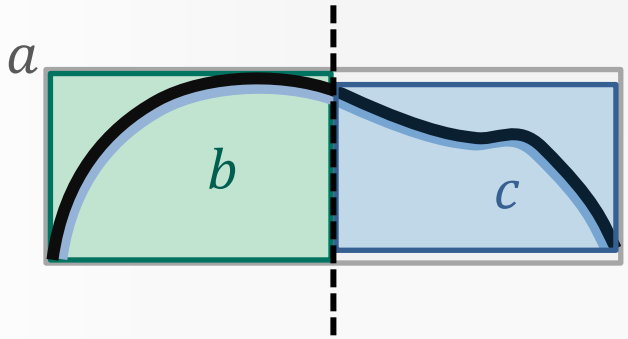
Construct RBVH (A)
Construct RBVH (B)

else

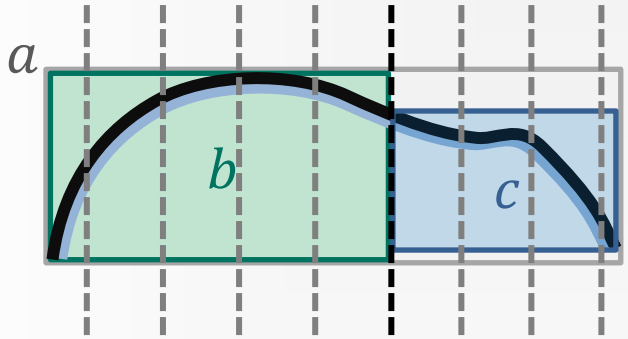
Rasterize surfaces into the atlas

1) Spatial Median

Split in the middle along the longest axis.



2) Modified Surface Area Heuristic (SAH)



Original SAH: $\boldsymbol{C_{split}} = \boldsymbol{p}(b|a)\,\underbrace{\boldsymbol{N_b C_{isect}}} + \boldsymbol{p}(c|a)\,\underbrace{\boldsymbol{N_c C_{isect}}}$

Modified SAH: $\boldsymbol{C_{split}} = \boldsymbol{p}(b|a)\,\underbrace{\boldsymbol{A_b}}_{\text{Area of surfaces in } b} + \boldsymbol{p}(c|a)\,\underbrace{\boldsymbol{A_c}}_{\text{Area of surfaces in } c}$

Cost of intersecting a child ← **Area of the child**

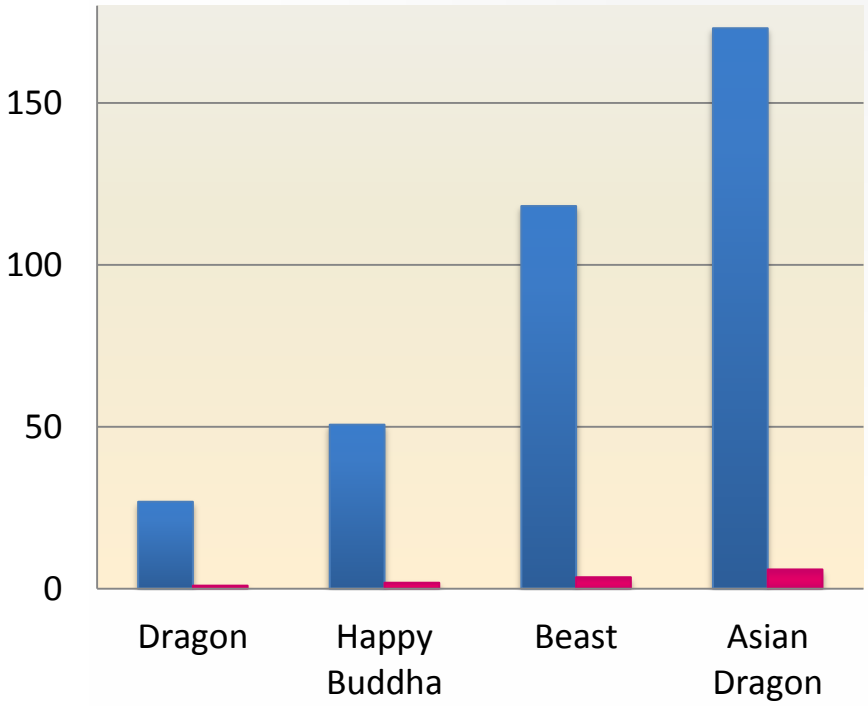
How much better is the **Modified SAH** than the **Spatial Median**?

Construction: II. SUBDIVISION STRATEGIES

- **Modified SAH** (32 split candidates along each axis)
- **Spatial Median**

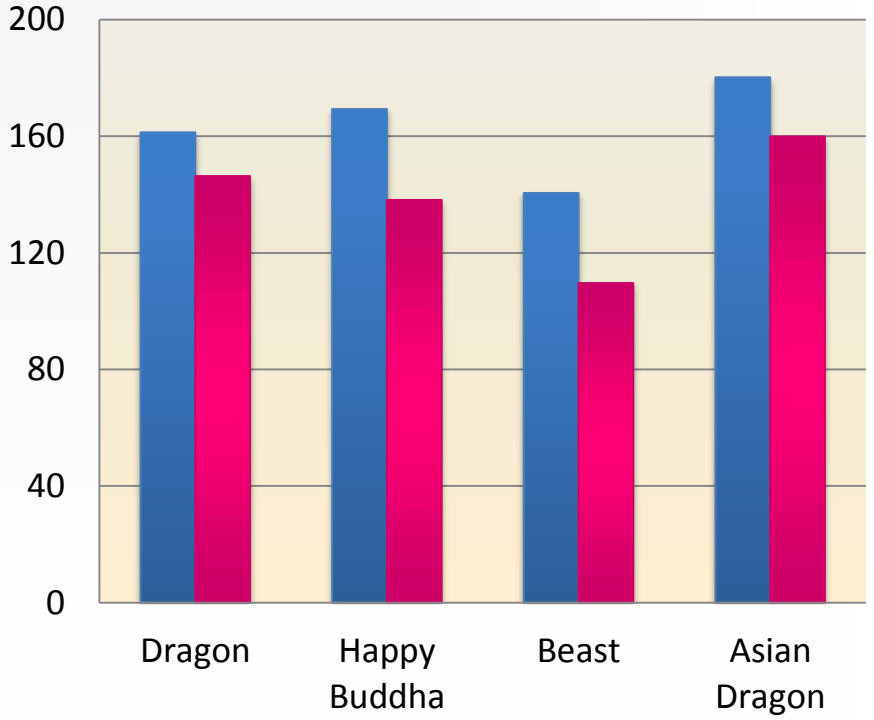
CPU Construction [seconds]

„smaller is better“



GPU Ray Tracing [MRays/second]

„bigger is better“

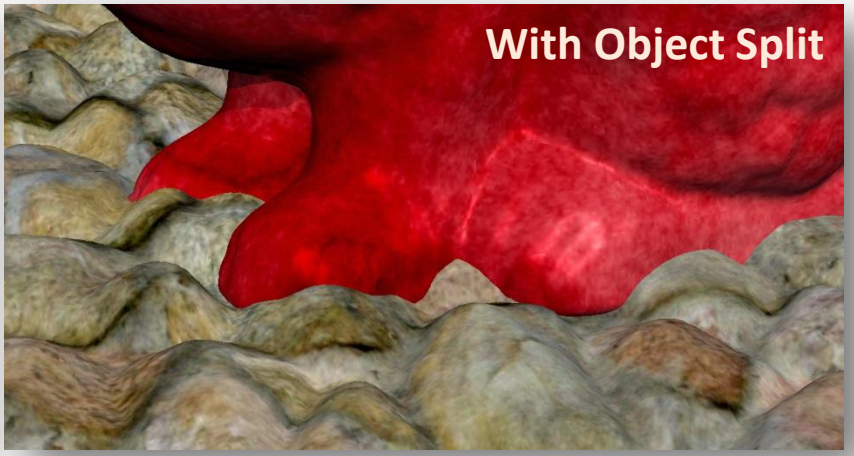


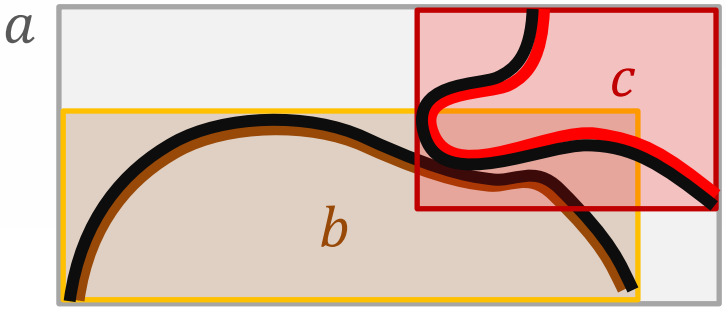
Spatial Median = fast construction + reasonable performance!

in case of RBVHs

3) Object Split

- complementary strategy
- avoids fusing objects into a single height field





Construction: OVERVIEW

Construct RBVH (surfaces):

if (surfaces *cannot be represented by a single height field*) **then**

Split surfaces into two sets A and B

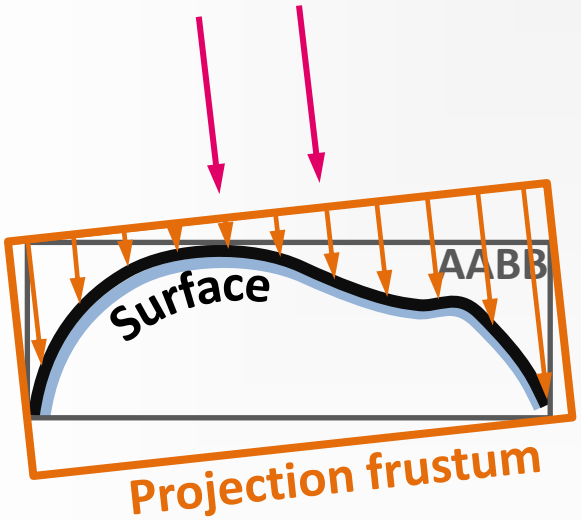
Construct RBVH (A)

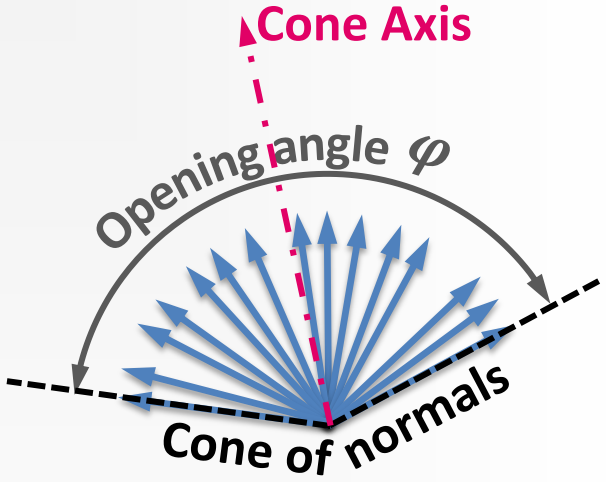
Construct RBVH (B)

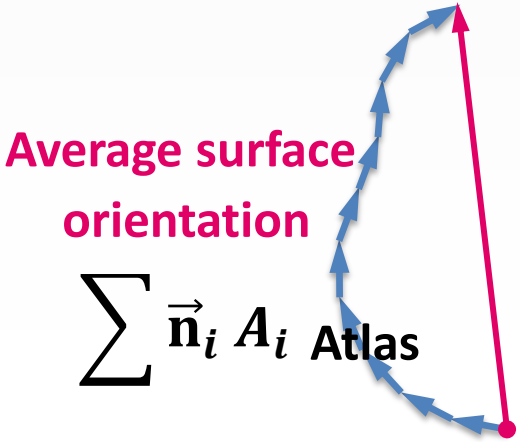
else

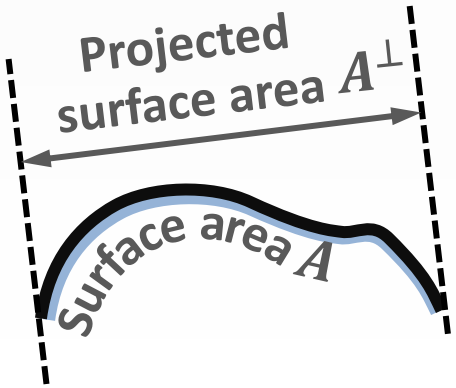
Rasterize surfaces into the atlas

Orthogonal projection frustum



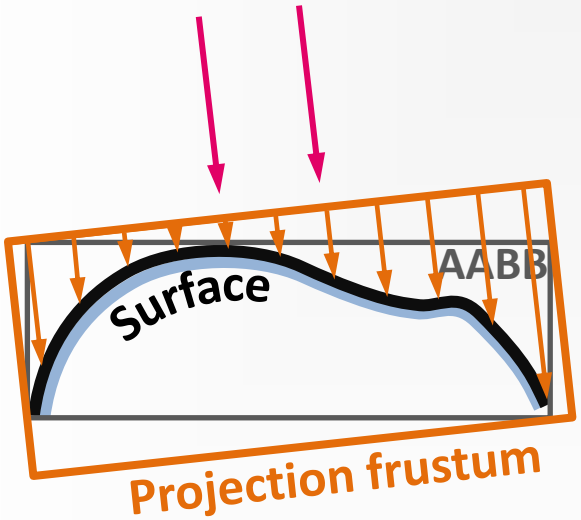


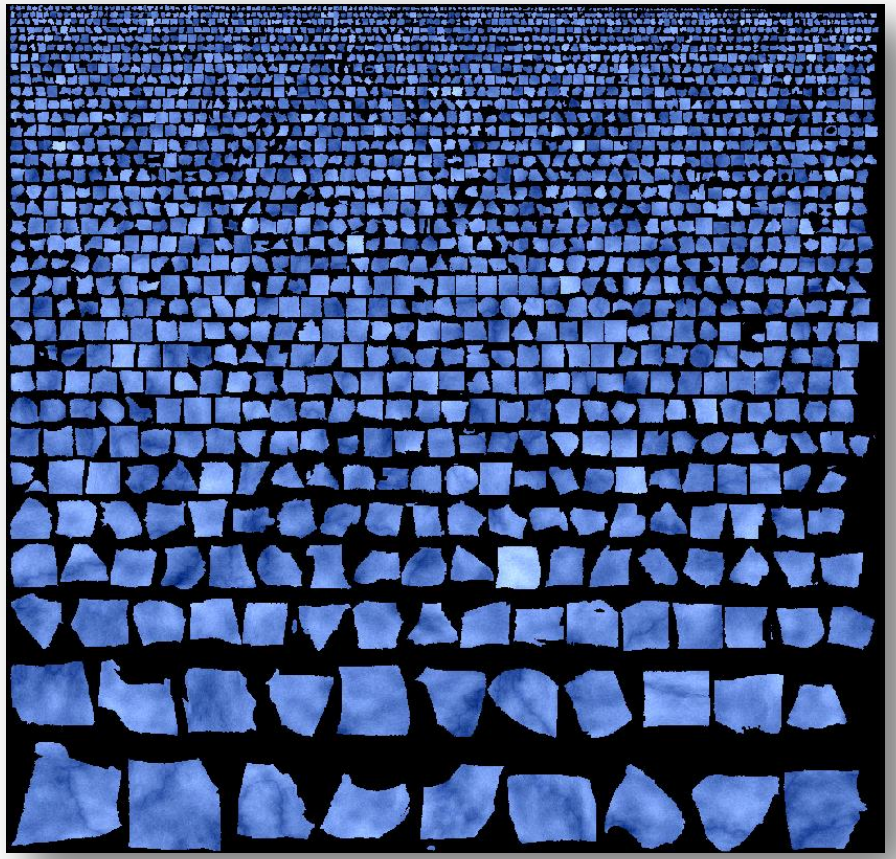




Construction: III. RASTERIZATION INTO ATLAS

Orthogonal projection frustum





Atlas

Construction: SUMMARY

- Refinement criteria (“*whether to split*”):

  Cone of normals *or* **Projected surface area**

- Subdivision strategies (*“where to split”*):

  Spatial median *or* **Modified SAH**

  and **Object split**

- User-defined parameters (*“what quality”*):

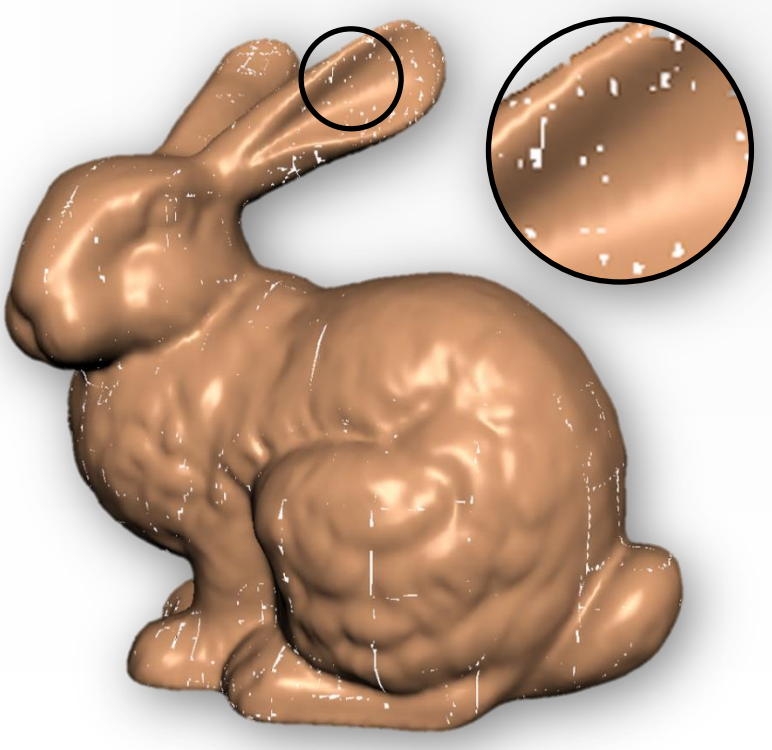
  global: **Sampling rate**

  local: **Opening angle** *or* **Area ratio**

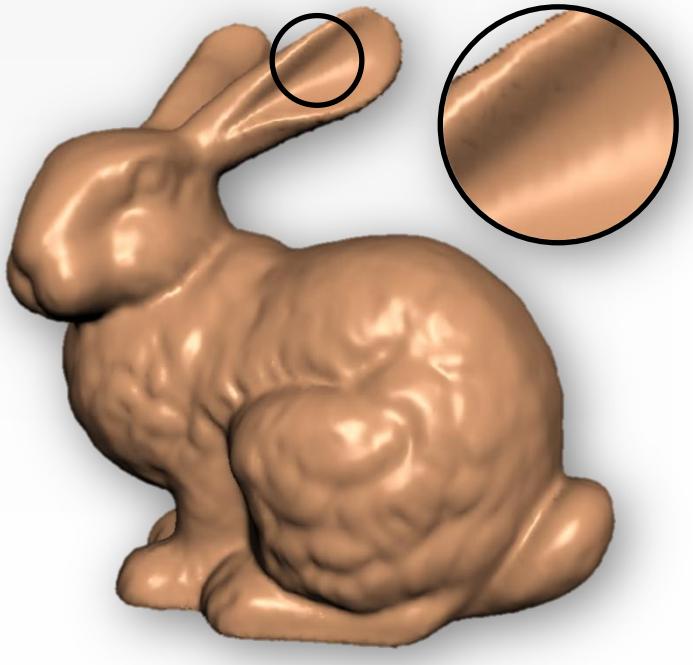
Construction: FURTHER IMPROVEMENTS

- Avoid cracks
  - **Allow overlaps**
  - **Dilatation filter** on the atlas

Original **atlas**



…after applying dilation filter

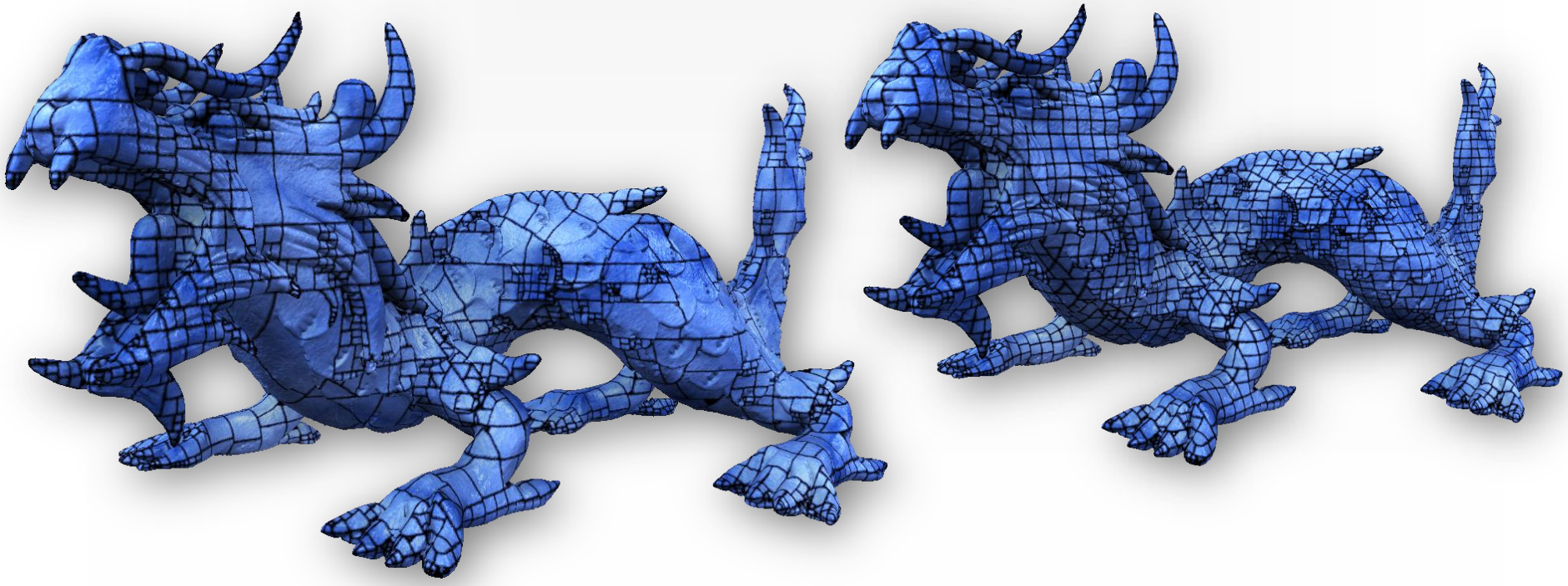


Construction: FURTHER IMPROVEMENTS

- **Subdivide large height fields** to speed up ray marching

Original **RBVH**

…optimized for fast traversal



Hybrid RBVH

Not all geometry is well-representable by RBVHs

Crytek Sponza with Asian Dragons (22 million triangles)

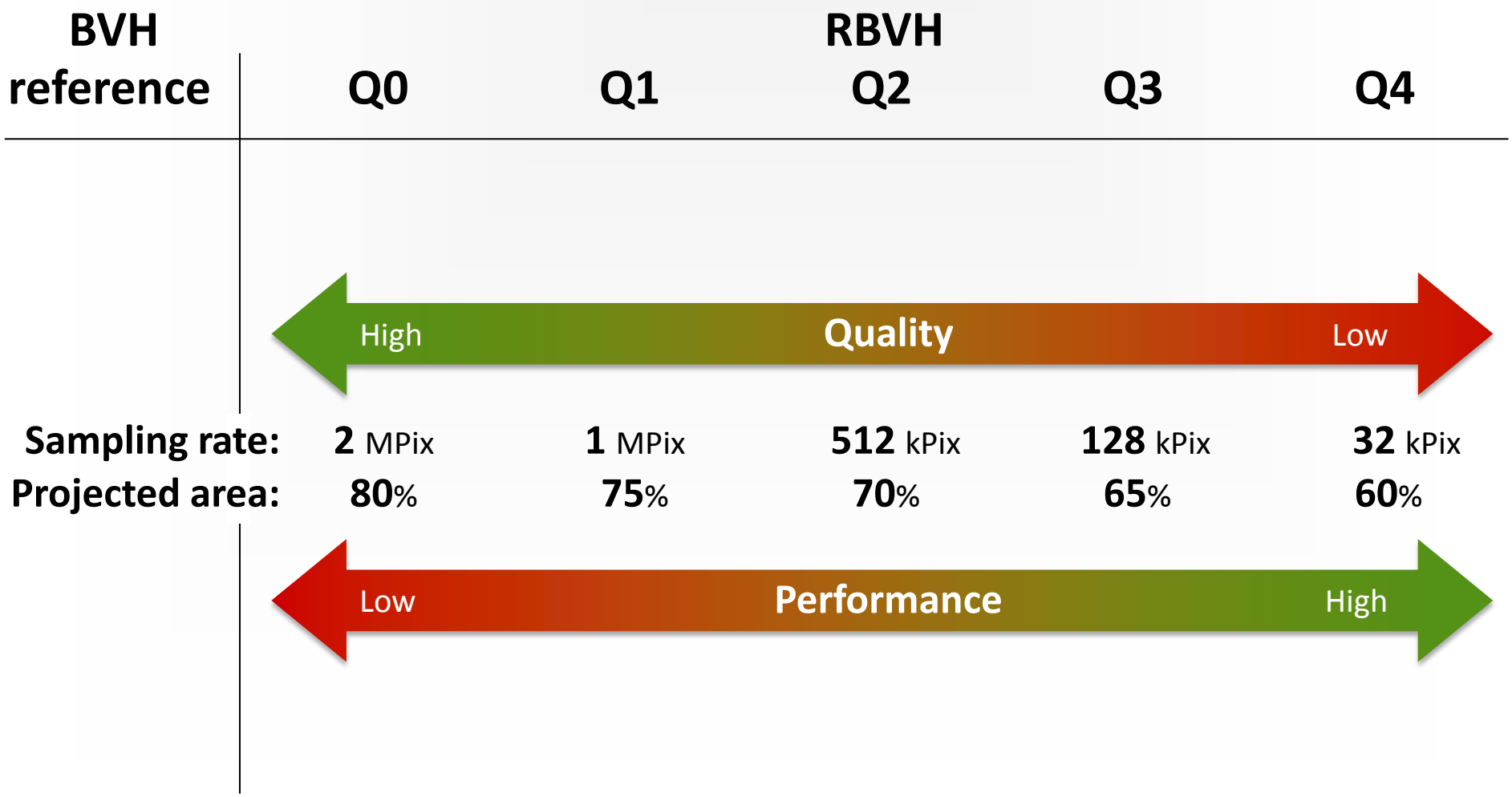
Hybrid RBVH

Not all geometry is well-representable by RBVHs

Crytek Sponza with Asian Dragons (22 million triangles)

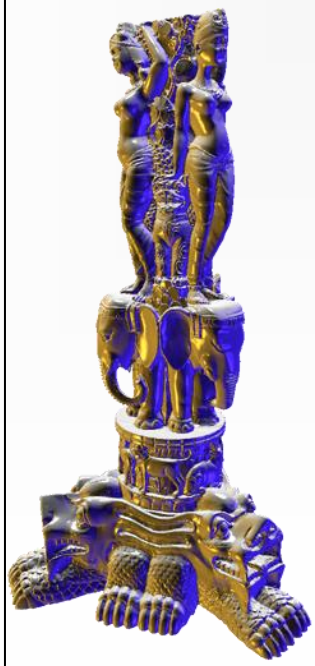
Something Practical: LEVEL OF DETAIL (video)

Evaluation: QUALITY



Evaluation: QUALITY

Reconstruction using ray casting

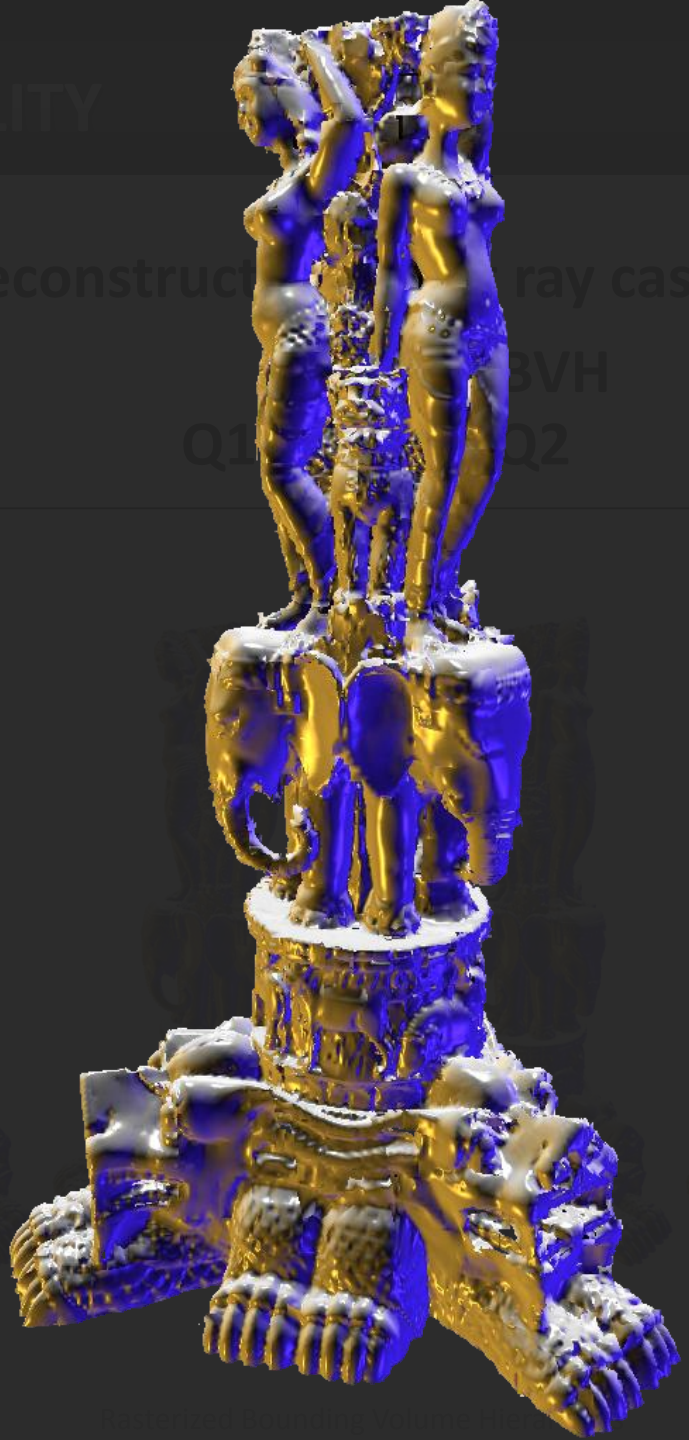
BVH reference	RBVH Q0	Q1	Q2	Q3	Q4
					

Reference

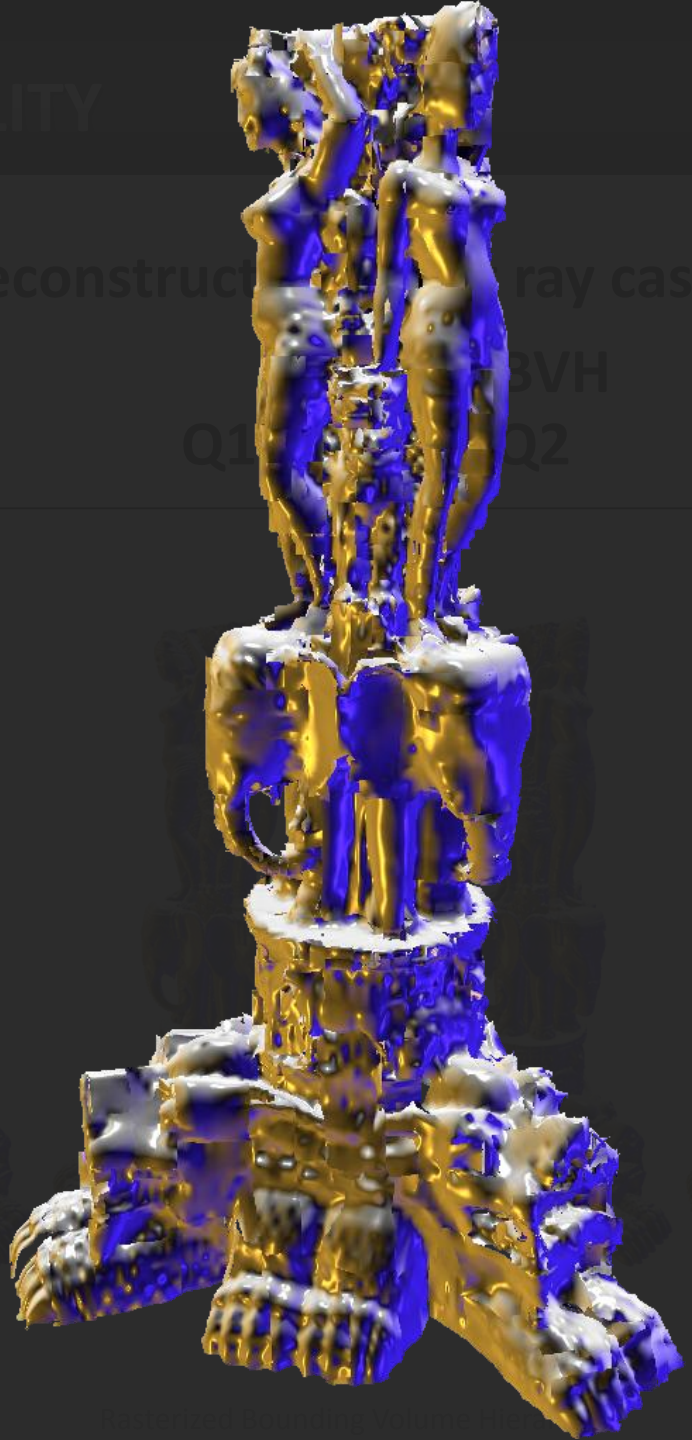
Q0


Q1

Q2



Q3



Q4

Evaluation: QUALITY

Application: Image based lighting

BVH reference	RBVH Q0	RBVH Q1	RBVH Q2	RBVH Q3	RBVH Q4
					

Reference

Reference

Applicat e based nting

BVH reference	Q0	Q1	BVH Q2	Q3	Q4

Q0

Applicat ze based nting

BVH reference	Q0	Q1	BVH Q2	Q3	Q4

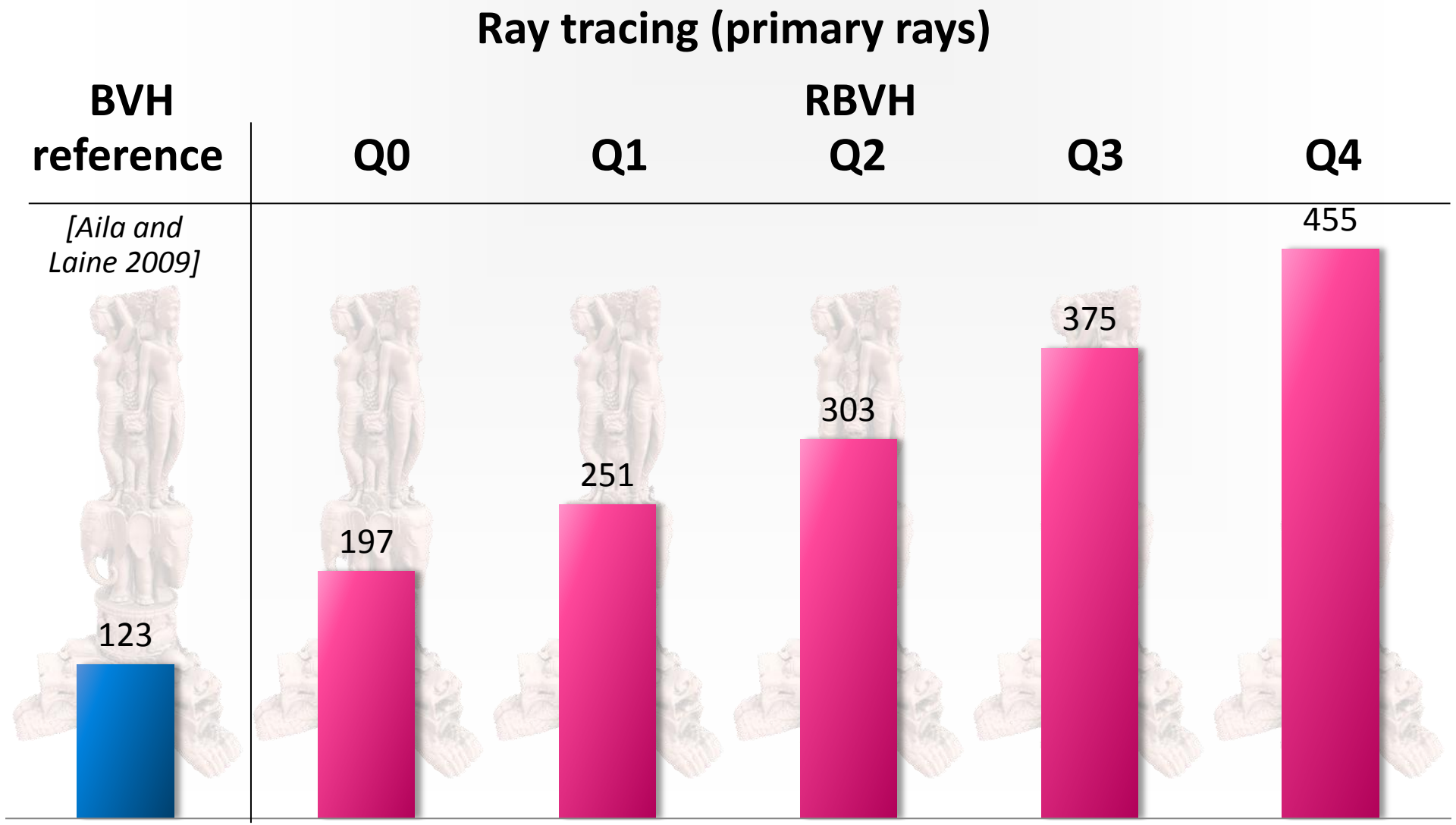
Q1


Q2

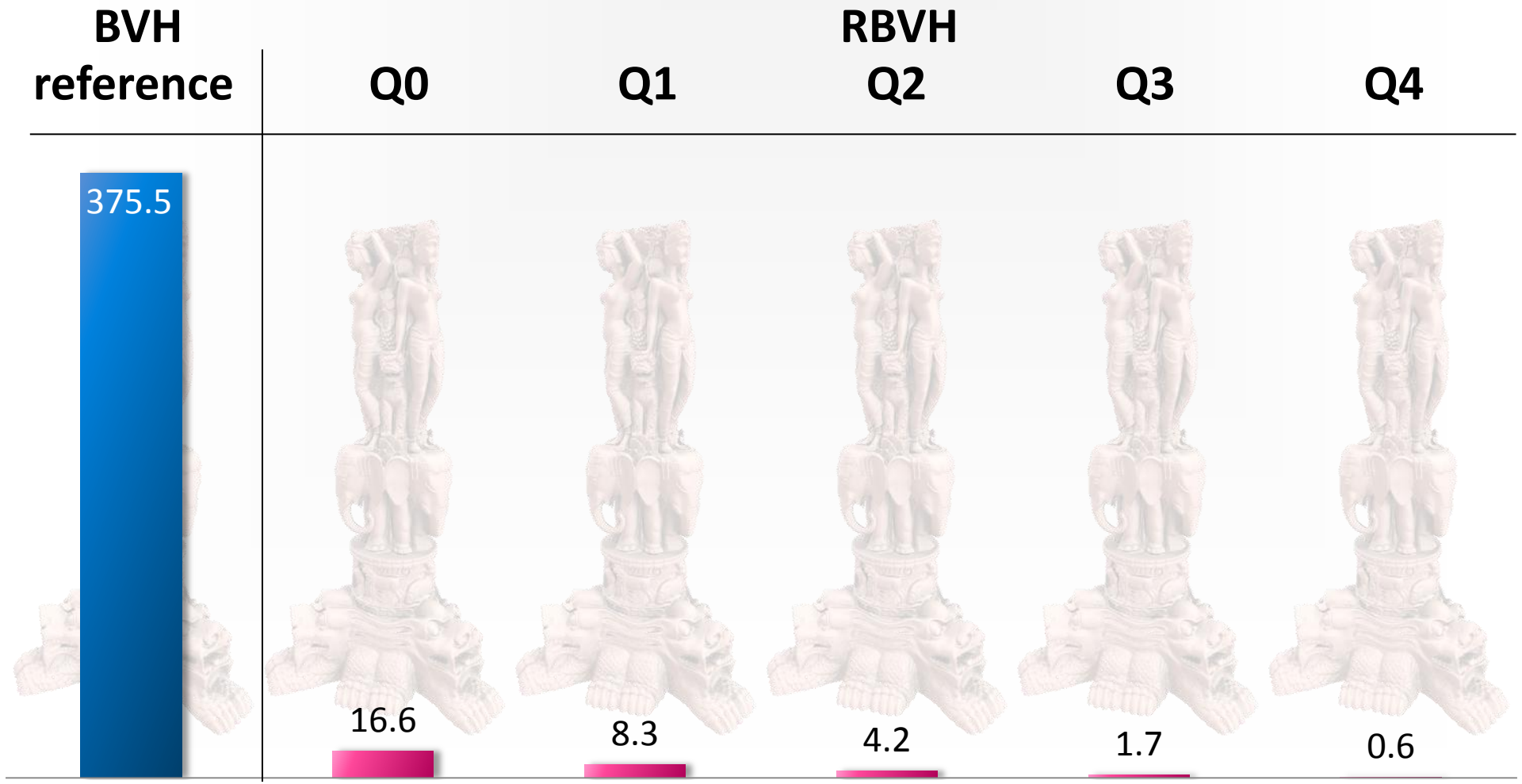

Q3


Q4

Evaluation: PERFORMANCE

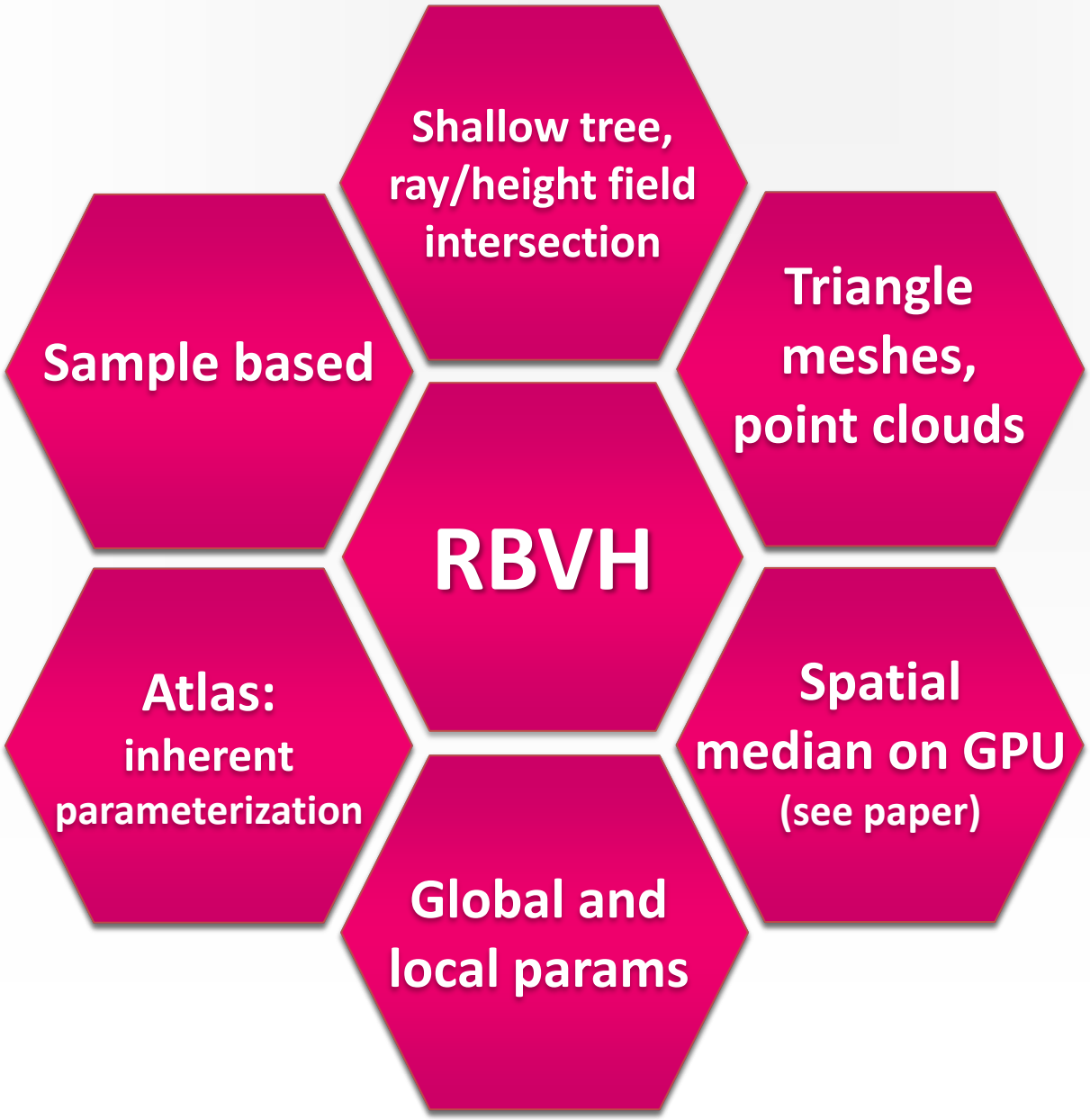


Evaluation: MEMORY REQUIREMENTS

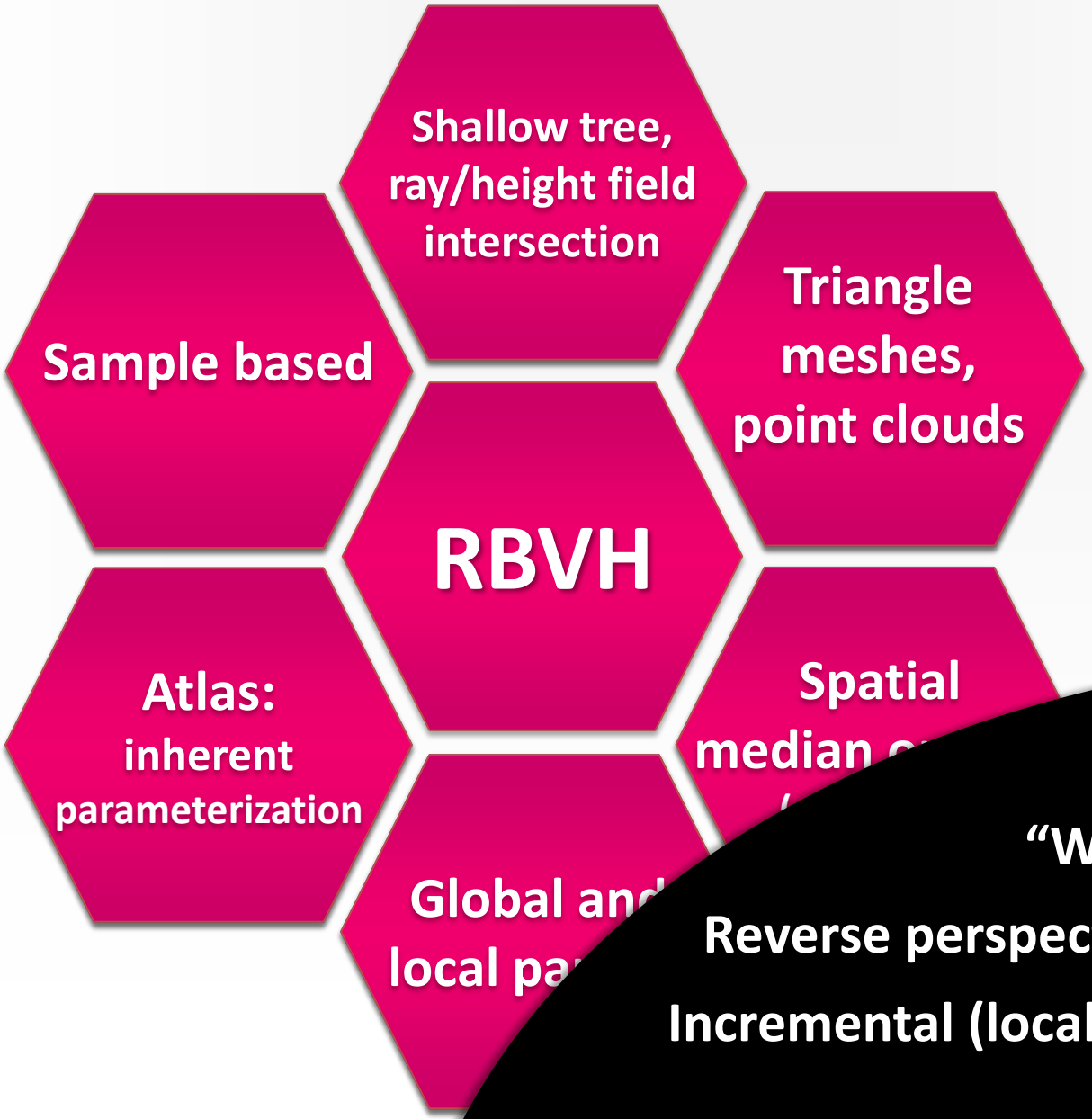


APPLICATIONS (video)

CONCLUSION


Shallow tree, ray/height field intersection
Sample based
Triangle meshes, point clouds
RBVH
Atlas: inherent parameterization
Spatial median on GPU (see paper)
Global and local params

CONCLUSION



…future work:

"Watertightness"

Reverse perspective projection

Incremental (local) maintenance