

# DYNAMIC MANY-LIGHT SAMPLING FOR REAL-TIME RAY TRACING

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**STILL FROM THE BISTRO EXTERIOR  
ANIMATION**

Only direct illumination



—Bistro Exterior—  
Reference @ 4,000 spp

**REFERENCE ANIMATION IN BISTRO EXTERIOR**

# PREVIOUS WORK: OVERVIEW

|                    | APPROXIMATE METHODS | UNBIASED METHODS |
|--------------------|---------------------|------------------|
| Consistent         | X                   | ✓                |
| Area lights        | X                   | ✓                |
| Light leakage-free | X                   | ✓                |
| Cheap              | ✓                   | X                |

# LIGHT IMPORTANCE SAMPLING

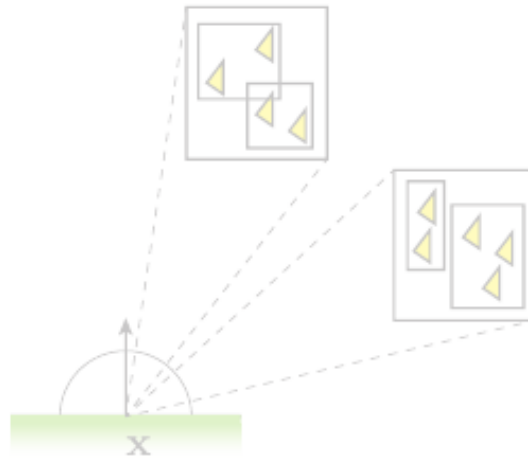
Vévoda2016,  
ContyEstévez2018

Dynamic PDFs per cluster or shading point

Adapts to dynamic scenes

Log scaling with number of light sources, from light hierarchy

Supports mesh, point and analytic lights



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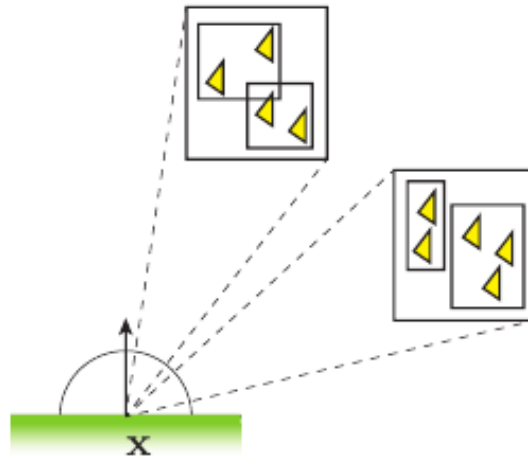
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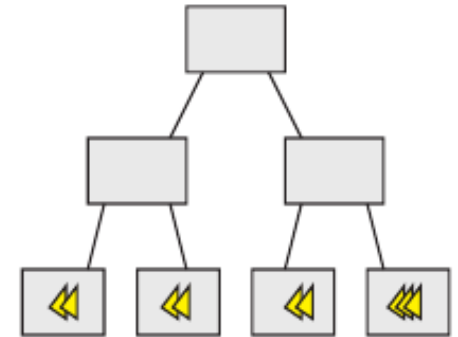
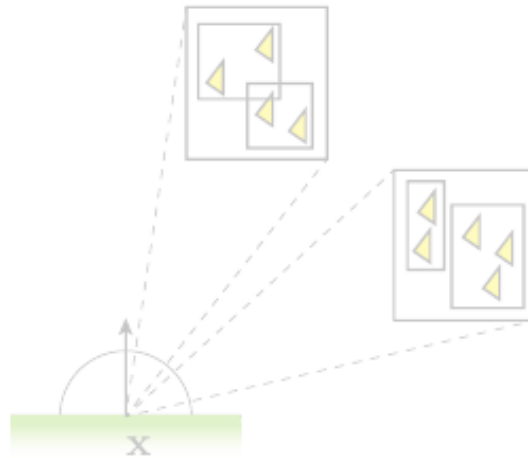
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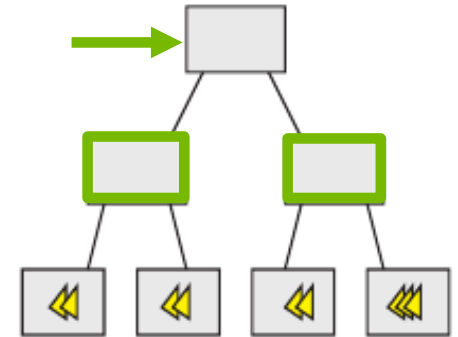
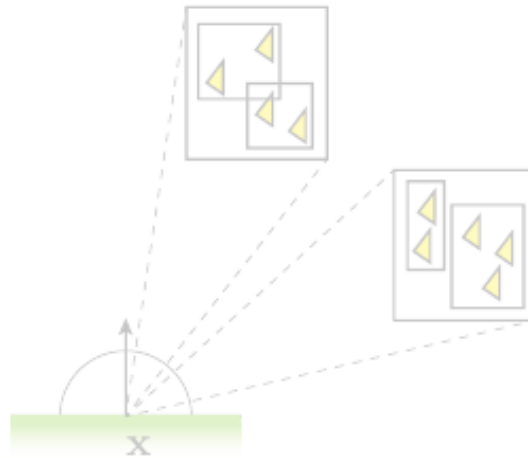
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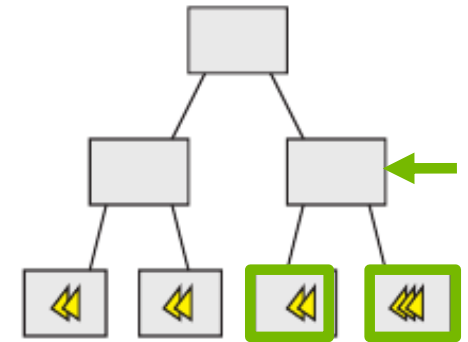
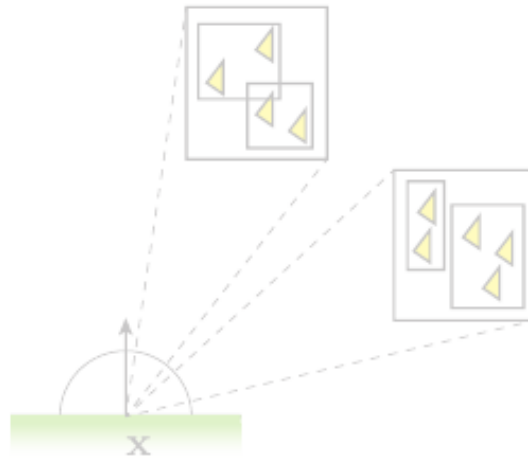
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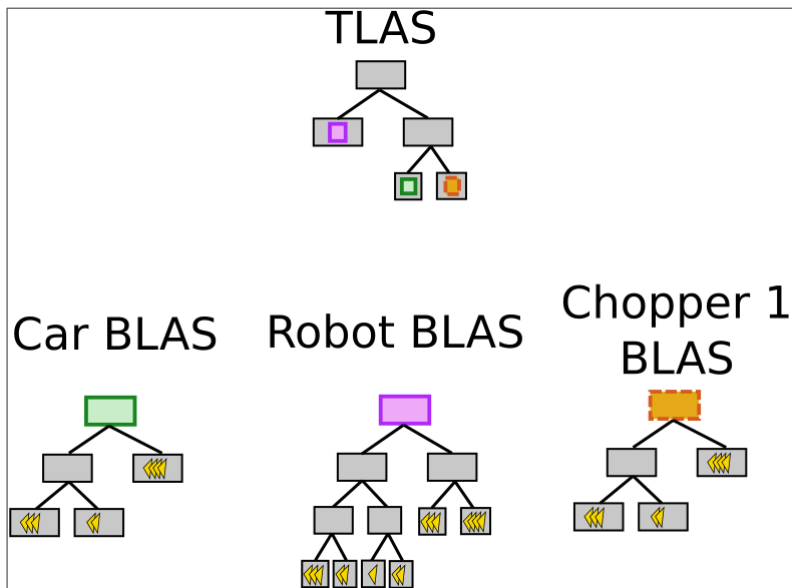
# CONTRIBUTIONS

Organise light sources in multiple BVHs, arranged in a 2-level hierarchy

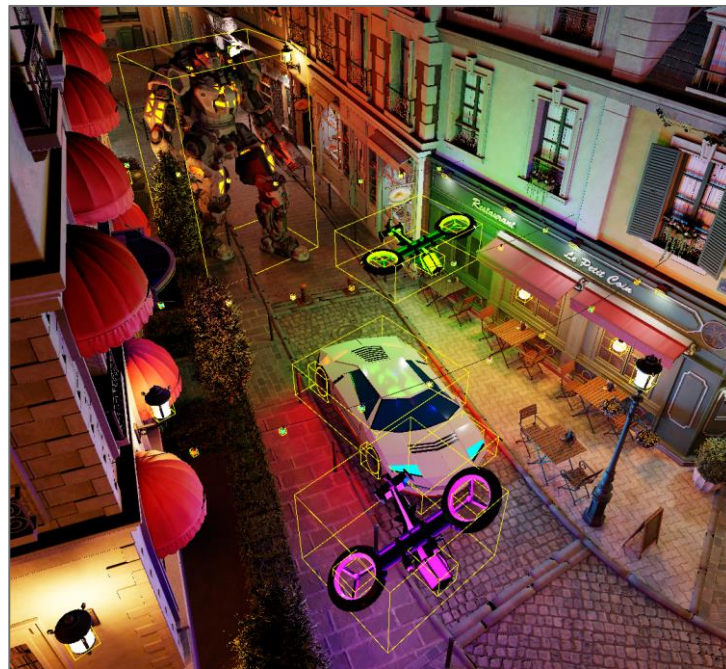
Top-level light BVH: cheap, good for large motions

Refitting light BVHs on GPU: efficient, good for small motion

# 2-LEVEL LIGHT BVH

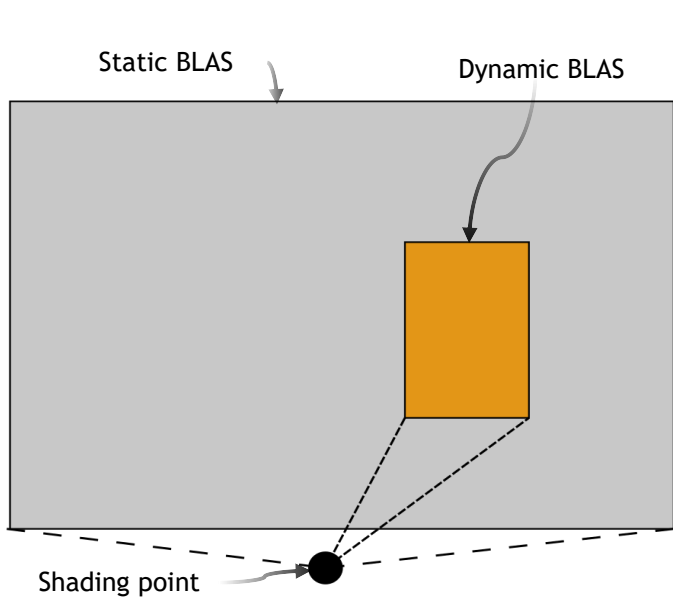


TLAS: top-level acceleration structure  
BLAS: bottom-level acceleration structure

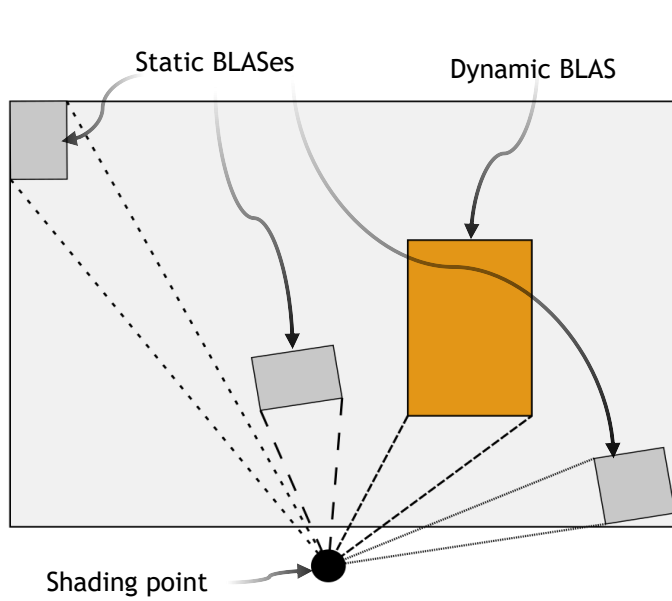


# 2-LEVEL LIGHT BVH

No single BLAS for static emissive meshes



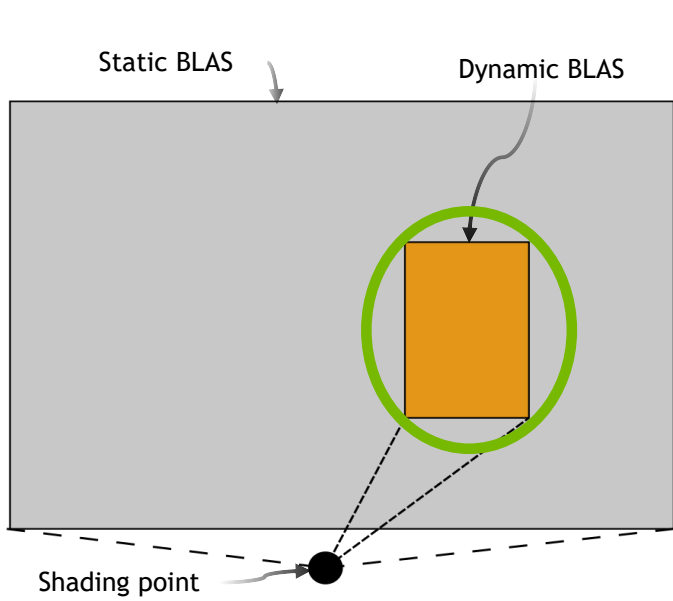
Single BLAS for all static emissive meshes



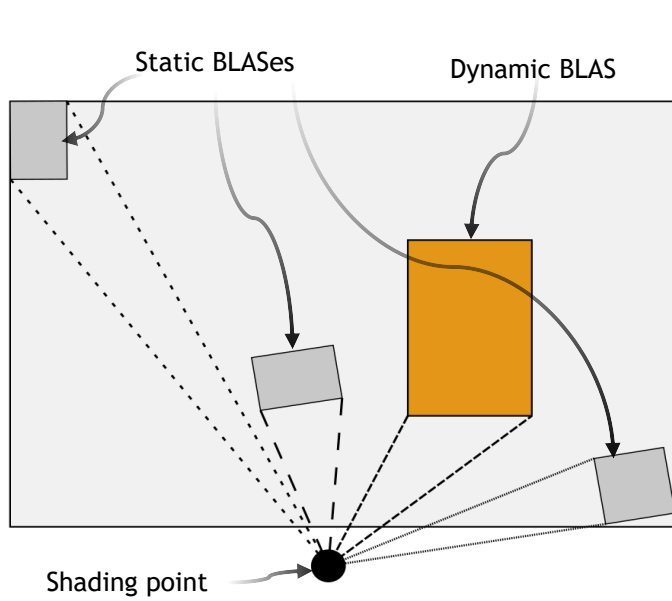
One BLAS per static emissive mesh

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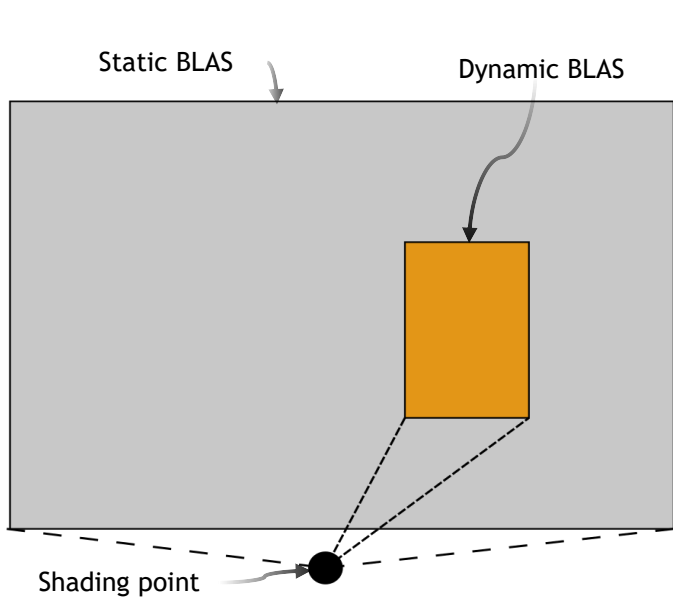


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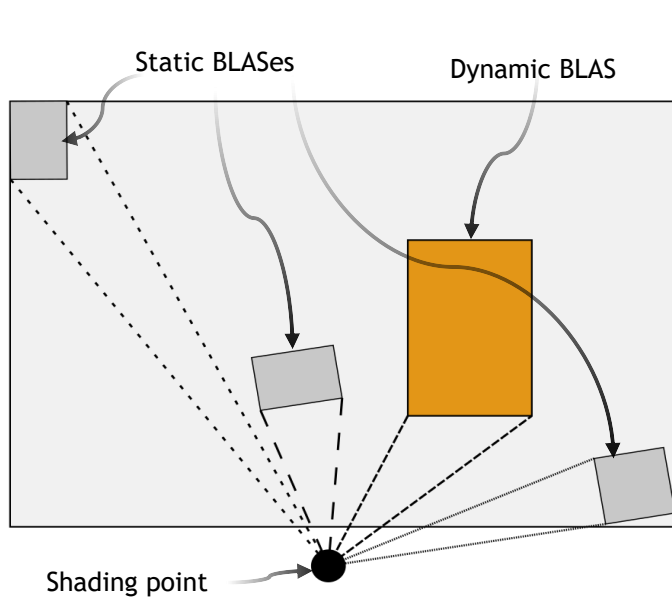


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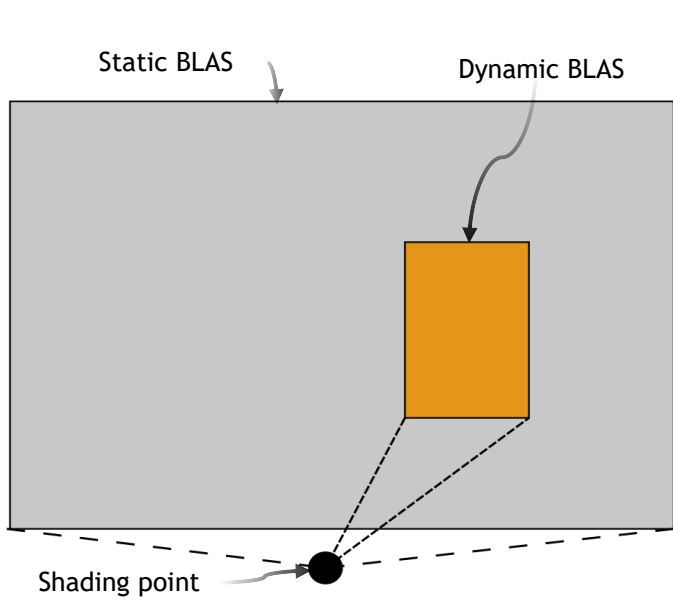
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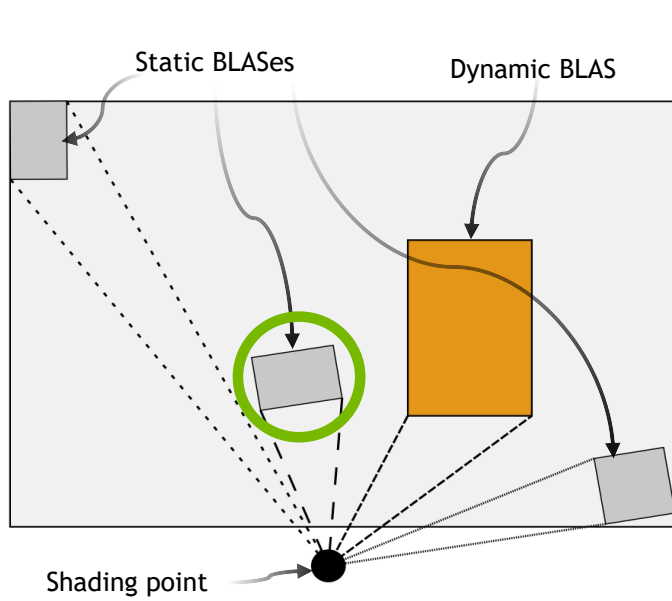
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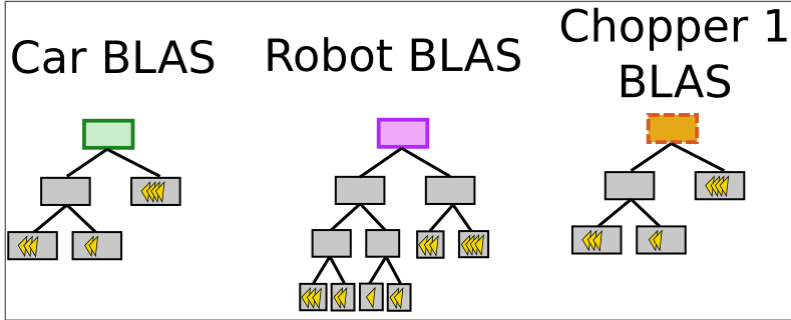


Single BLAS for all static emissive meshes



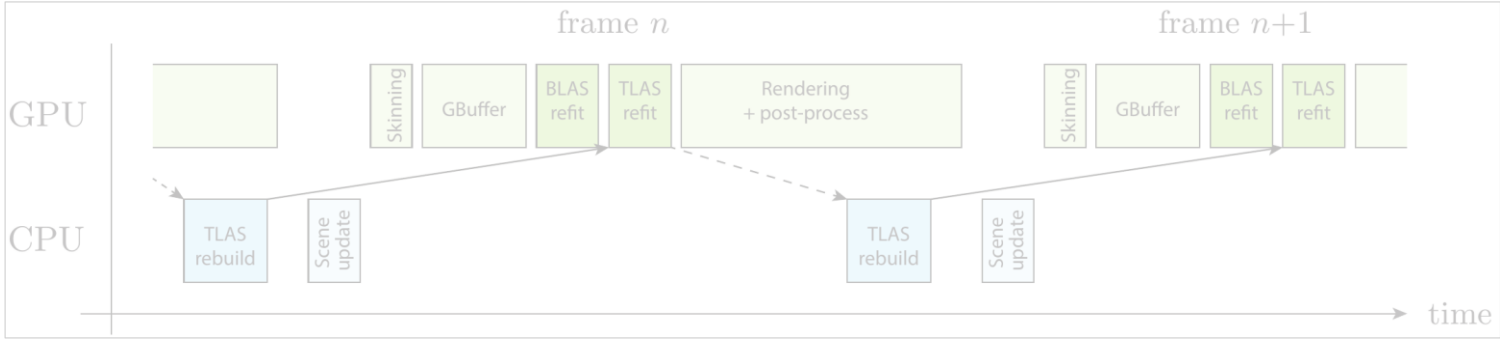
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# 2-LEVEL LIGHT BVH UPDATES

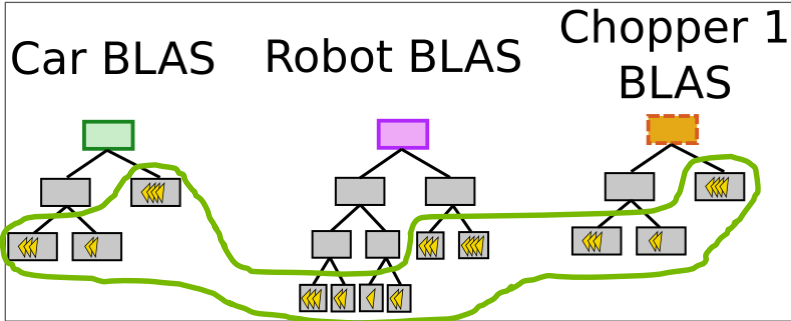


## BLAS REFIT

- 1. Update all leaf nodes
- 2. Update all internal nodes at depth:  $\text{tree\_height} - 1$
- 3. Iteratively update remaining internal nodes, bottom to top

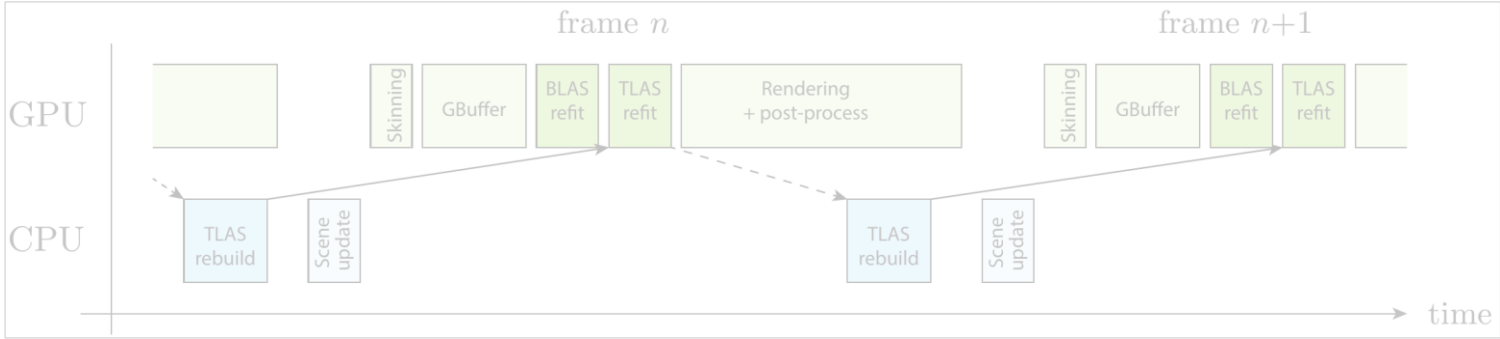


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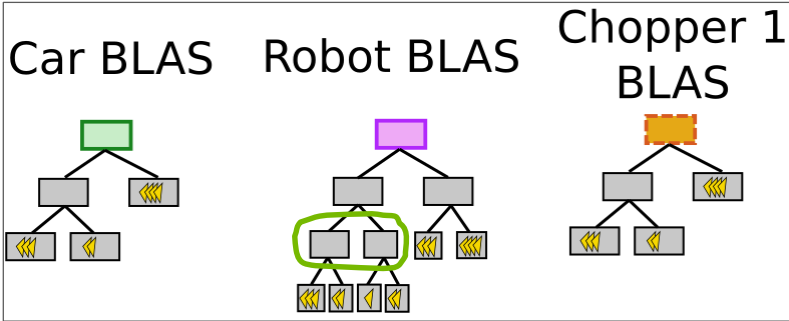


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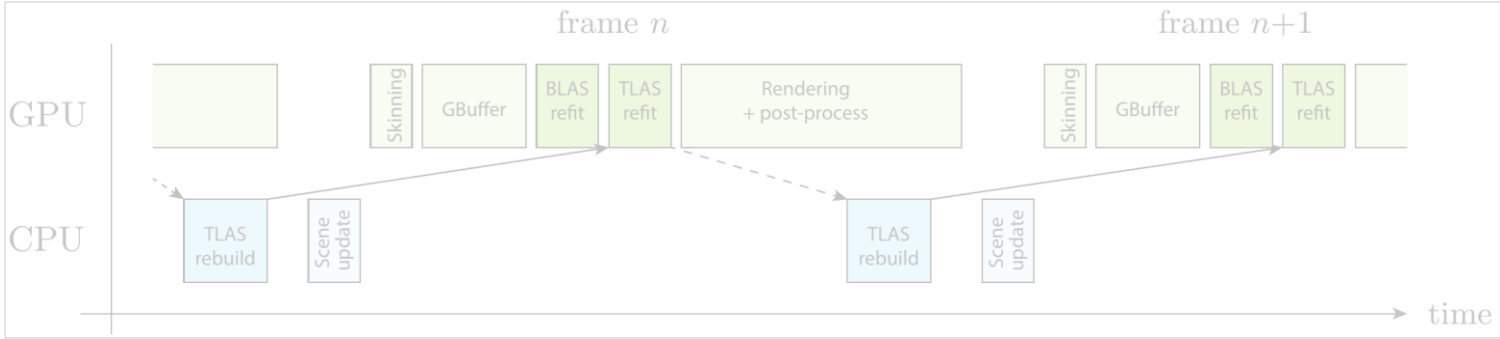


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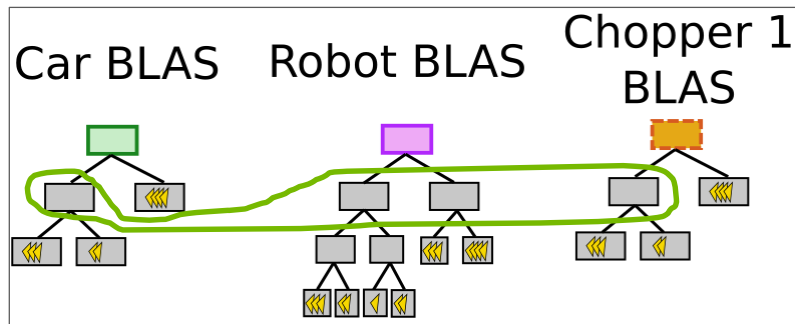
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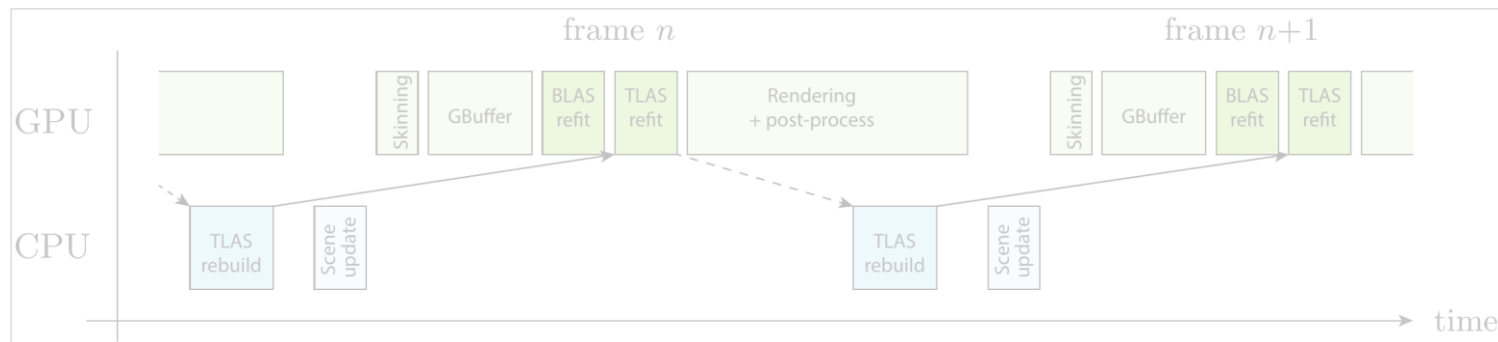


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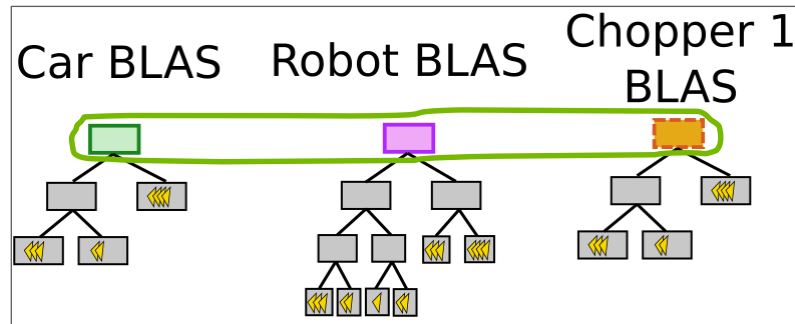


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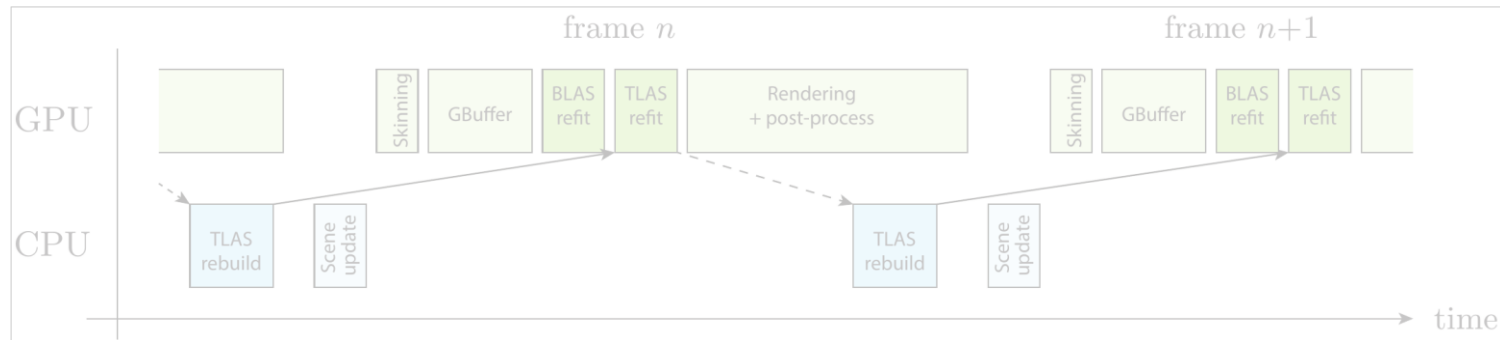


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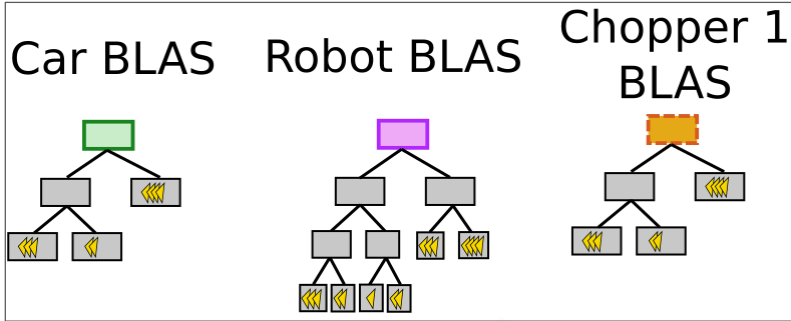


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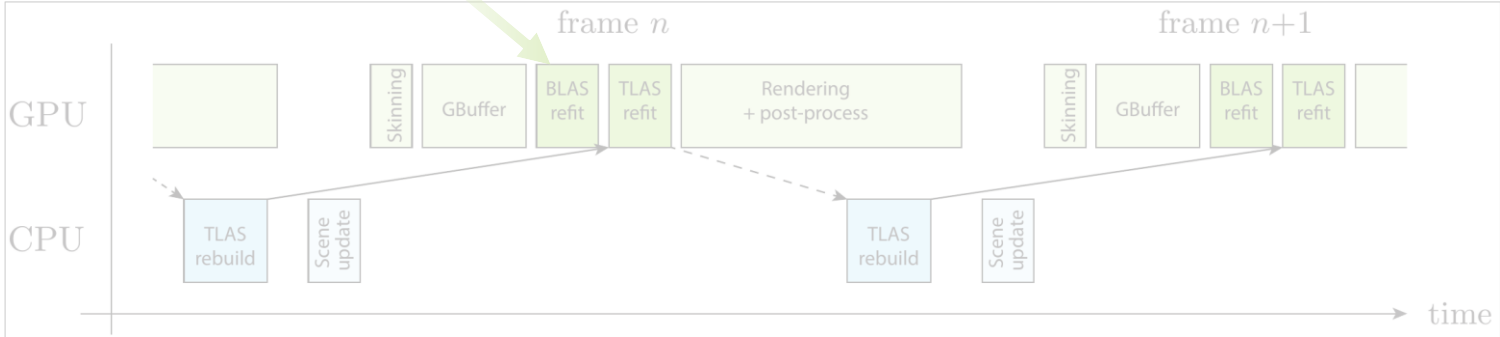


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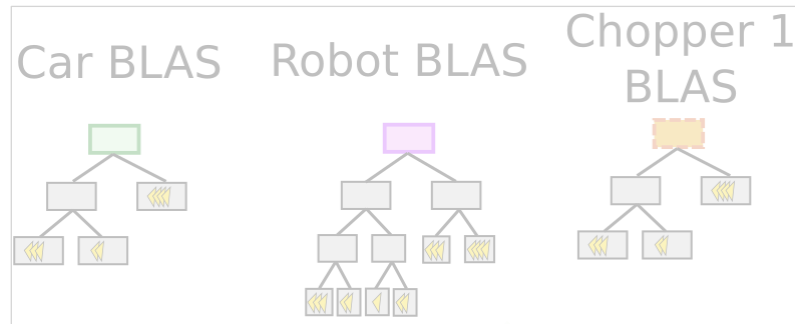


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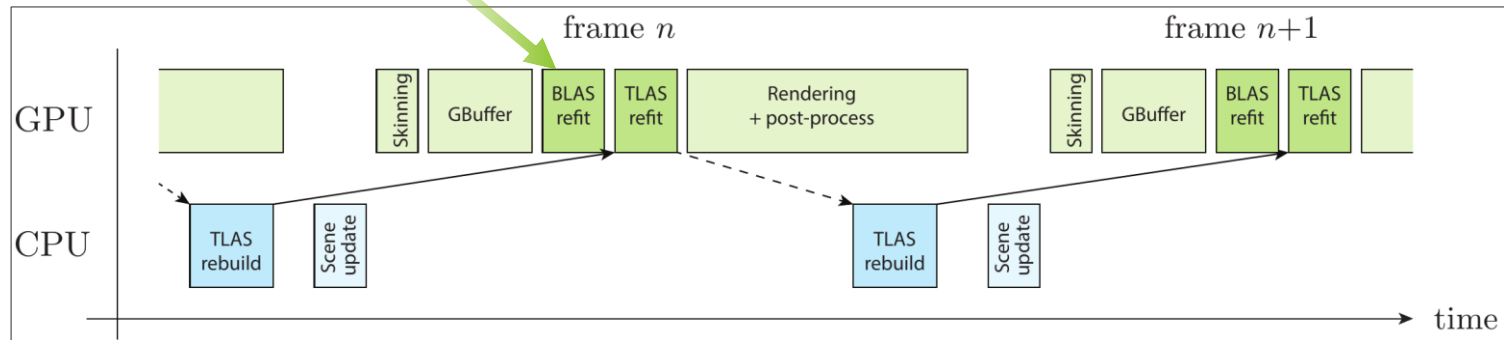


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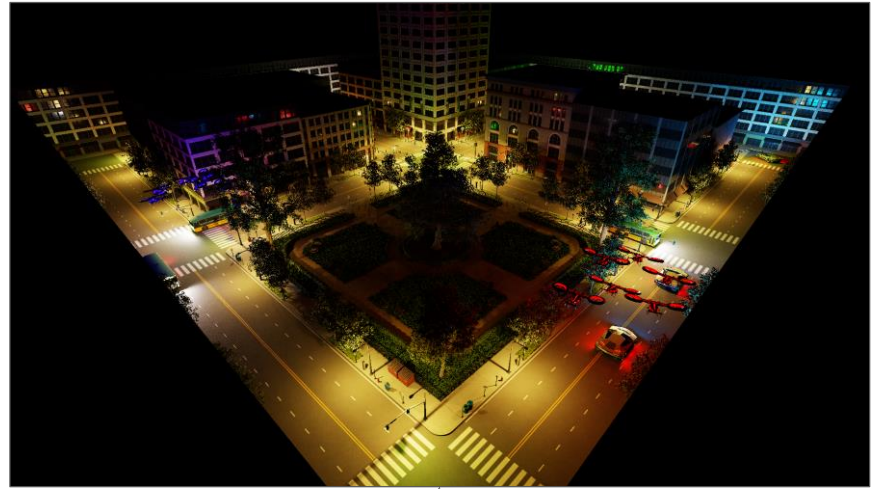
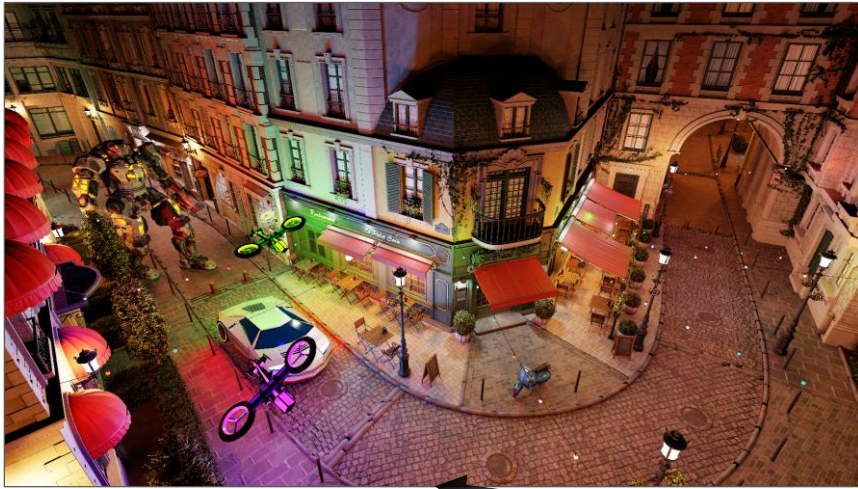
## EACH FRAME

- Refit every BLAS that needs it
- Refit the TLAS before use



# RESULTS

## Scenes information



|                            | BISTRO EXTERIOR | EMERALD SQUARE |
|----------------------------|-----------------|----------------|
| Static emissive triangles  | 20k             | 19k            |
| Dynamic emissive triangles | 6k              | 66k            |
| Total triangles            | 3m              | 10m            |

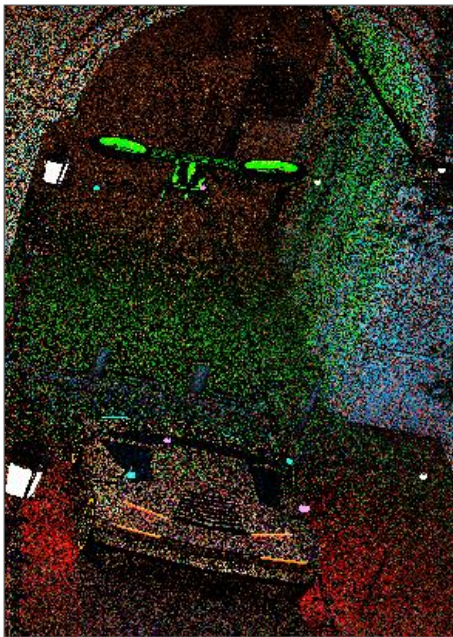


# N-LEVEL BVH COMPARISON

Sampling results after large amount of light movement



1-level BVH, 4 spp  
Refitted every frame



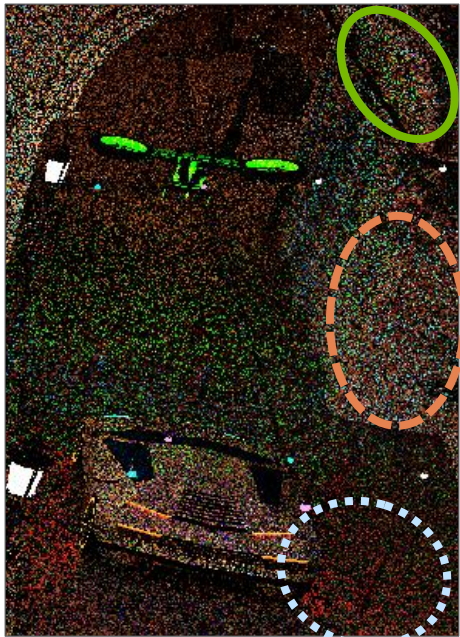
2-level BVH, 4 spp  
Every frame, TLAS rebuilt and BLASes refitted



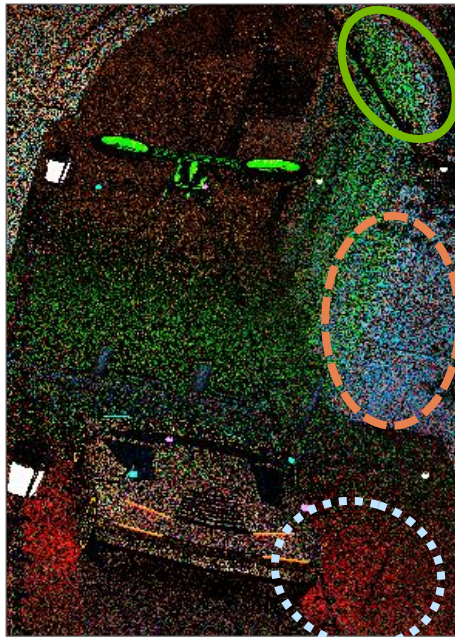
Reference

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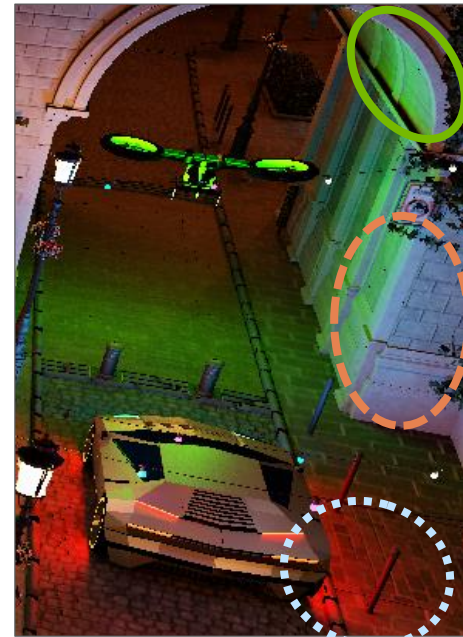
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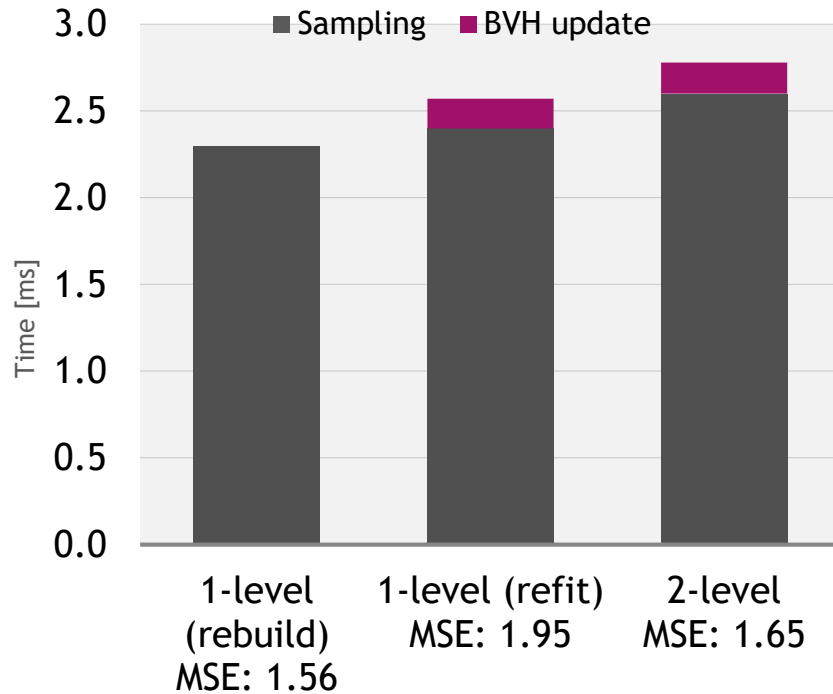
2-level BVH, 4 spp  
Every frame, TLAS rebuilt and BLASes refitted



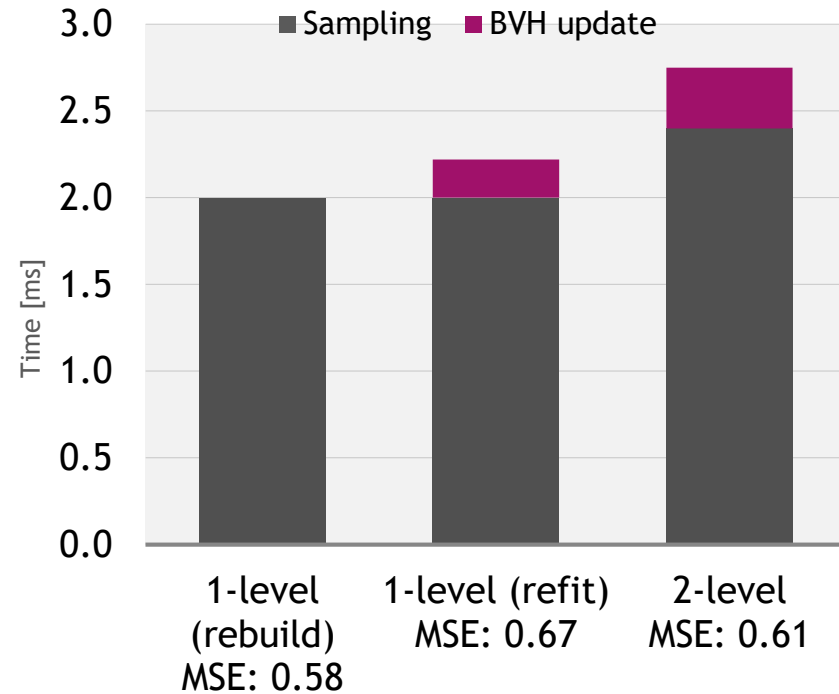
Reference

# QUALITY AND PERFORMANCE RESULTS

## Bistro Exterior



## Emerald Square





# FILTERED RESULTS

## Comparison with Uniform Sampling



Uniform sampling  
1 spp



Uniform with SVGF  
1 spp, 5 accum. frames



2-level BVH  
1 spp



2-level with SVGF  
1 spp, 5 accum. frames



Reference

# SUMMARY

## CONTRIBUTIONS

Light sources: multiple BVHs, 2-level hierarchy

Refitting light BVHs: efficient, small motions

Top-level light BVH: cheap, large motions

## FUTURE WORK

Detect: rebuild >>> refit

Use light visibility information

Reuse previous frame(s) light samples

## TAKE-AWAY

Light BVH benefits from geometry BVH improvements

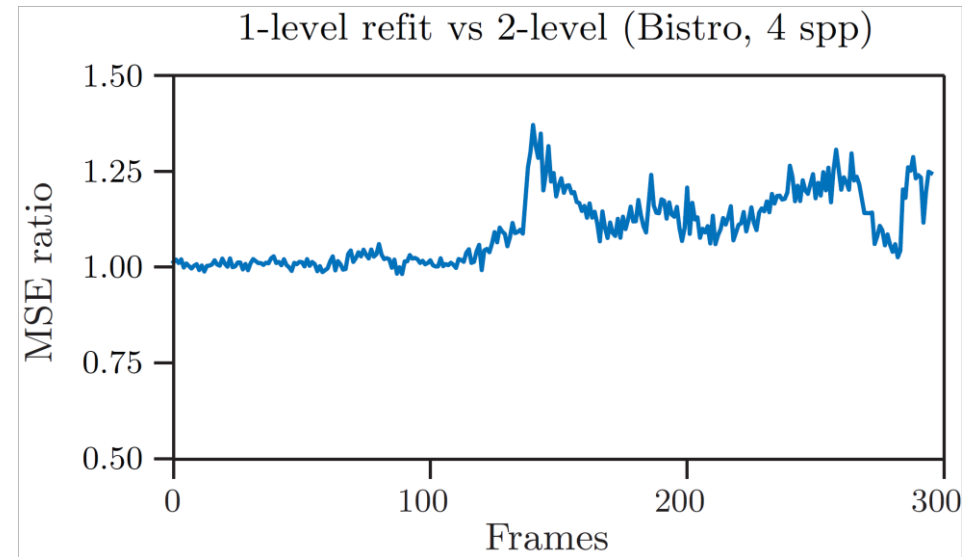
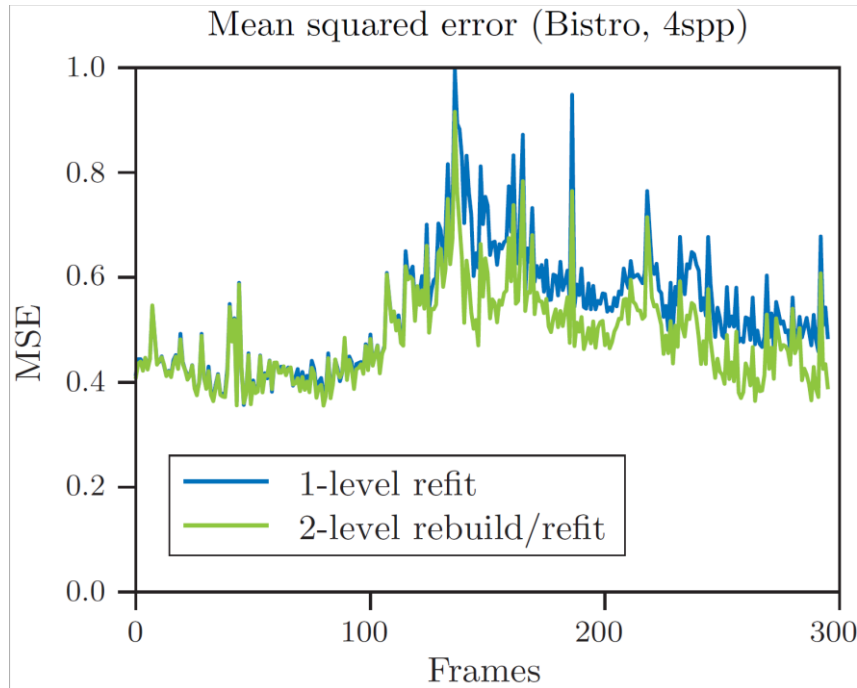
2-level light BVH: quality of 1-level rebuild & speed of 1-level refit

Source code will be part of Falcor 4.0, to be released around October 2019

<https://github.com/NVIDIAGameWorks/Falcor>



# N-LEVEL BVH COMPARISON OVER TIME



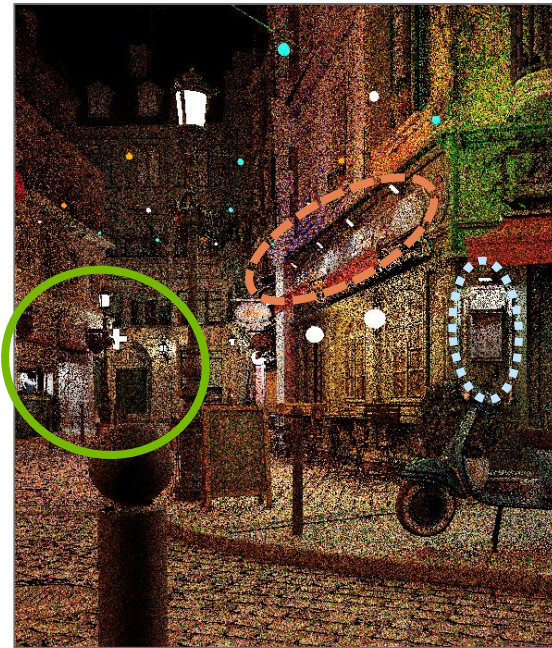


# RESULTS

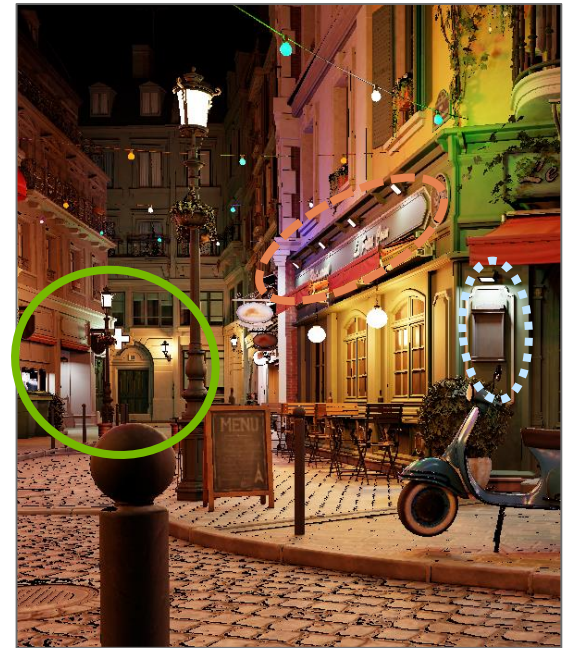
Uniform vs 1-level (rebuilt) at equal time



Uniform: 20 spp, 39.7 ms



DFBO: 6 spp, 41.8 ms



Reference



# RESULTS IN BISTRO EXTERIOR

|                          | UNIFORM | ONE-LEVEL<br>(REBUILD) | ONE-LEVEL<br>(REFIT) | TWO-LEVEL<br>(REBUILD/REFIT) |
|--------------------------|---------|------------------------|----------------------|------------------------------|
| BVH update<br>time (ms)  | 0       | ~90                    | 0.17                 | 0.85/0.18                    |
| Sampling time<br>(ms)    | 0.34    | 2.3                    | 2.4                  | 2.6                          |
| Total time (ms)          | 6.2     | 101                    | 10.8                 | 12.0                         |
| MSE                      | 16.5    | 1.56                   | 1.95                 | 1.65                         |
| MC efficiency $\epsilon$ | 0.0097  | 0.0064                 | 0.048                | 0.050                        |
| E w.r.t.<br>uniform      | 1x      | 0.66x                  | 4.9x                 | 5.2x                         |

# RESULTS IN EMERALD SQUARE

|                          | UNIFORM | ONE-LEVEL<br>(REBUILD) | ONE-LEVEL<br>(REFIT) | TWO-LEVEL<br>(REBUILD/REFIT) |
|--------------------------|---------|------------------------|----------------------|------------------------------|
| BVH update<br>time (ms)  | 0       | ~300                   | 0.22                 | 0.89/0.35                    |
| Sampling time<br>(ms)    | 0.32    | 2.0                    | 2.0                  | 2.2                          |
| Total time (ms)          | 7.7     | 311                    | 11.3                 | 12.6                         |
| MSE                      | 20      | 0.58                   | 0.67                 | 0.61                         |
| MC efficiency $\epsilon$ | 0.0065  | 0.0055                 | 0.132                | 0.130                        |
| E w.r.t.<br>uniform      | 1x      | 0.85x                  | 20.3x                | 20.1x                        |

# FILTERED RESULTS

In motion closeup

