Radiance Caching with On-Surface Caches for Real-Time Global Illumination

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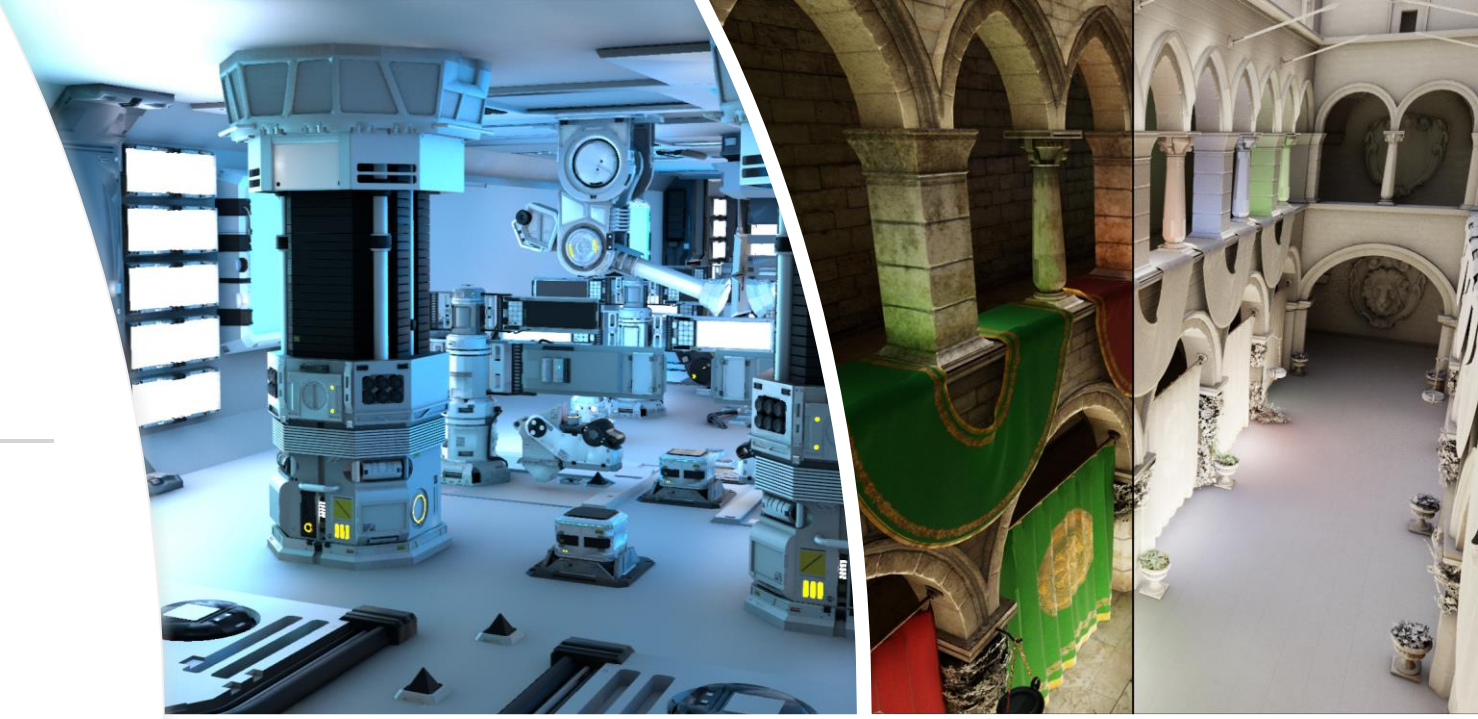
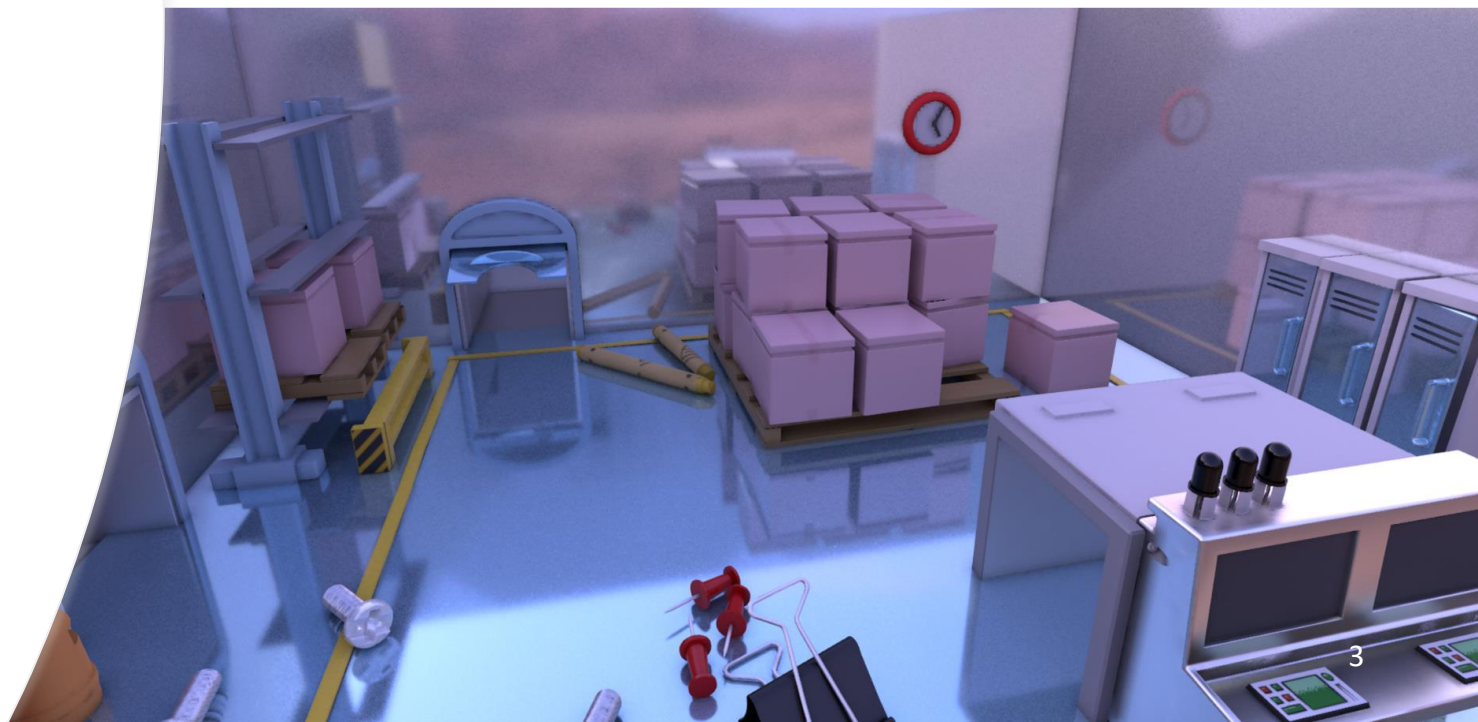
Flying World

Motivation and Goals

- Real-time global illumination
- Diffuse and (glossy) reflections
- Multiple Bounces
- Efficient multi-viewer rendering by sharing caches between viewers



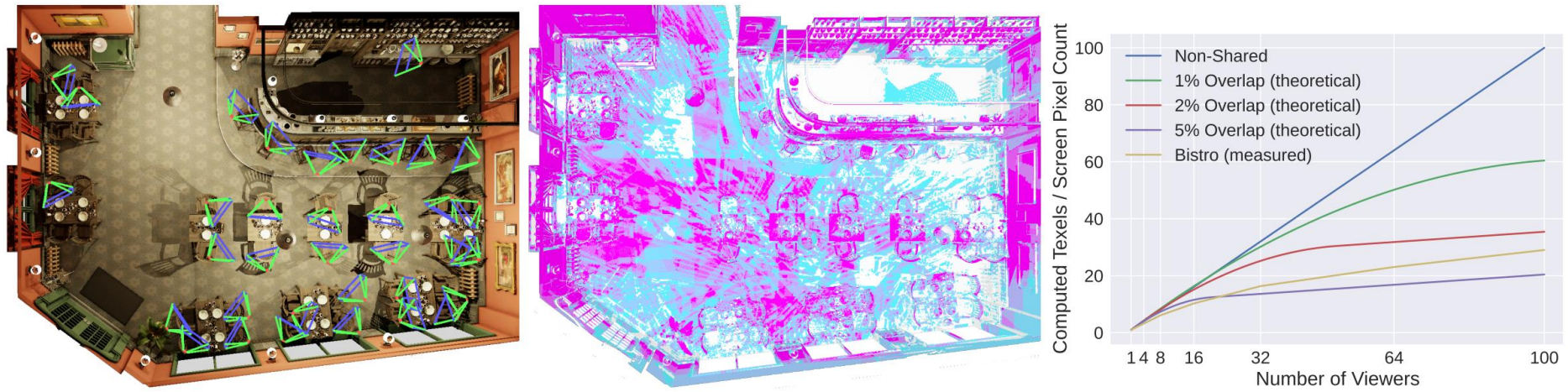


Related Work

- Irradiance Probes [Majercik et al. 2019]
- Screen Space Denoising [Schied et al. 2017]
- Screen Space Radiance Caching
  - Unreal Engine Lumen [Wright et al. 2021]
  - AMD GI1.0/G1.1 [Boissé et al. 2022, Eto et al. 2023]
  - Screen space probes combined with world space caching structure

On-Surface Caches

- Share computations between multiple viewers
  - Triangles shaded multiple times
  - Redundant computations
- Texel shading approach



"Effect-based Multi-viewer Caching for Cloud-native Rendering" [Weinrauch & Tatzgern et al. 2023]

On-Surface Caches

- Scene split into *Islands*
  - Small group of connected triangles
  - Constrained by face normal and triangle count
- Island mapped to continuous region in memory
  - Neighboring texels can be accessed
  - No access to neighboring islands
- Adjustable cache resolutions with mip biases

Island Visualization

On-Surface Caches

- Store Irradiance in On-Surface Caches [Weinrauch & Tatzgern et al. 2023]

Global Illumination from "Effect-based Multi-viewer Caching for Cloud-native Rendering" [Weinrauch & Tatzgern et al. 2023]

On-Surface Caches

- Store Irradiance in On-Surface Caches [Weinrauch & Tatzgern et al. 2023]
  - Surface details are lost
  - Diffuse only

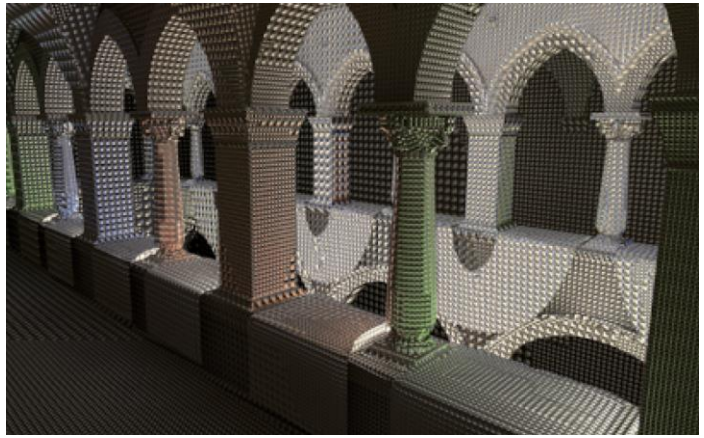
Mip Bias = 0.0 Mip Bias = 2.0 Indirect Illumination Mip Bias = 0.0 Mip Bias = 2.0

Global Illumination from "Effect-based Multi-viewer Caching for Cloud-native Rendering" [Weinrauch & Tatzgern et al. 2023]

Radiance Caching with On-Surface-Caches

- Unified radiance caching system in texture space
  - Radiance is cached on primary and secondary hits
  - Both store radiance hemisphere
- Primary caches store incoming radiance
  - Preserves surface detail
- Secondary caches store outgoing radiance
  - Secondary caches span ~30cm × 30cm
    - Quantizes secondary caches to allow for more reuse
  - Provide radiance for every direction

    ➔multiple viewers, reflections, ..

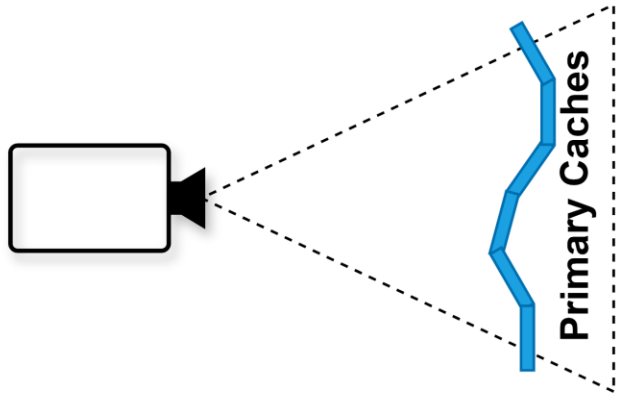


Primary Radiance Caches

Secondary Radiance Caches

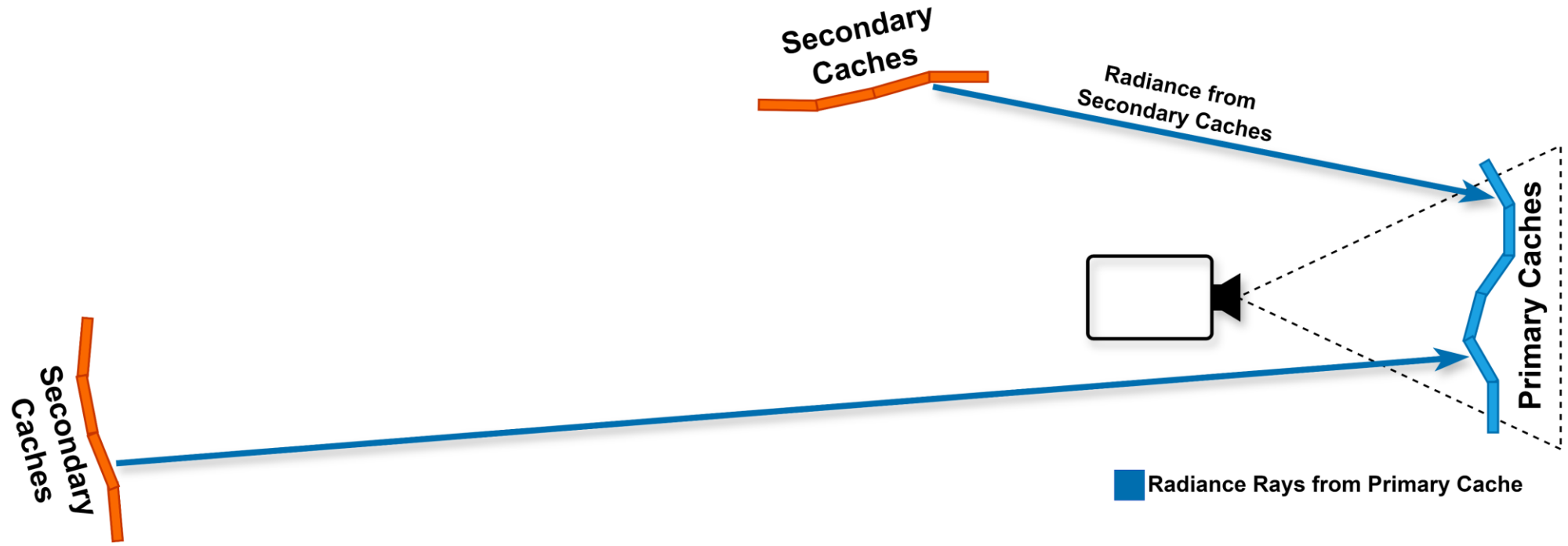
Cache Interactions

Primary caches are allocated from Visibility Buffer



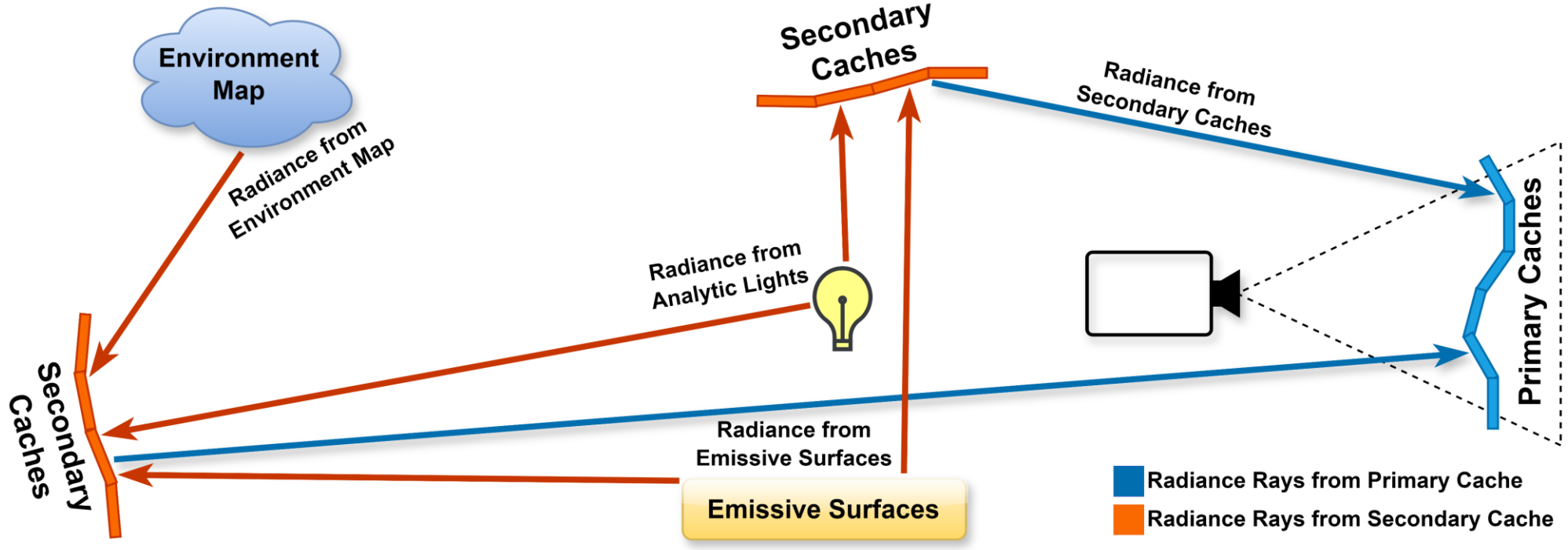
Cache Interactions

Secondary caches are allocated from Primary cache rays



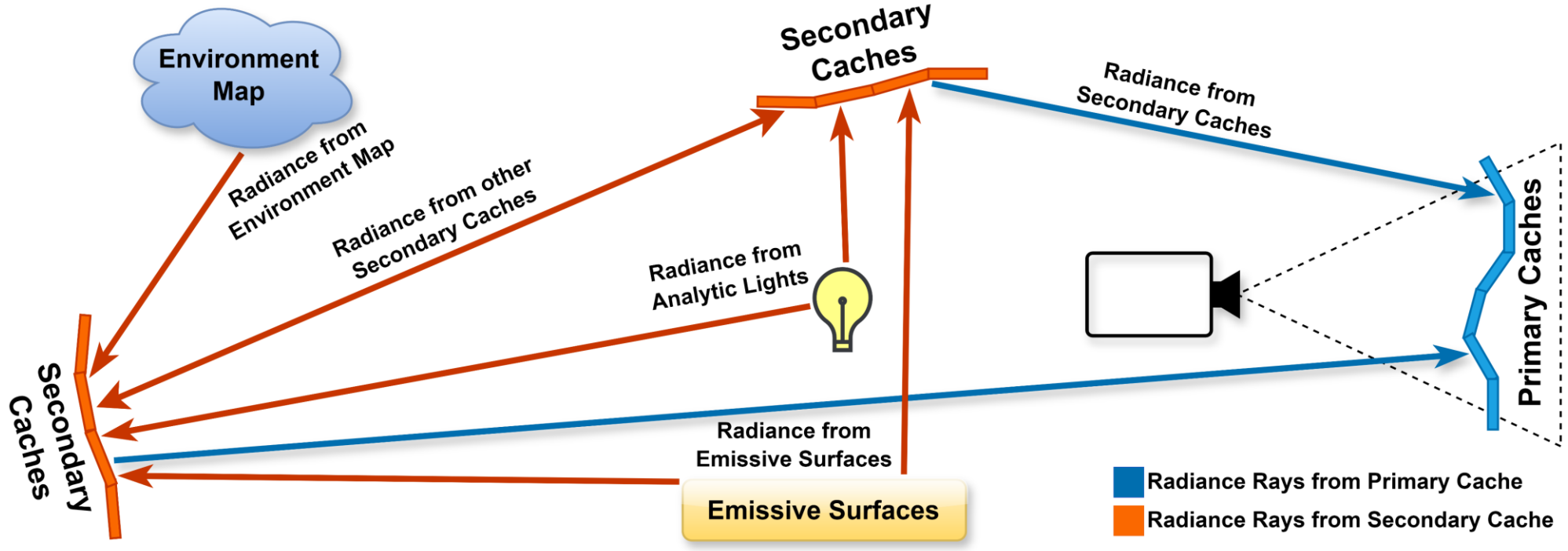
Cache Interactions

Secondary caches sample direct light sources and store outgoing radiance (ReSTIR [Bitterli et al.])



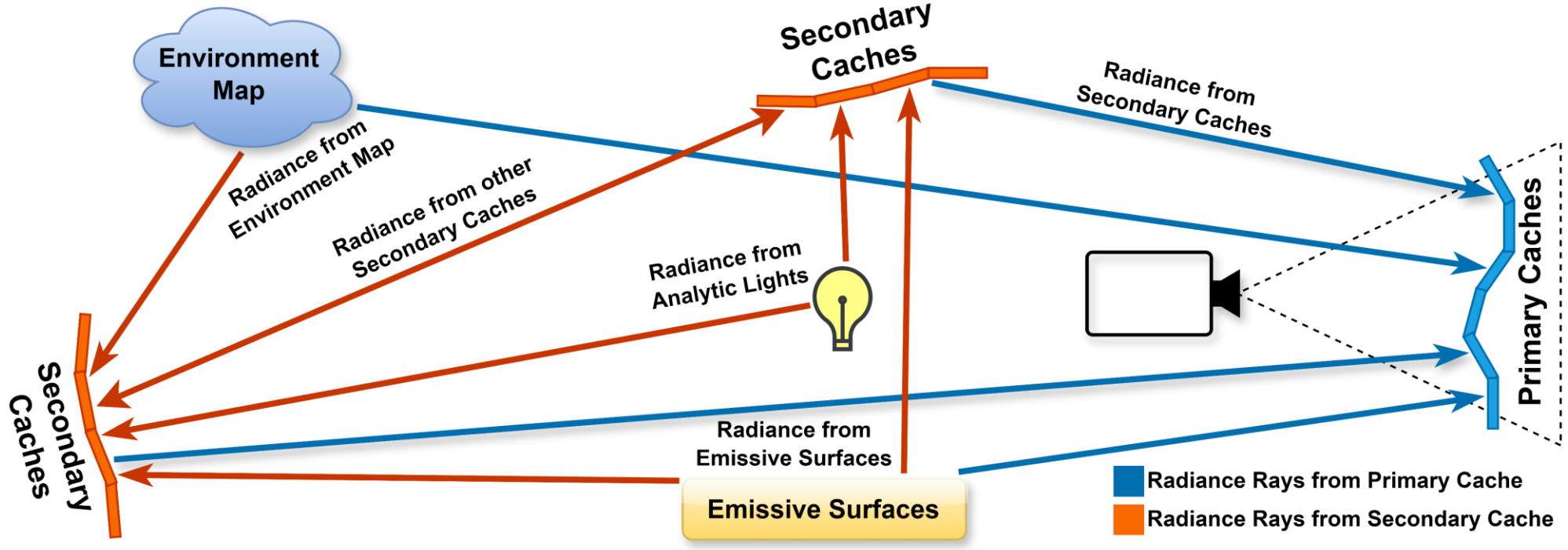
Cache Interactions

Secondary caches sample each other ➔ multiple bounces over time

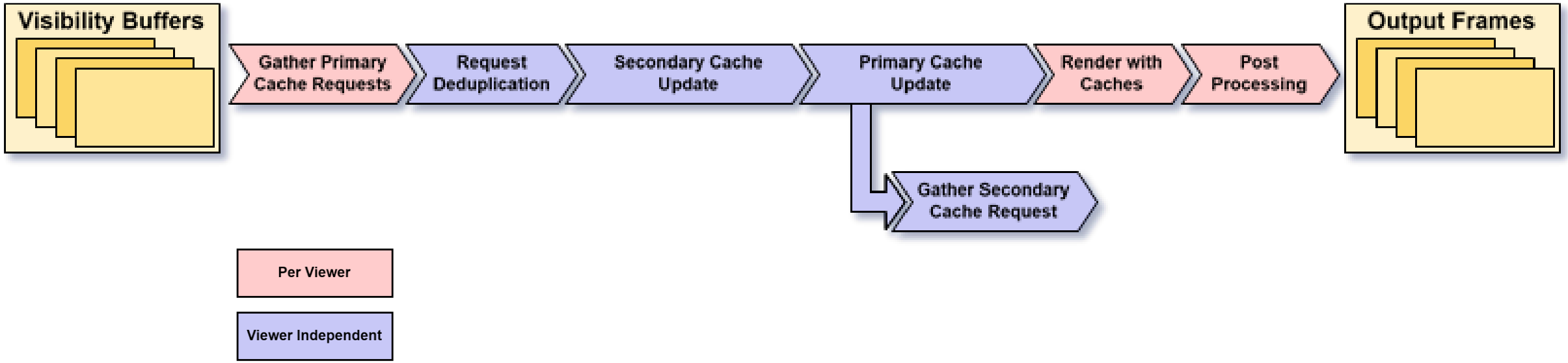


Cache Interactions

Primary cache rays hitting environment map or emissive surface



Rendering Pipeline



Lower Cache Resolution

- Radiance caches for every visible pixel is not feasible
  - Excessive needs for compute and memory

Lower Cache Resolution

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➔ Use mip bias to lower cache resolution

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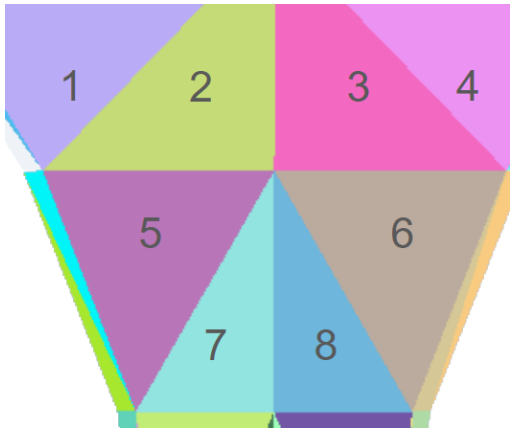
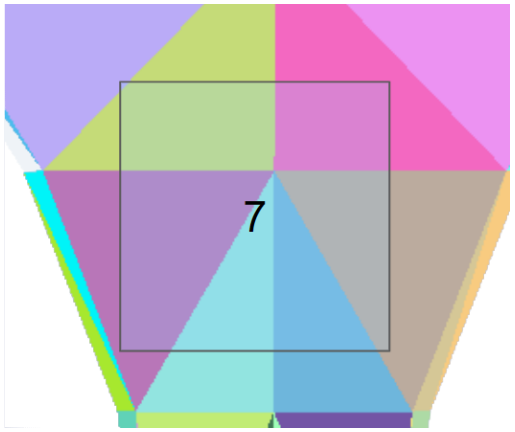
Triangle IDs

- Artifacts arise from bad ray starting positions
  - e.g., inside geometry, triangle is bad representative
- Triangle Id resolution not high enough ➔ bad triangle for the cache



Triangle Ids



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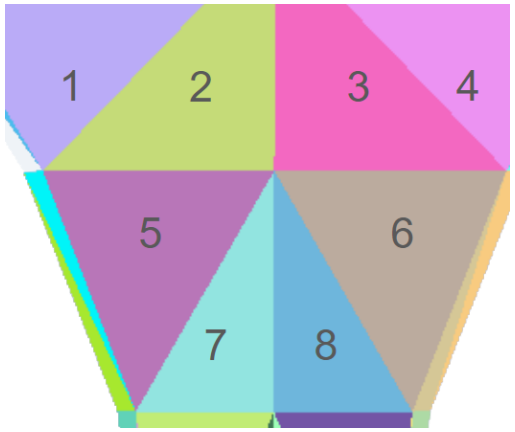

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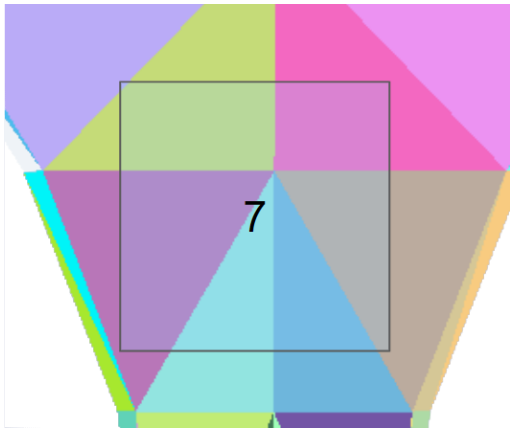
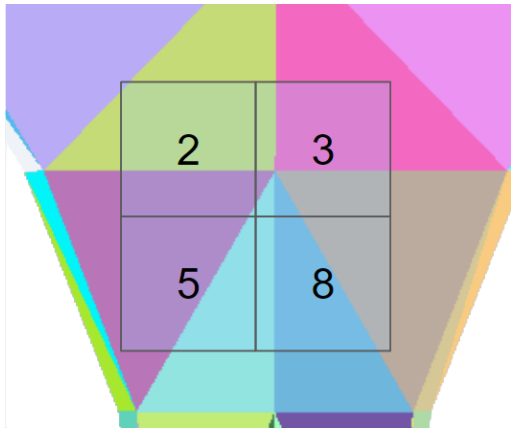
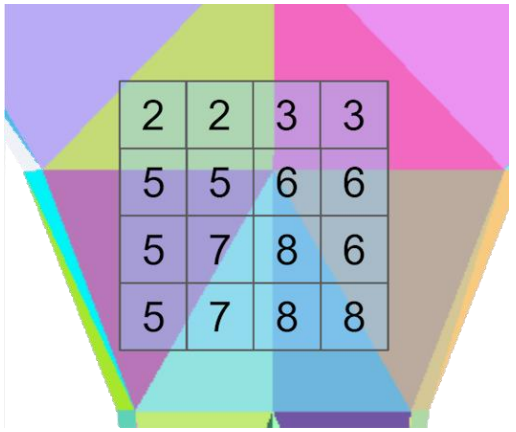


Cache Triangle Id

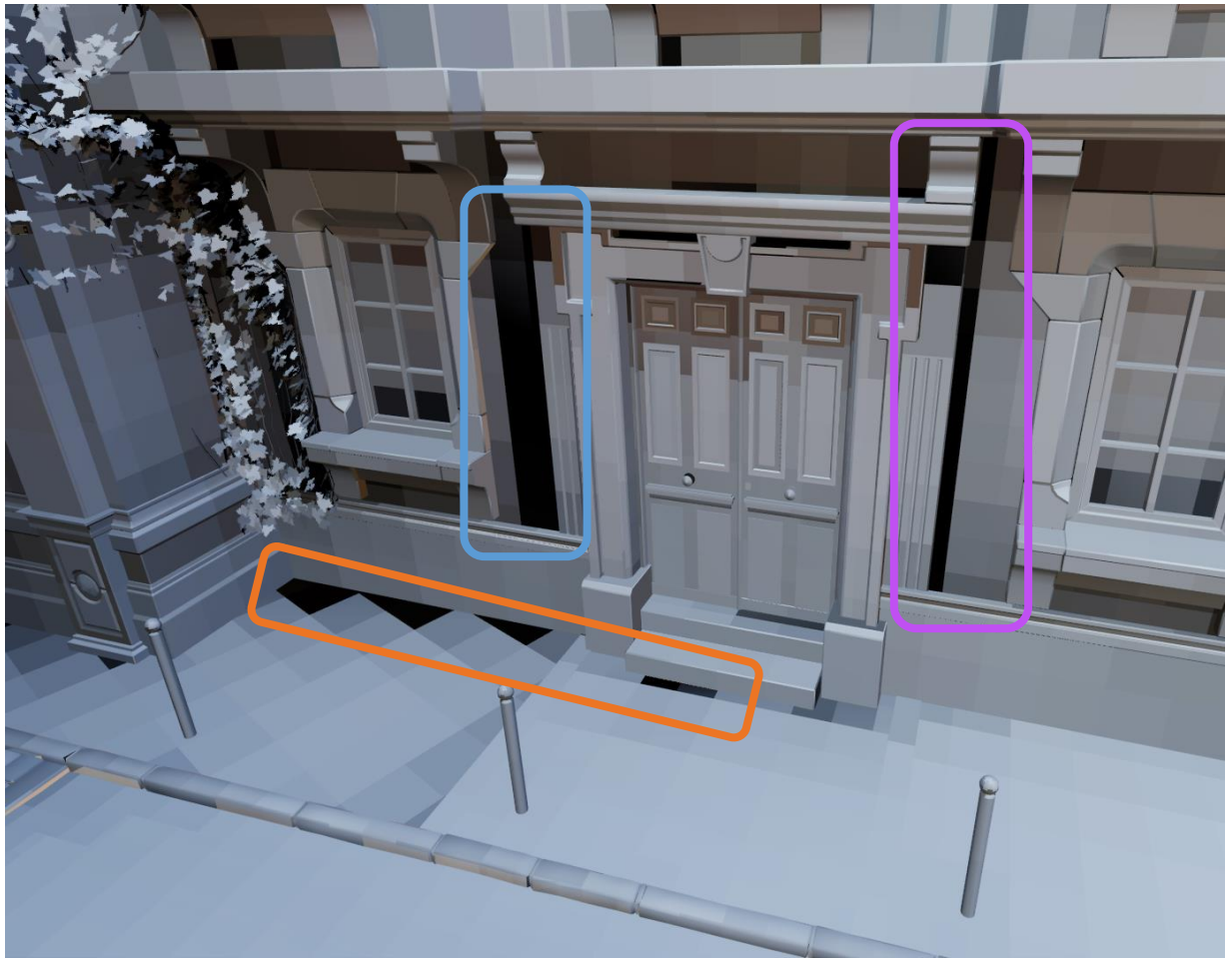


Cache Triangle Id (Mip -1)

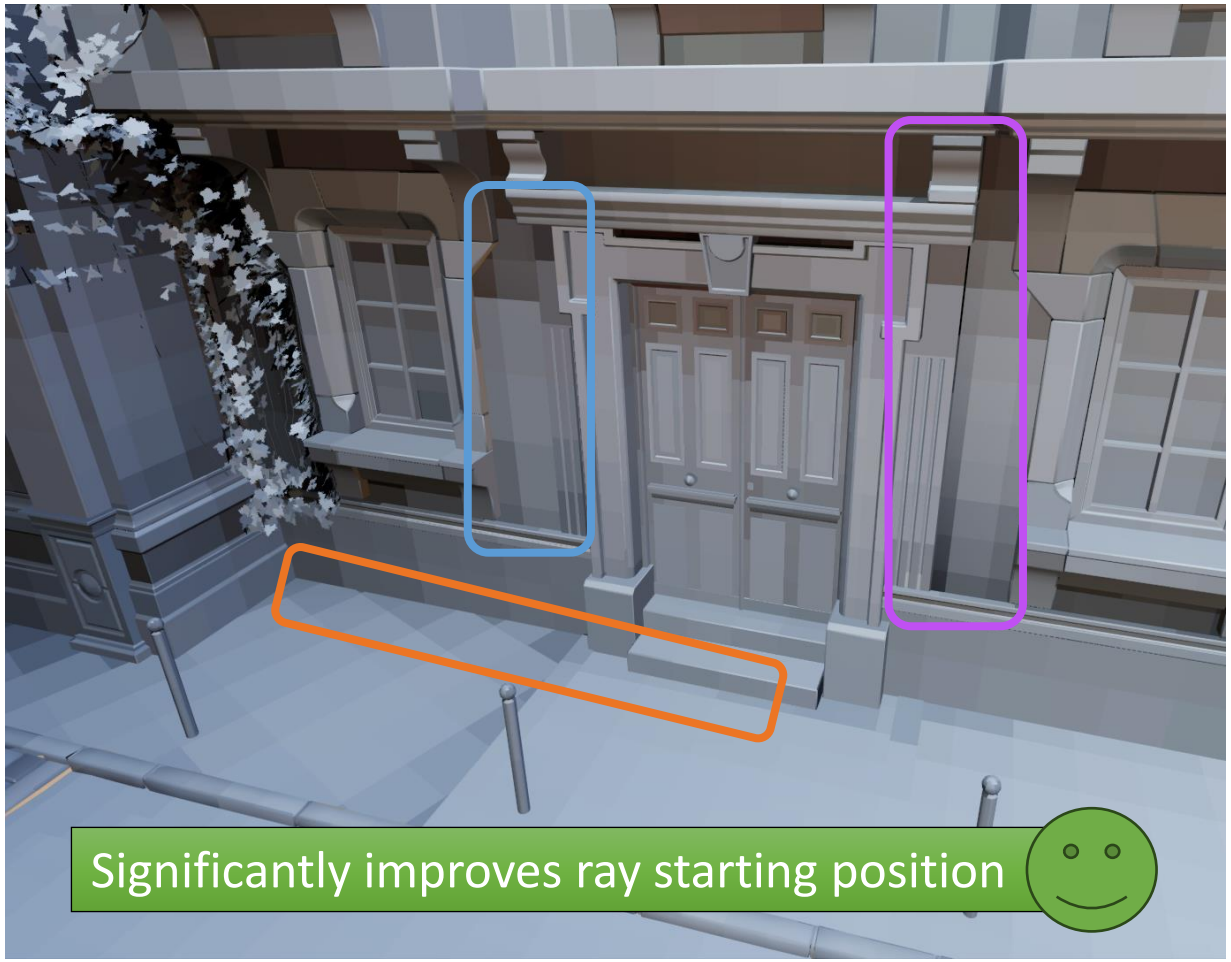


Cache Triangle Id (Mip -2)

Decoupled Triangle Ids



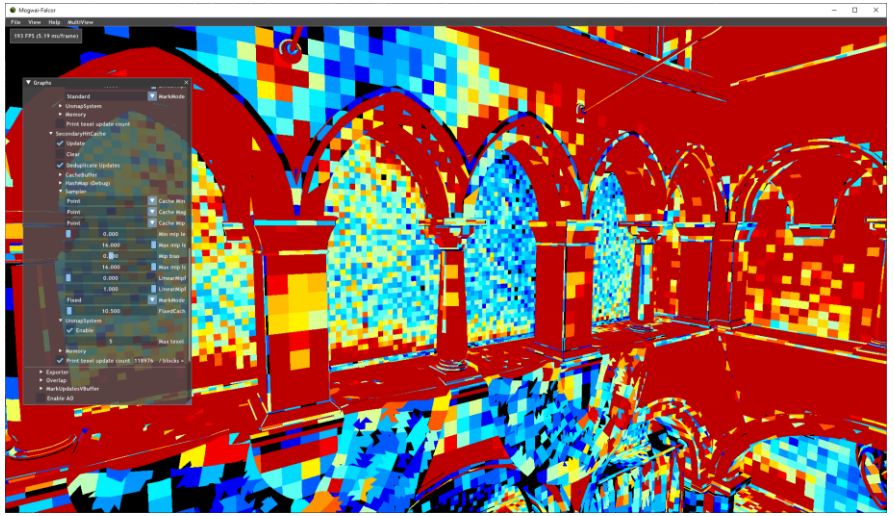
Original Triangle Ids



Decoupled Triangle Ids

Sharing of Secondary Cache

- Secondary Hit caches have a low cache resolution
  - Many primary cache rays hit same secondary cache
- Multiple viewers can look in different directions
  - Rays from primary caches still hit same secondary caches



Reuse of secondary hit caches

Black: 0x Reuse
Red: 20x Reuse

Filtering

- Temporal
  - No re-projection necessary
  - Exponential Moving Average
  - Blend factor inverse to sample count
- Spatial
  - No depth/normal check heuristics necessary
  - Blur with radius of 3
  - Angle error detection [Wright et al. 2021, Boissé et al. 2022]
  - Parallax corrected directions

Filtering

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  - Parallax corrected directions

Uncorrected directions

Parallax correct directions

Primary Cache Mip Level Transitions

- Primary caches have mip levels
  - Changes based on camera distance to surface
- Newly allocated primary caches
  - Initialized with adjacent mip level information
  - Valid cache will be available in either lower or upper mip level
  - Ensures seamless mip level transition

Irradiance Evaluation

- For diffuse
  - Spherical Harmonics
- For reflections
  - Glossy
    - BRDF importance sampling of primary radiance cache hemisphere
  - Sharp
    - Trace reflections rays to secondary cache

Reflections

- BRDF importance sampling
  - Noisy, trilinear interpolation costly for multiple samples
  - Stochastic trilinear interpolation based on interpolation weights
- Trace dedicated reflections rays to secondary caches
  - Sharper reflections
  - Secondary caches provide the incoming radiance

Performance - Timings

Scene	*AMD-GI1.0*	Ours			
		Cache	Effect	Display	Total
PicaPica	1.78	0.27	0.78	0.40	1.45
Sponza	2.23	0.31	1.25	0.62	2.18
FlyingWorld	1.82	0.32	1.01	0.39	1.72
BistroExterior	2.56	0.31	1.72	0.61	2.64

- Foliage in Bistro Exterior causes increased cache allocations

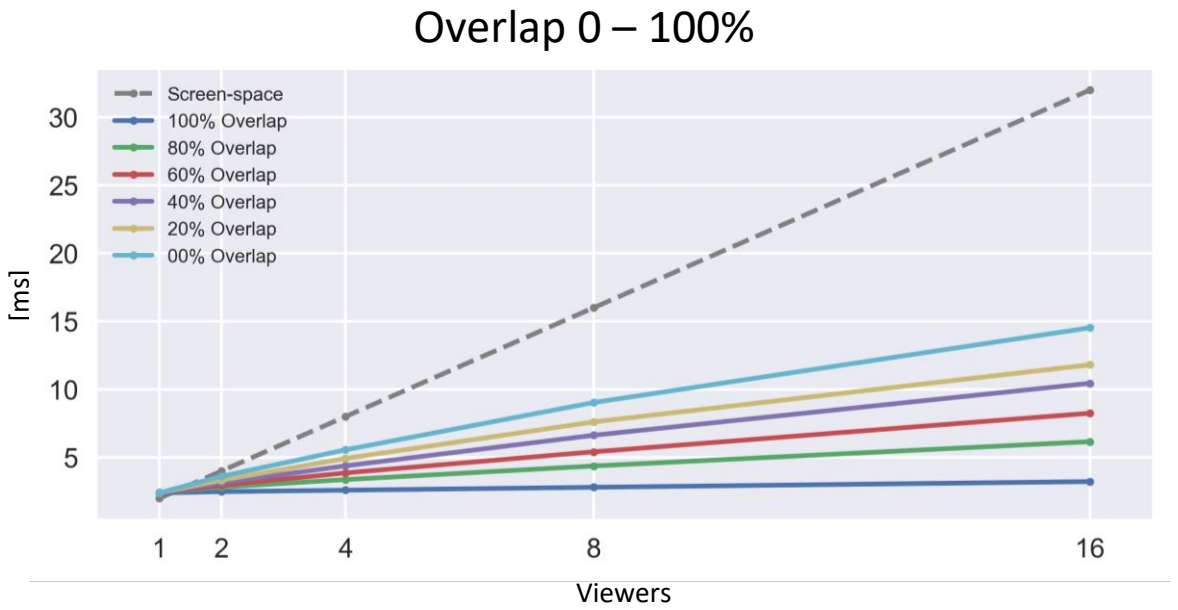
Performance - Memory

- Reduced Block size to 2x2 instead of 8x8 (OSC)
  - Decreases memory requirements up to 14x
  - Cache allocation overhead increases insignificantly
- Memory requirements for a single viewer
  - 300MB – 700MB

Cache Memory Consumption in [MB]

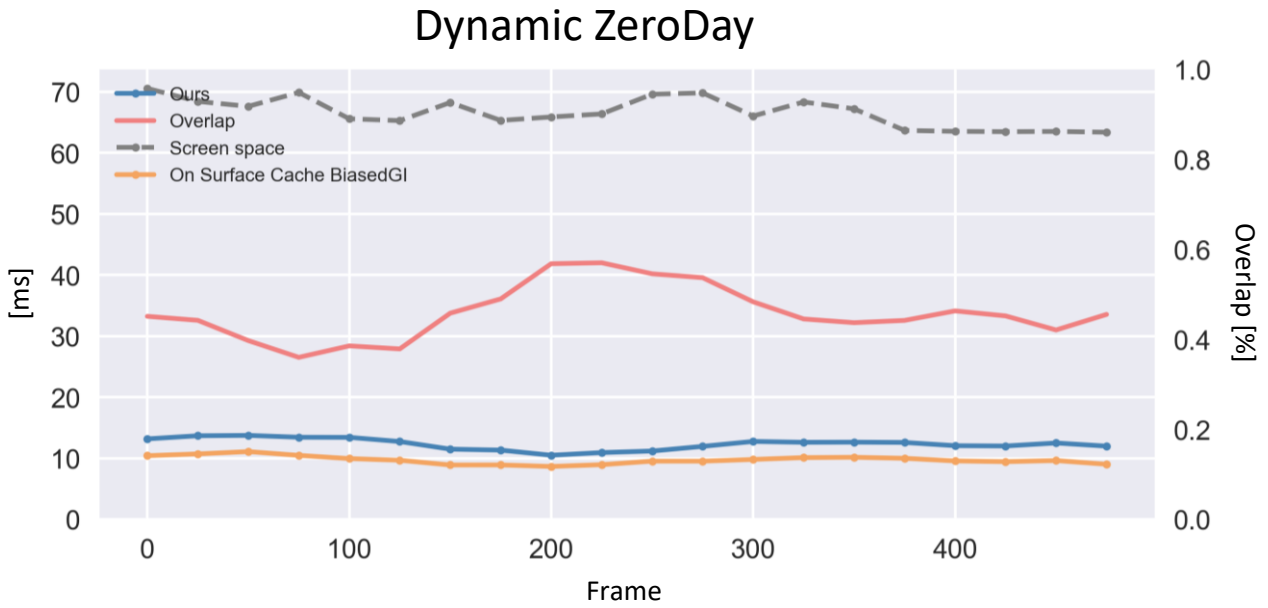
Cache	PicaPica		Sponza		FlyingWorld		Bistro	
	min	max	min	max	min	max	min	max
Primary	69	171	44	127	32	106	75	224
Secondary	89	185	93	134	55	242	116	456

Multi-Viewer Performance

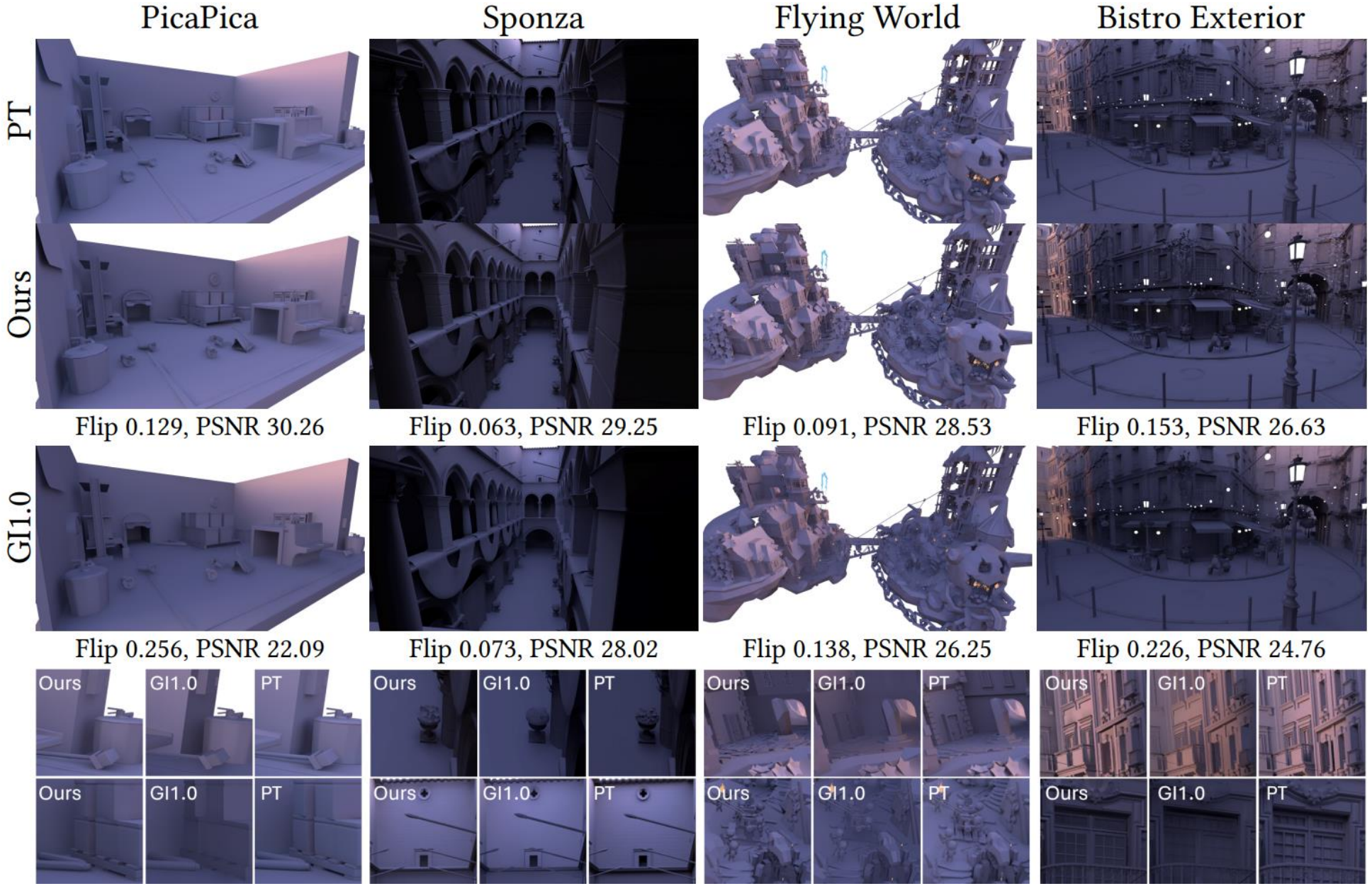


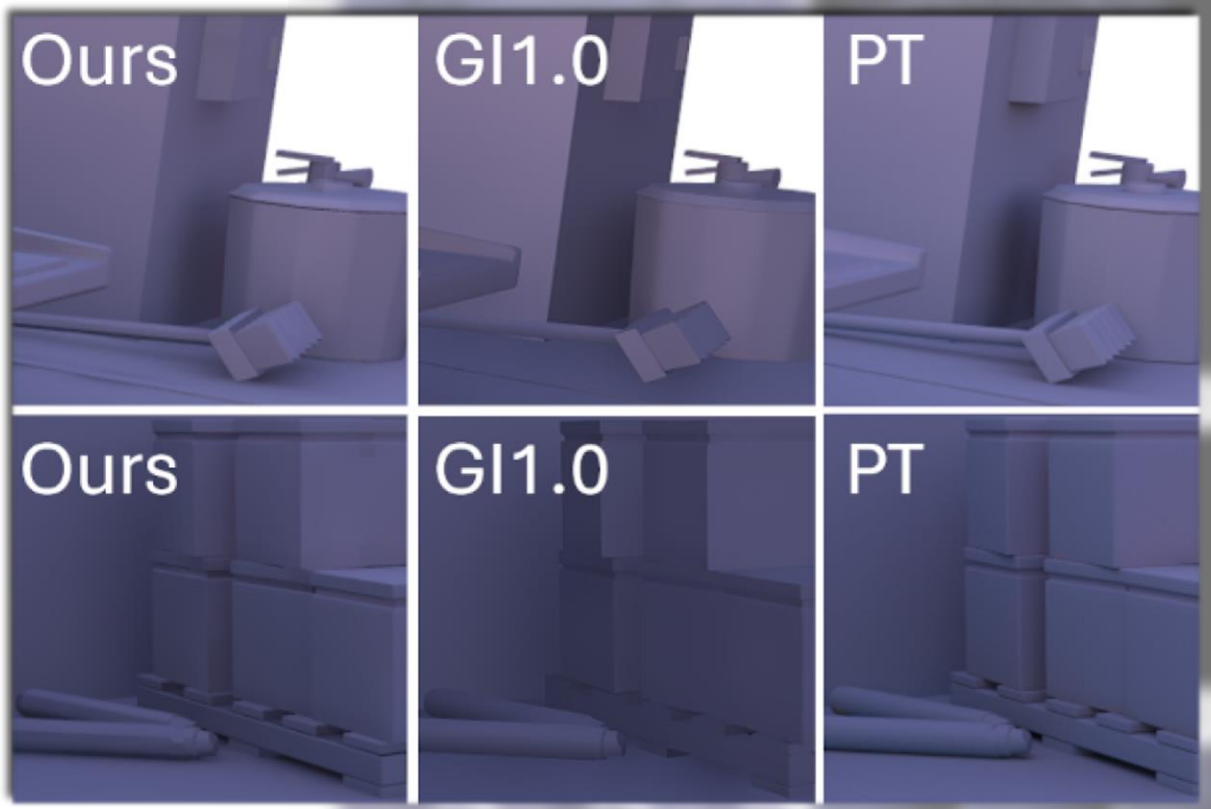
- Increasing #viewers and overlap ranging from 0% to 100%
- Render timings correlate with overlap percentage

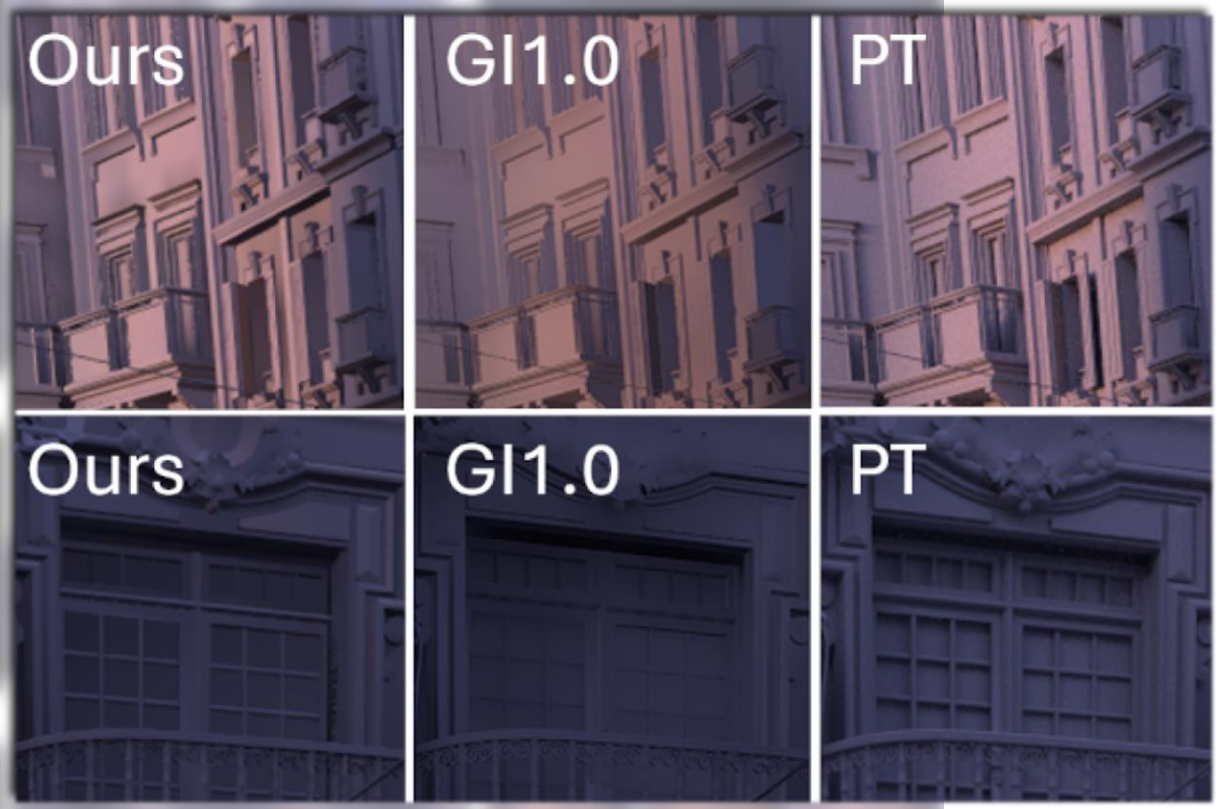
Multi-Viewer Performance



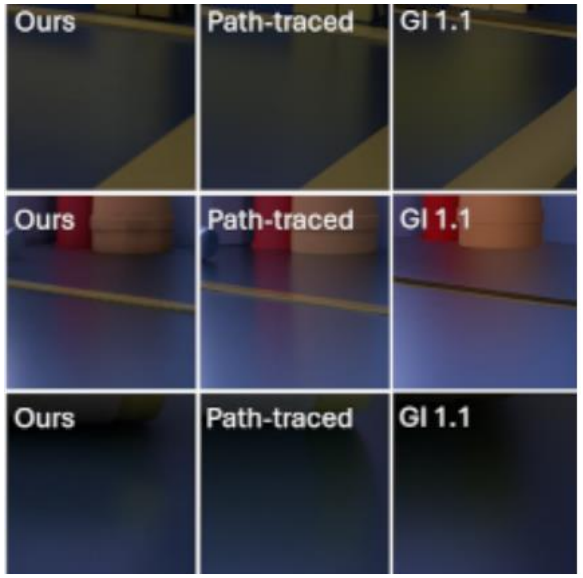
- 16 camera paths through ZeroDay scene
  - Slightly slower compared to OSC, but
    - Multiple bounces, reflections and preserves surface features


PicaPica
Sponza
Flying World
Bistro Exterior
PT
Ours
Flip 0.129, PSNR 30.26
Flip 0.063, PSNR 29.25
Flip 0.091, PSNR 28.53
Flip 0.153, PSNR 26.63
GI1.0
Flip 0.256, PSNR 22.09
Flip 0.073, PSNR 28.02
Flip 0.138, PSNR 26.25
Flip 0.226, PSNR 24.76
Ours
GI1.0
PT


Ours
GI1.0
PT
Ours
GI1.0
PT

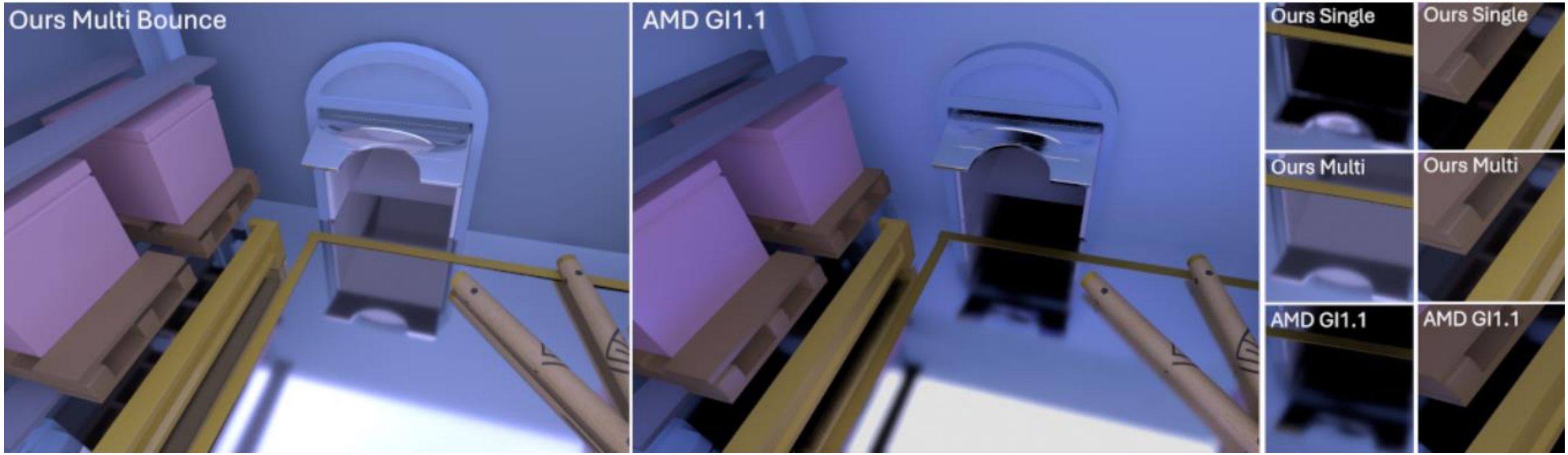

Ours
GI1.0
PT
Ours
GI1.0
PT

Quality - Glossy Reflections



- BRDF importance sampling of the primary radiance caches

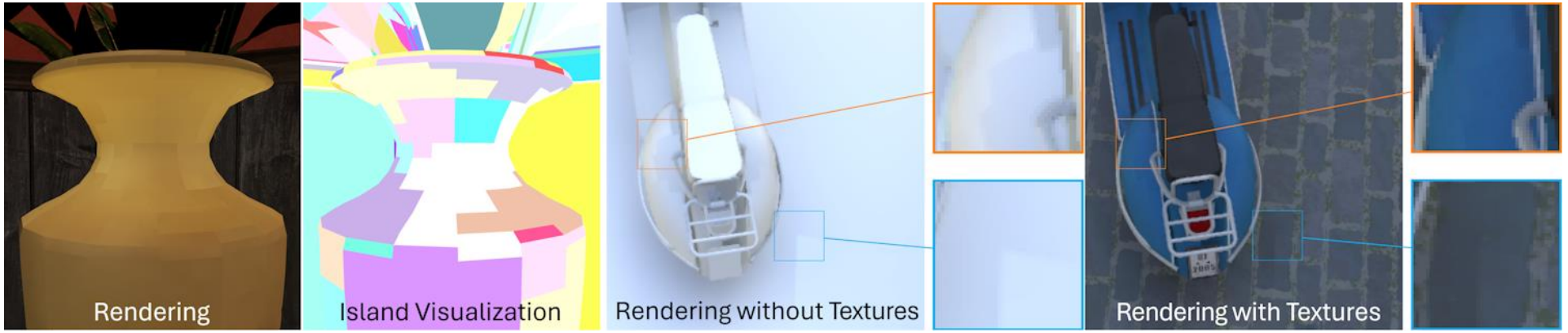
Quality - Multi Bounce Reflections



- Multiple light bounces everywhere

Limitations and Future Work

- Island Borders
  - No access to neighboring Islands for filtering
    - Visible borders at island borders
- Fine geometry (e.g., abundant foliage)
  - Increased cache allocations



Conclusion

- Texture space based global illumination
- Supports
  - Multiple bounces
  - (Glossy) Reflections
  - Suited for cloud-native rendering for multiple viewers
- *Quality*/Speed matches/exceeds state of the art