Multi-Scale Global Illumination in Quantum Break

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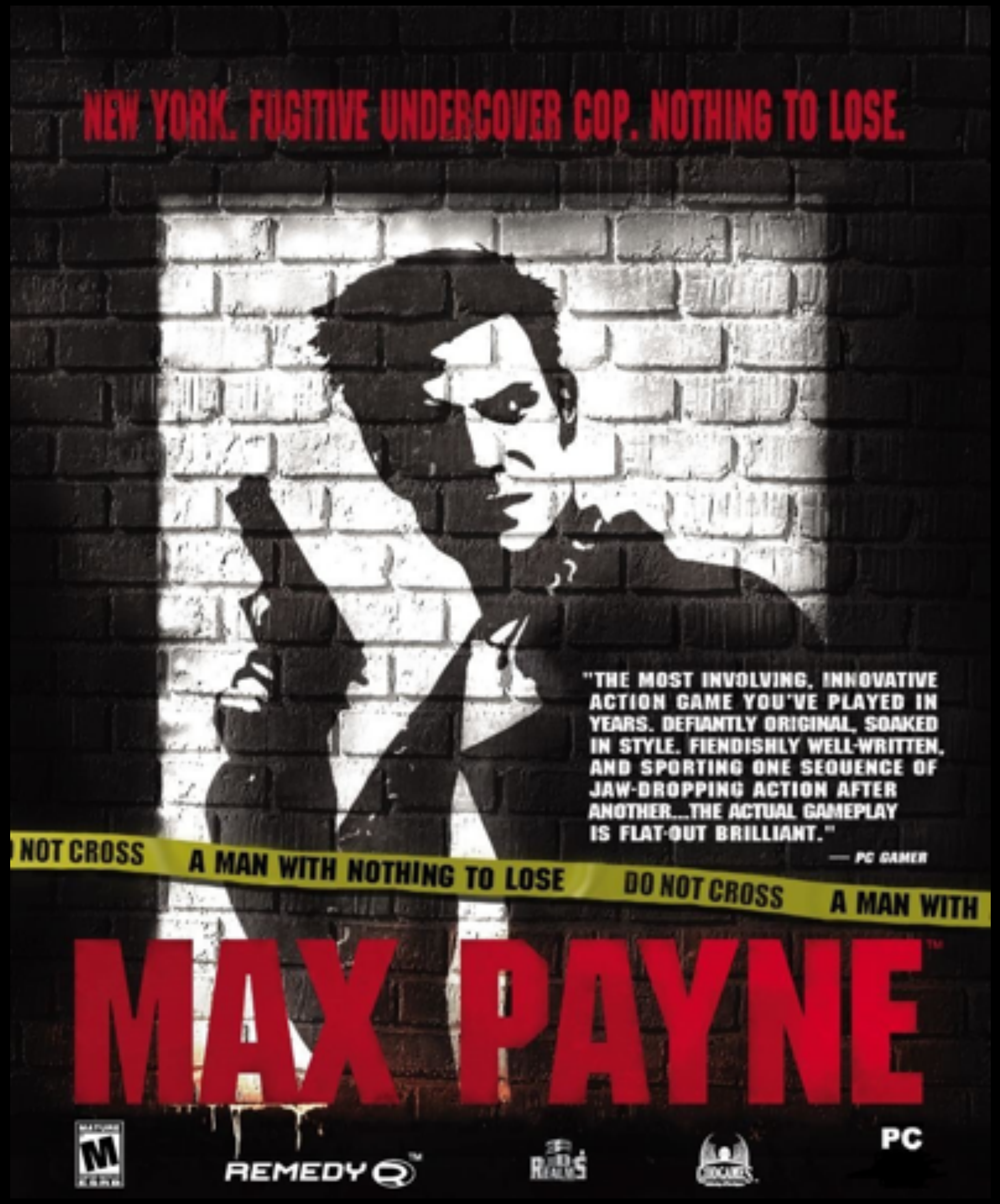
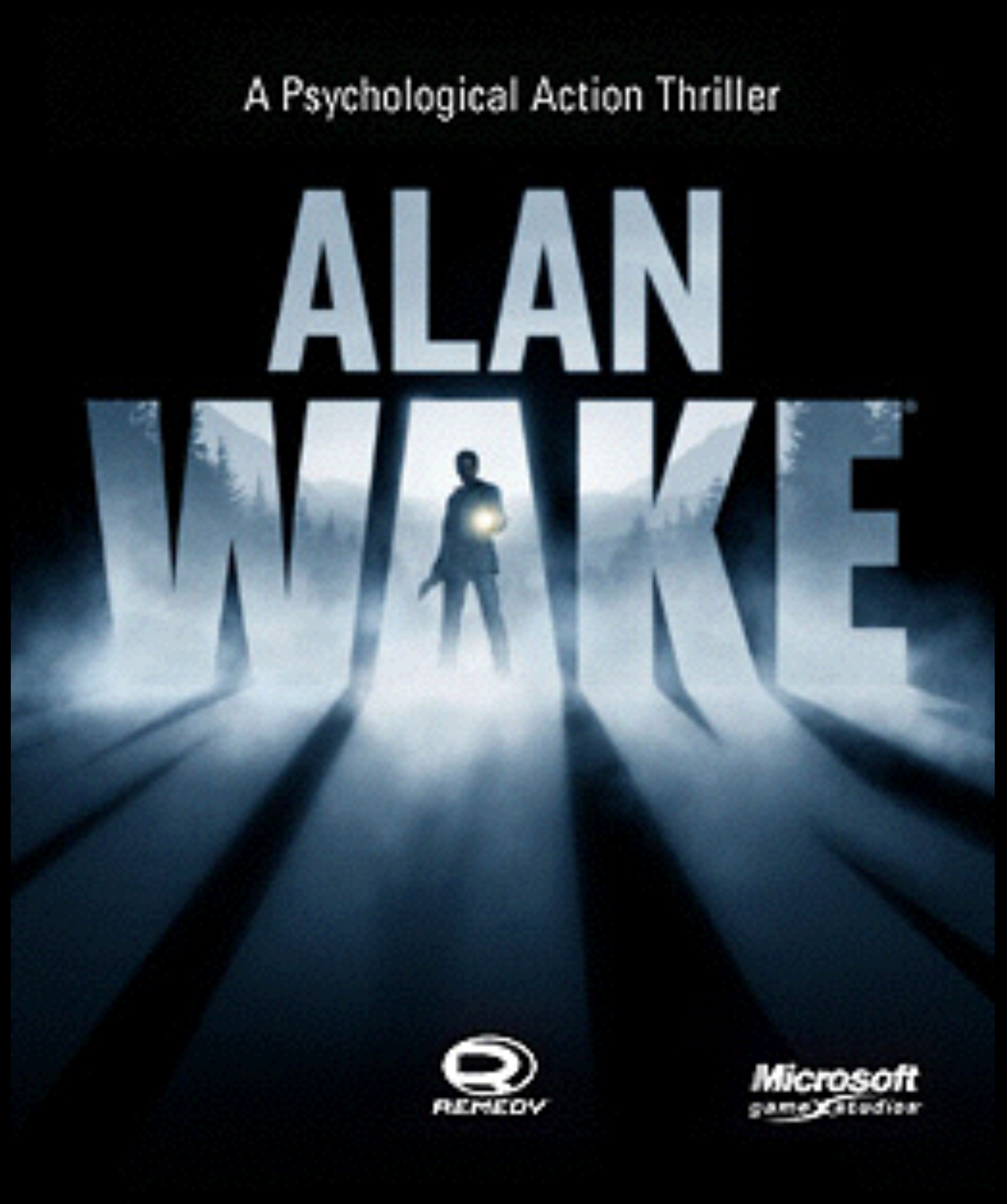
SIGGRAPH2015

REMEDY

Remedy Entertainment





northlight®

Custom in-house engine

Physically based light pre-pass renderer


FRACTURE FIXER ROOM
KEEP CLEAR
KEEP CLEAR


KEEP CLEAR
KEEP CLEAR
FRACTURE FIXER ROOM

Design Goals and Constraints

Consistency

Design Goals and Constraints

Consistency

Semi-dynamic environments and lighting

Design Goals and Constraints

- Consistency
- Semi-dynamic environments and lighting
- Fully automatic

Screen-Space Lighting

Screen-Space Lighting

Screen-Space Lighting

Large Scale Lighting

Multi-Scale Lighting

SIGGRAPH 2015: Advances in Real-Time Rendering course

Talk Outline

Part I: Large-scale lighting

Part II: Screen-space lighting

SIGGRAPH 2015: Advances in Real-Time Rendering course

Talk Outline

Part I: Large-scale lighting

Part II: Screen-space lighting

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Possible Solutions for Global Illumination

Dynamic Approaches

- Virtual Point Lights (VPLs) [Keller97]
- Light Propagation Volumes [Kaplaynan10]
- Voxel Cone Tracing [Crassin11]
- Distance Field Tracing [Wright15]

Possible Solutions for Global Illumination

Dynamic Approaches

- Virtual Point Lights (VPLs) [Keller97]
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- Voxel Cone Tracing [Crassin11]
- Distance Field Tracing [Wright15]

Cost was too high for the **quality** we wanted

Possible Solutions for Global Illumination

Mesh-based Precomputation

- Precomputed Radiance Transfer (PRT) [Sloan02]
- Spherical Harmonic Light Maps

Meshless Precomputation

- Irradiance Volumes [Greger98]

Possible Solutions for Global Illumination

Mesh-based Precomputation

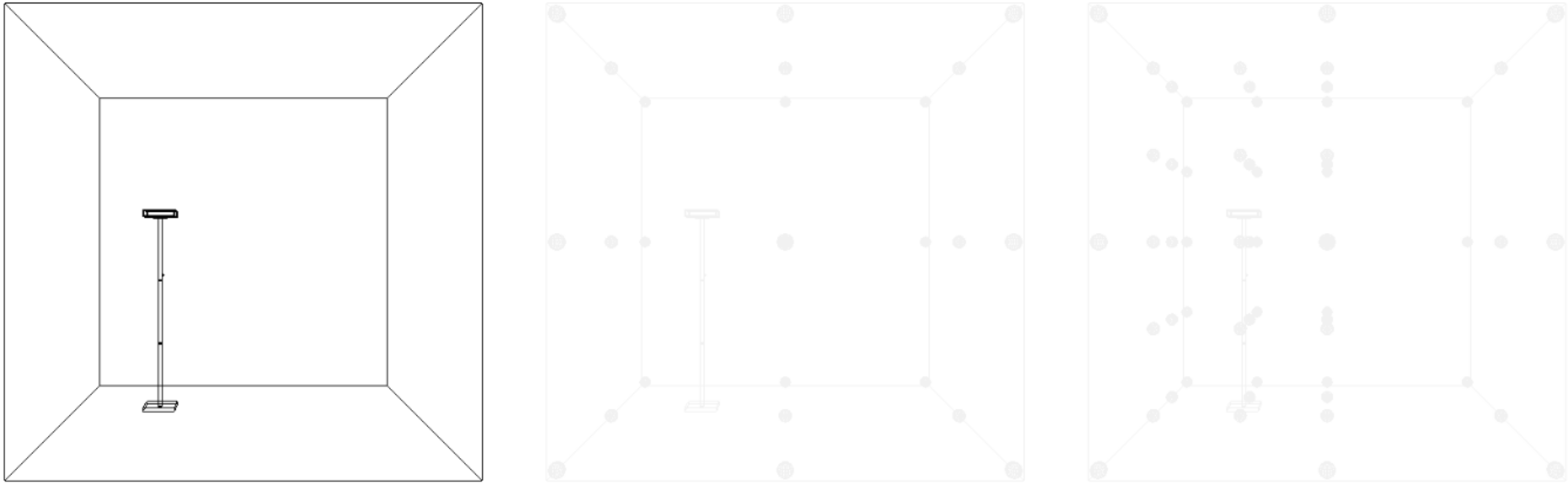
— Precomputed Radiance Transfer (PRT) [Sloan02] ✗

— Spherical Harmonic Light Maps ✗

Meshless Precomputation

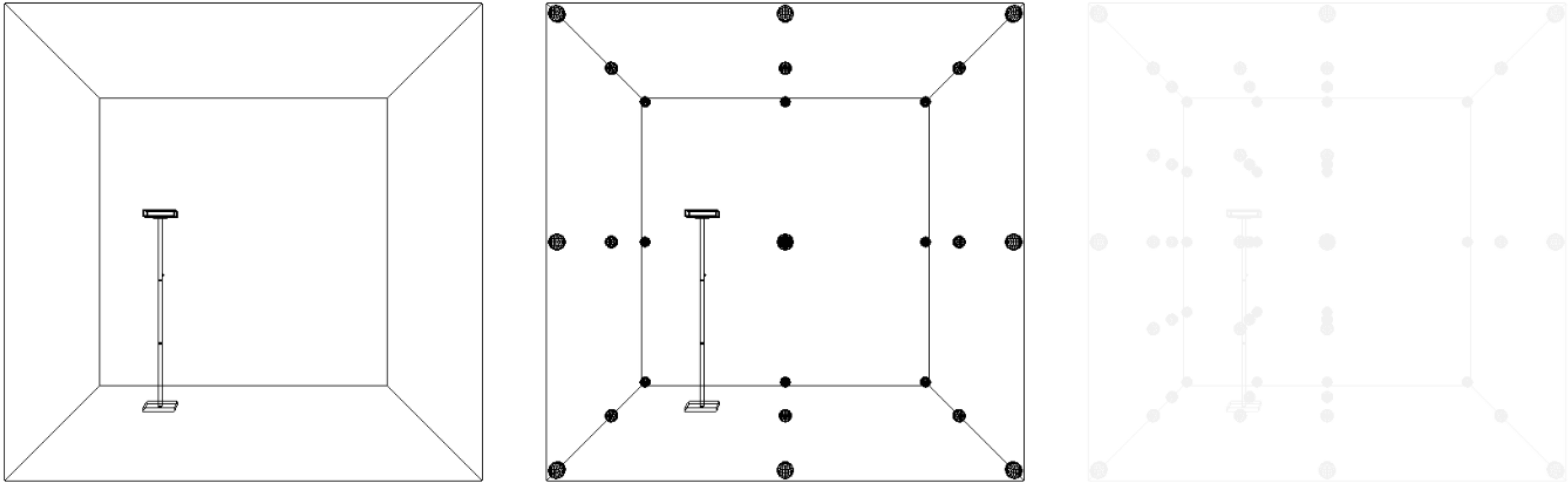
— Irradiance Volumes [Greger98] ✔

Irradiance Volumes



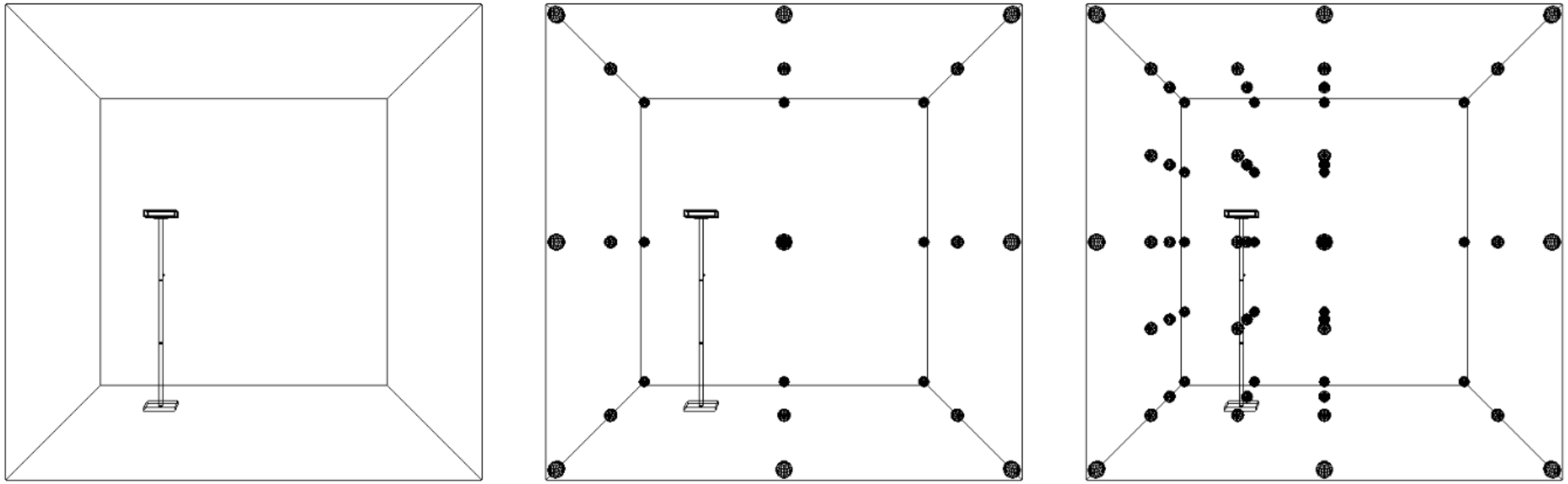
[Greger 1998]

Irradiance Volumes



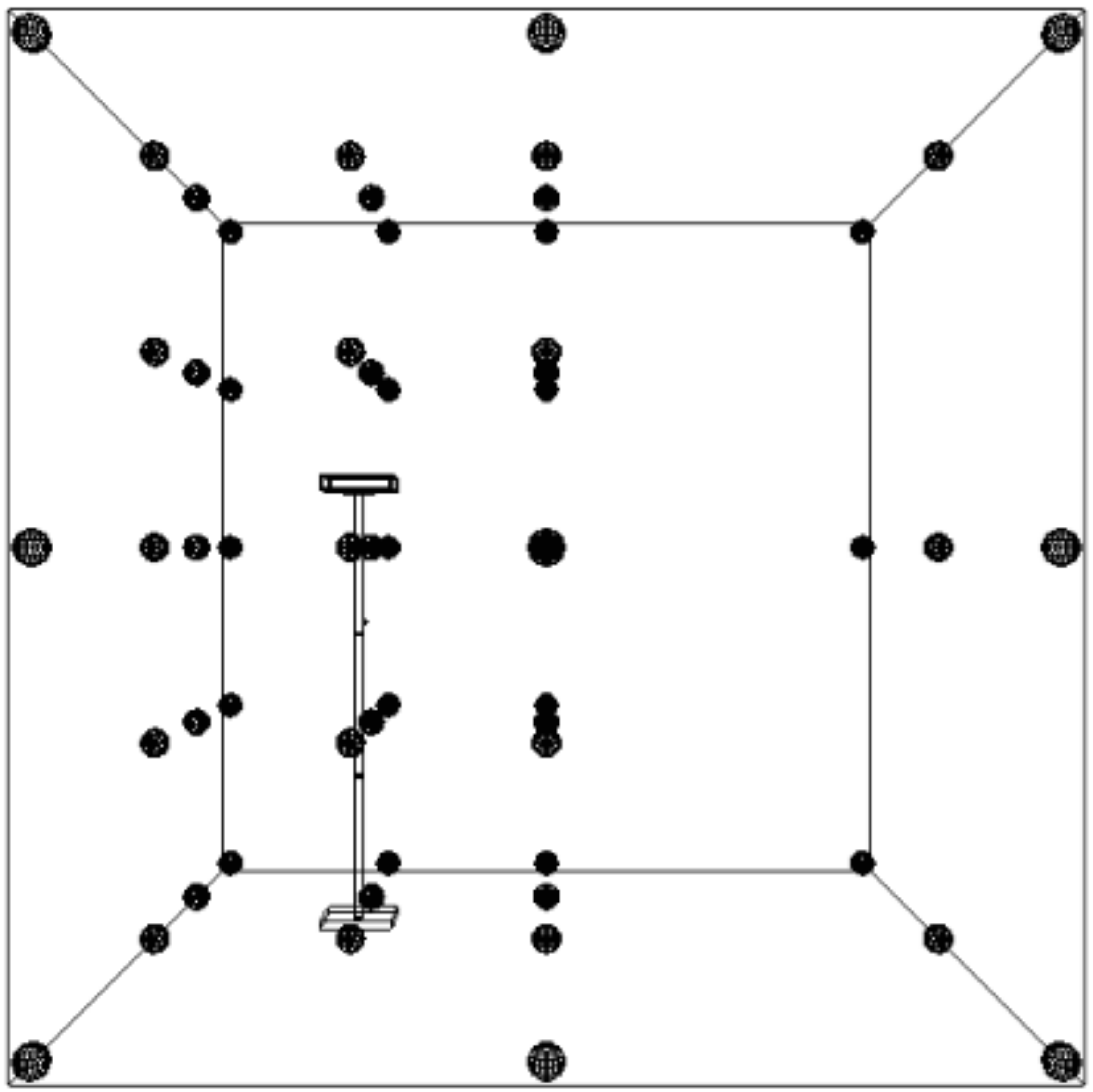
[Greger 1998]

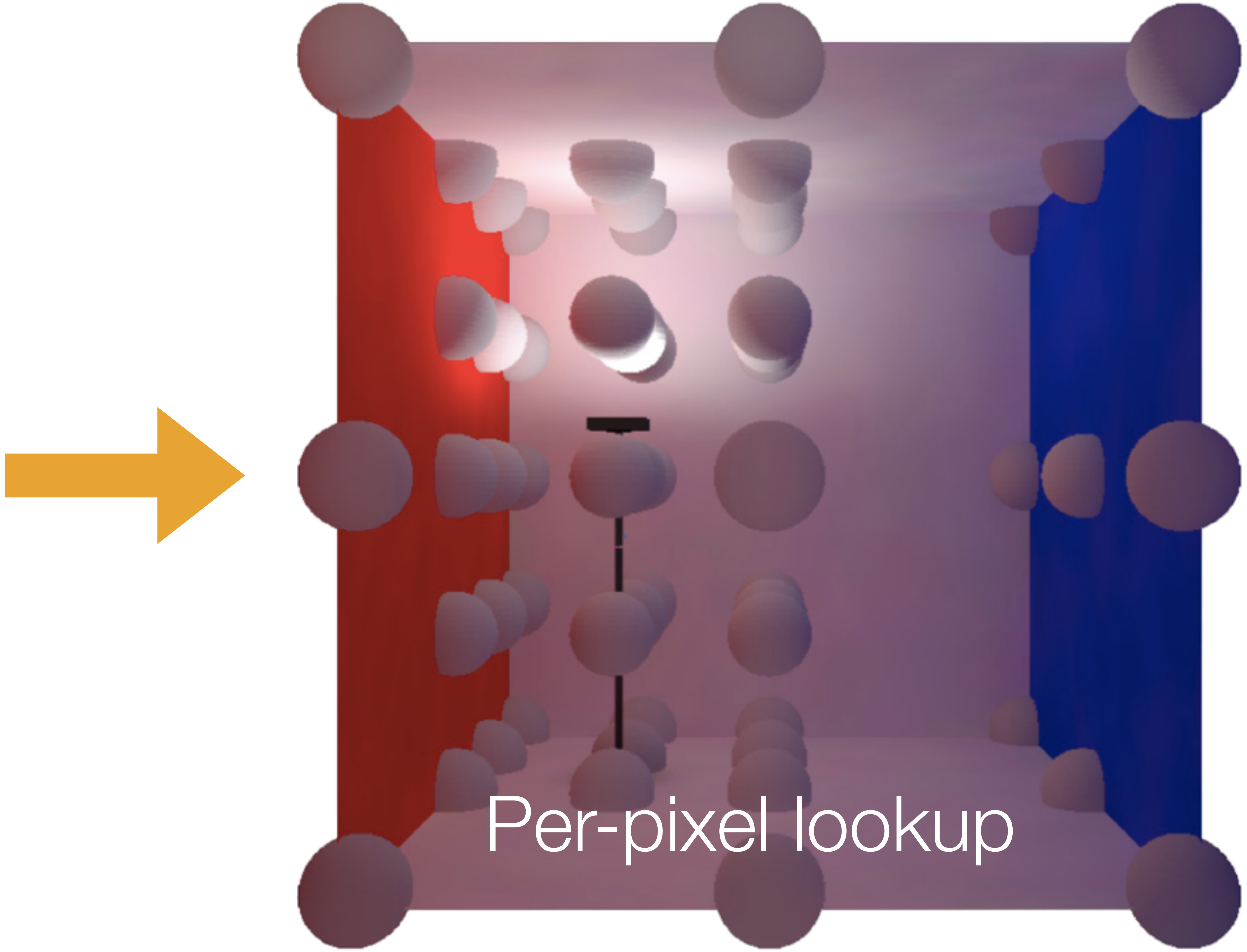
Irradiance Volumes



[Greger 1998]

Irradiance Volumes





[Greger 1998]

Global Illumination Volumes

Augment irradiance volumes with global illumination data


Lighting Only
Local Irradiance
Indirect Sun Light Transport
Sky Light Transport
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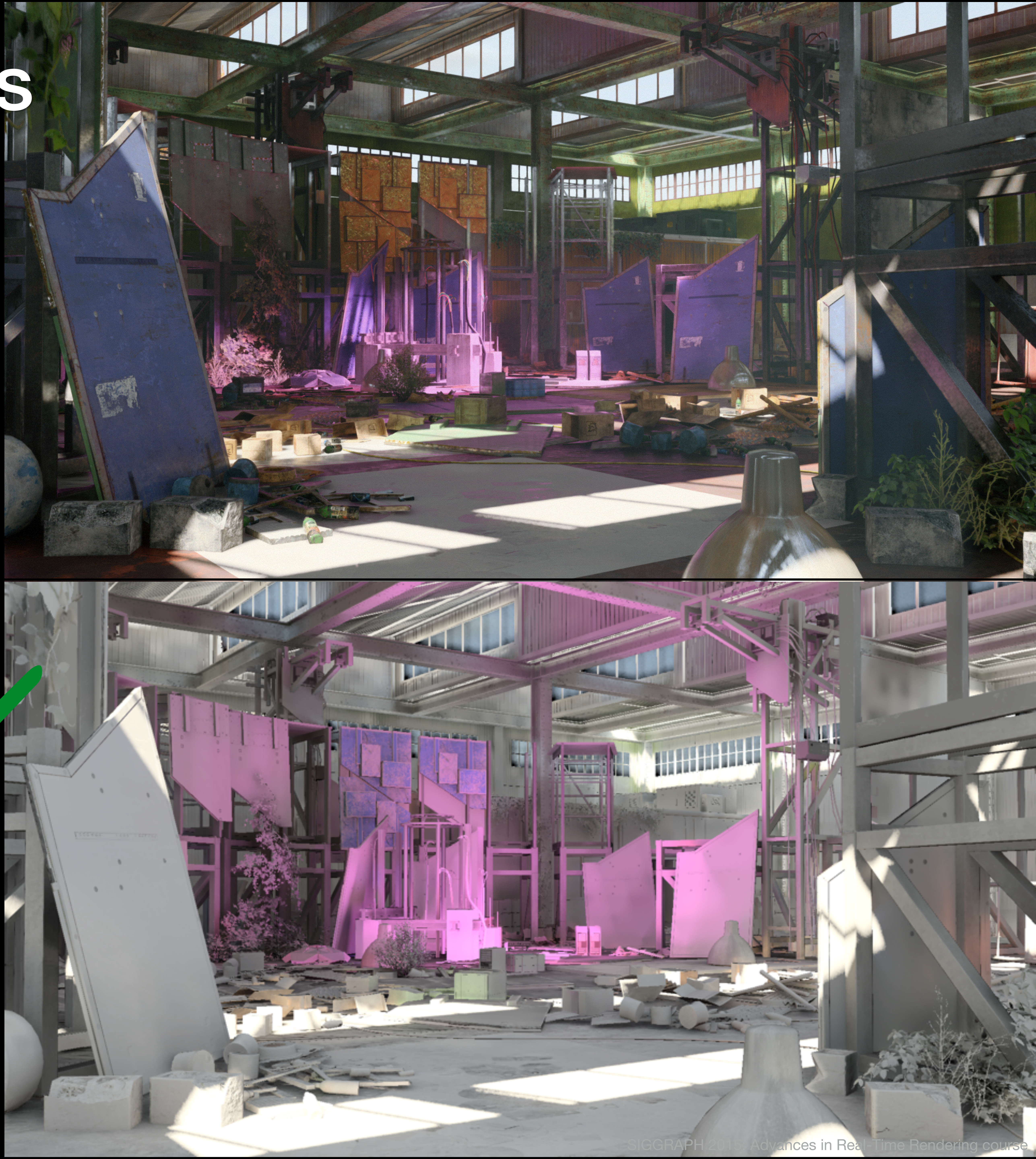
Lighting Only
Local Irradiance
Indirect Sun Light Transport
Sky Light Transport


Lighting Only
Local Irradiance
Indirect Sun Light Transport
Sky Light Transport


Lighting Only
Local Irradiance
Indirect Sun Light Transport
Sky Light Transport

Global Illumination Volumes

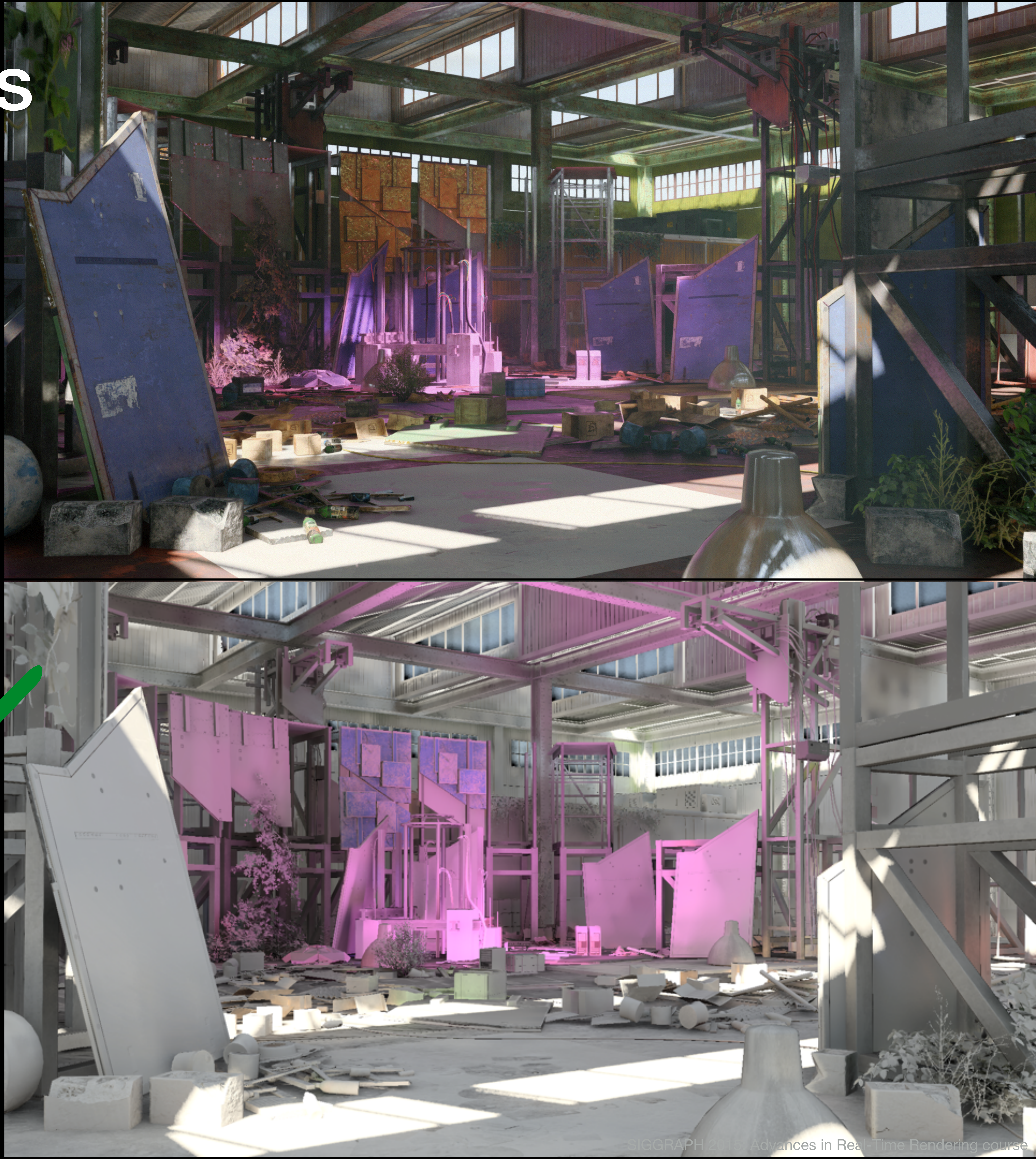
- No UVs ✔
- Works for LOD models ✔
- Volumetric lighting ✔
- Consistent with dynamic objects ✔



Global Illumination Volumes

No UVs ✔
Works for LOD models ✔
Volumetric lighting ✔
Consistent with dynamic objects ✔

Specular **infeasible**
due to data size ✘



Specular Reflections

Specular Reflections

Specular Reflections

Specular Reflections

Screen space info available

Specular Reflections

Specular Reflections

Fall back to local reflection probes

How to Blend Reflection Probes?

How to Blend Reflection Probes?

Reflection Probe Visibility

Reflection Probe Visibility

Reflection Probe Visibility

Reflection Probe Visibility

Reflection Probe Visibility

Reflection Probe Visibility

Main idea: extend global illumination volumes to store **reflection probe visibility**

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Reflection Probe Visibility

Main idea: extend global illumination volumes to store **reflection probe visibility**

Store best reflection probes in the voxel

Reflection Probes

Reflection Probes


On


Off


On
Off

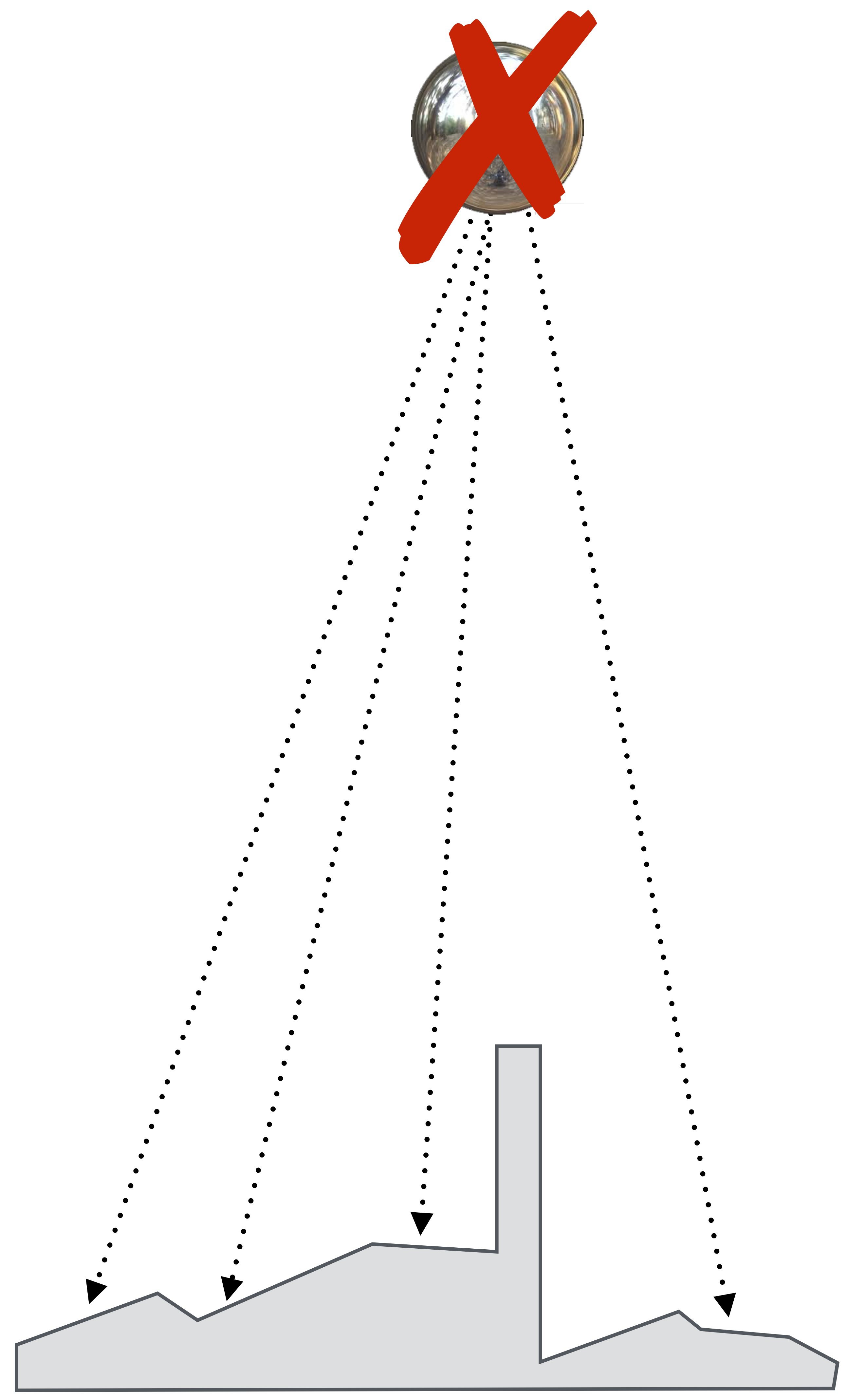
Where to Place Reflection Probes?

Where to Place Reflection Probes?

Not too close to geometry

Where to Place Reflection Probes?

Not too far from geometry



Observation

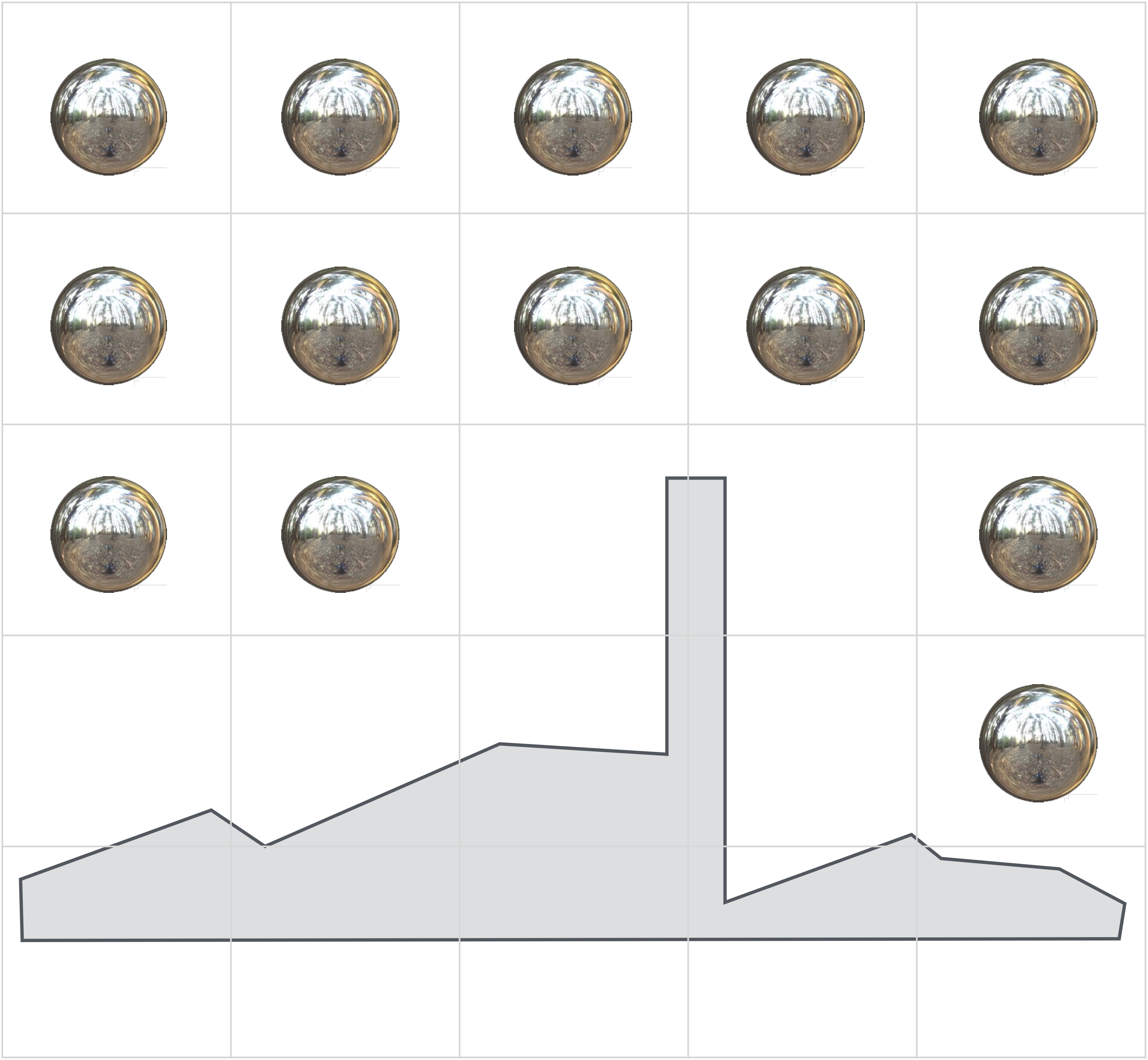
Maximise **visible surface area**

Minimize **distance** to surface

Automatic Probe Placement

Maximise **visible surface area**

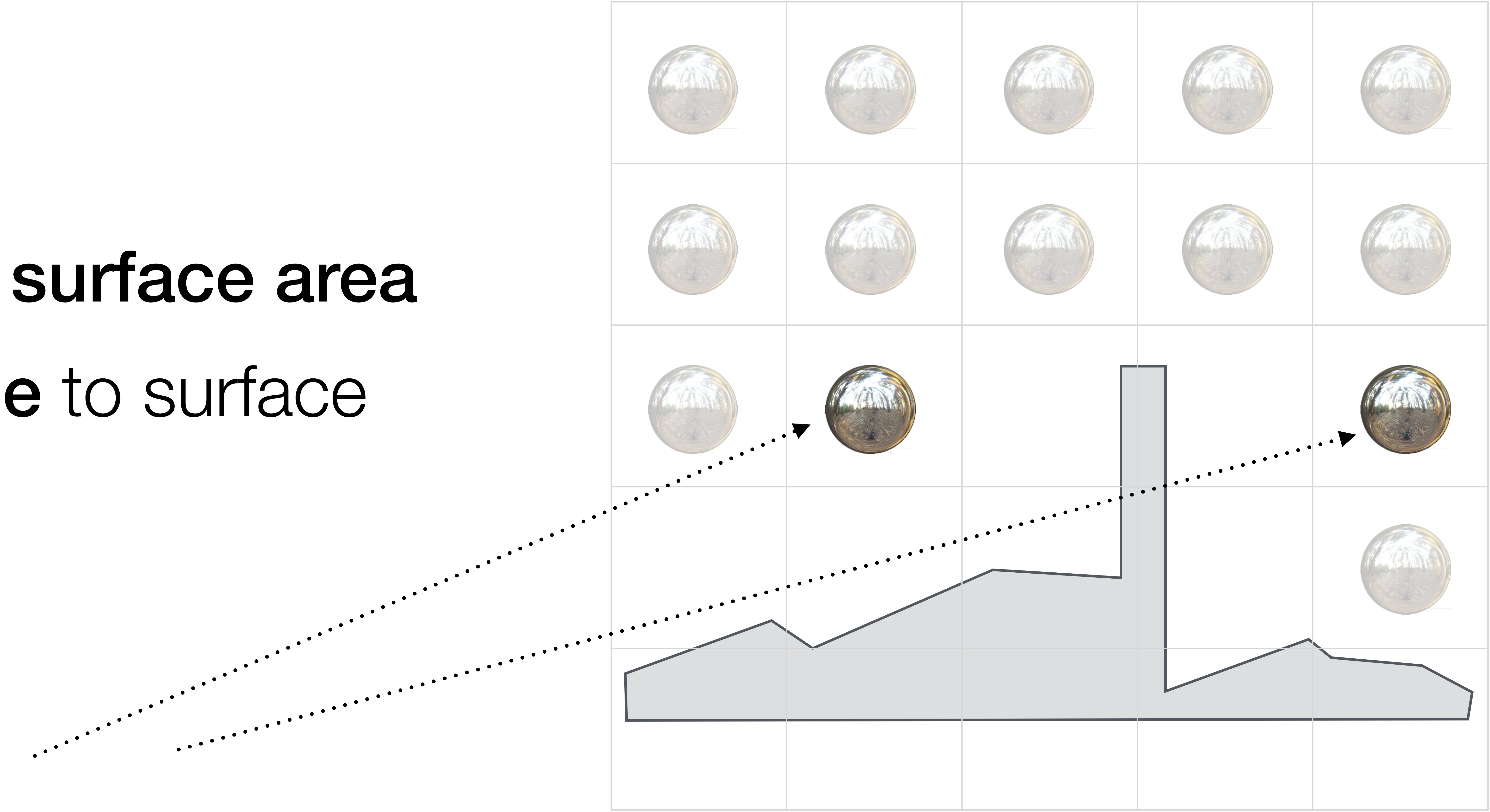
Minimize **distance** to surface



Automatic Probe Placement

Maximise **visible surface area**

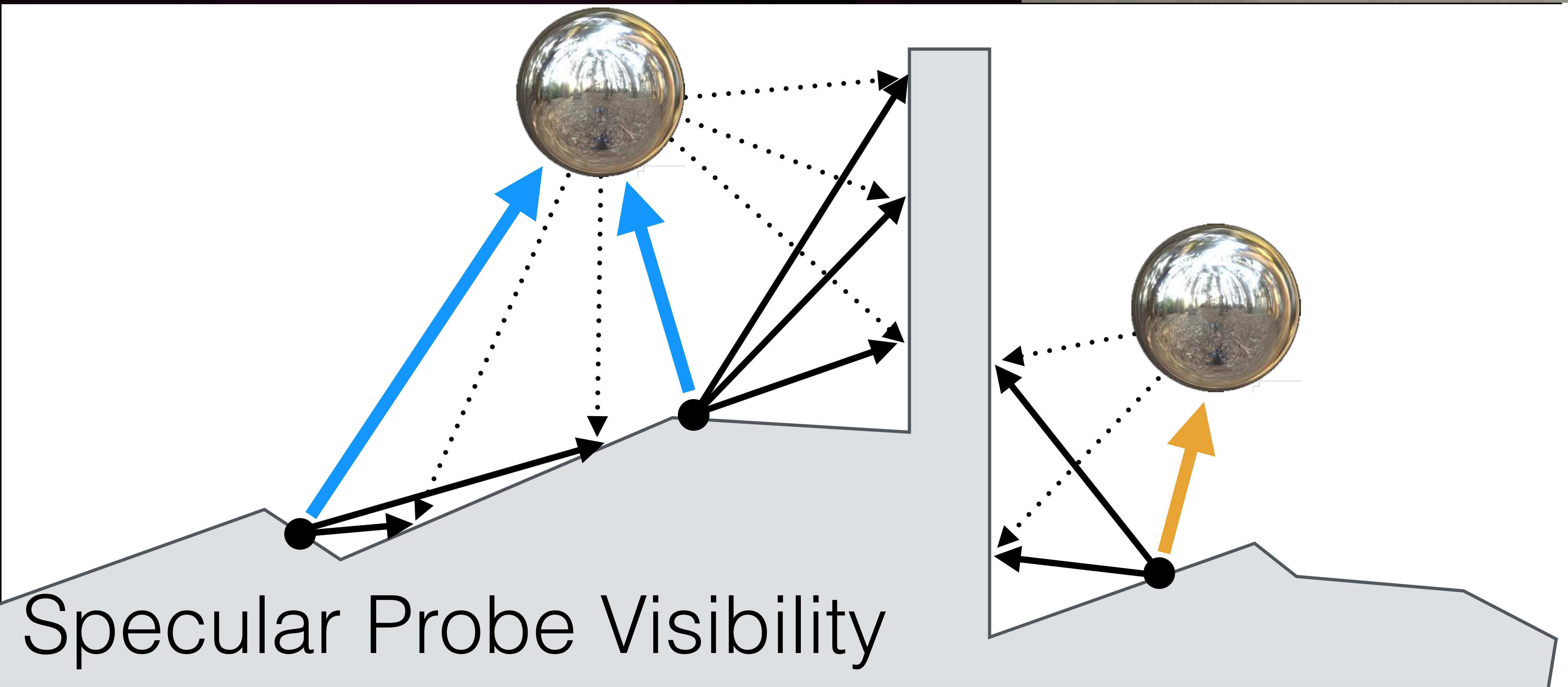
Minimize **distance** to surface

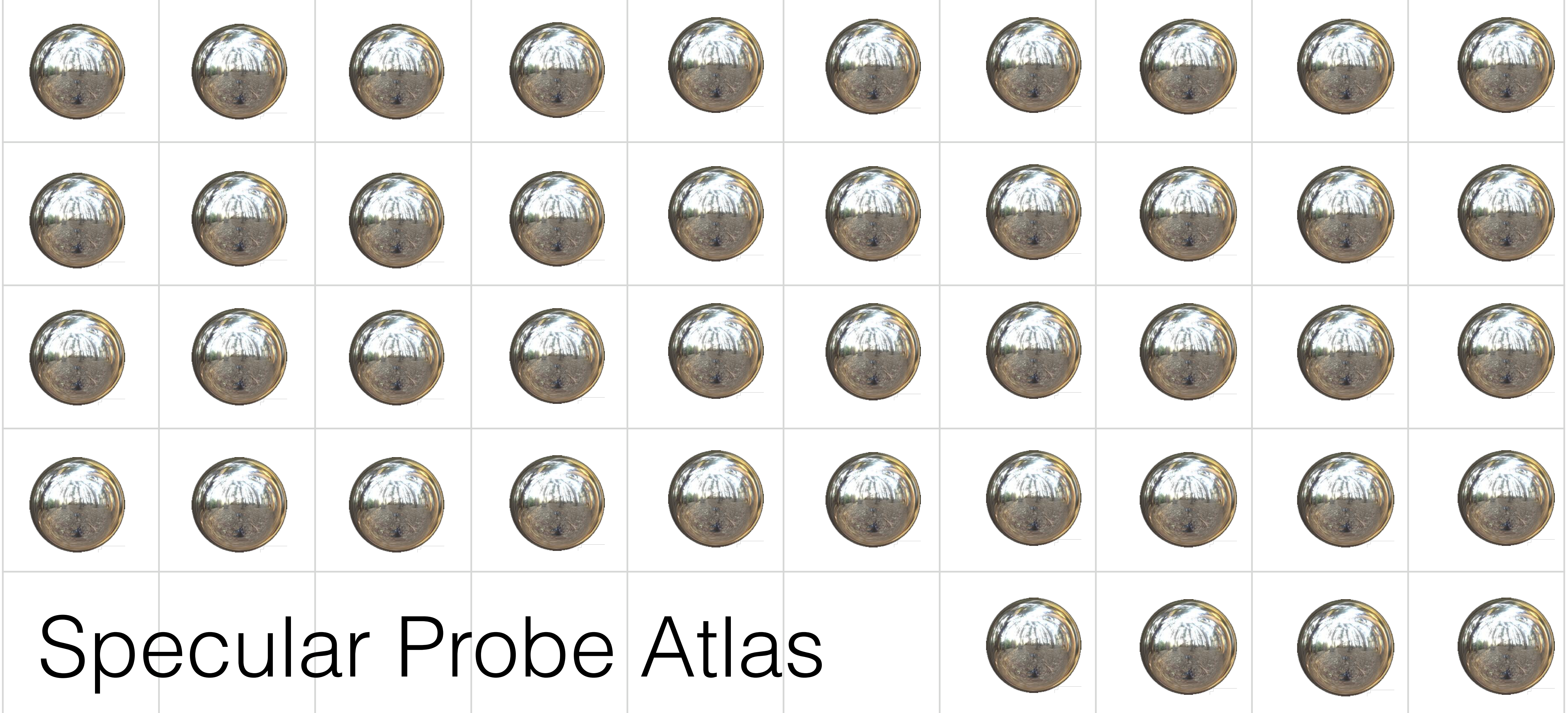


Choose K best probe locations

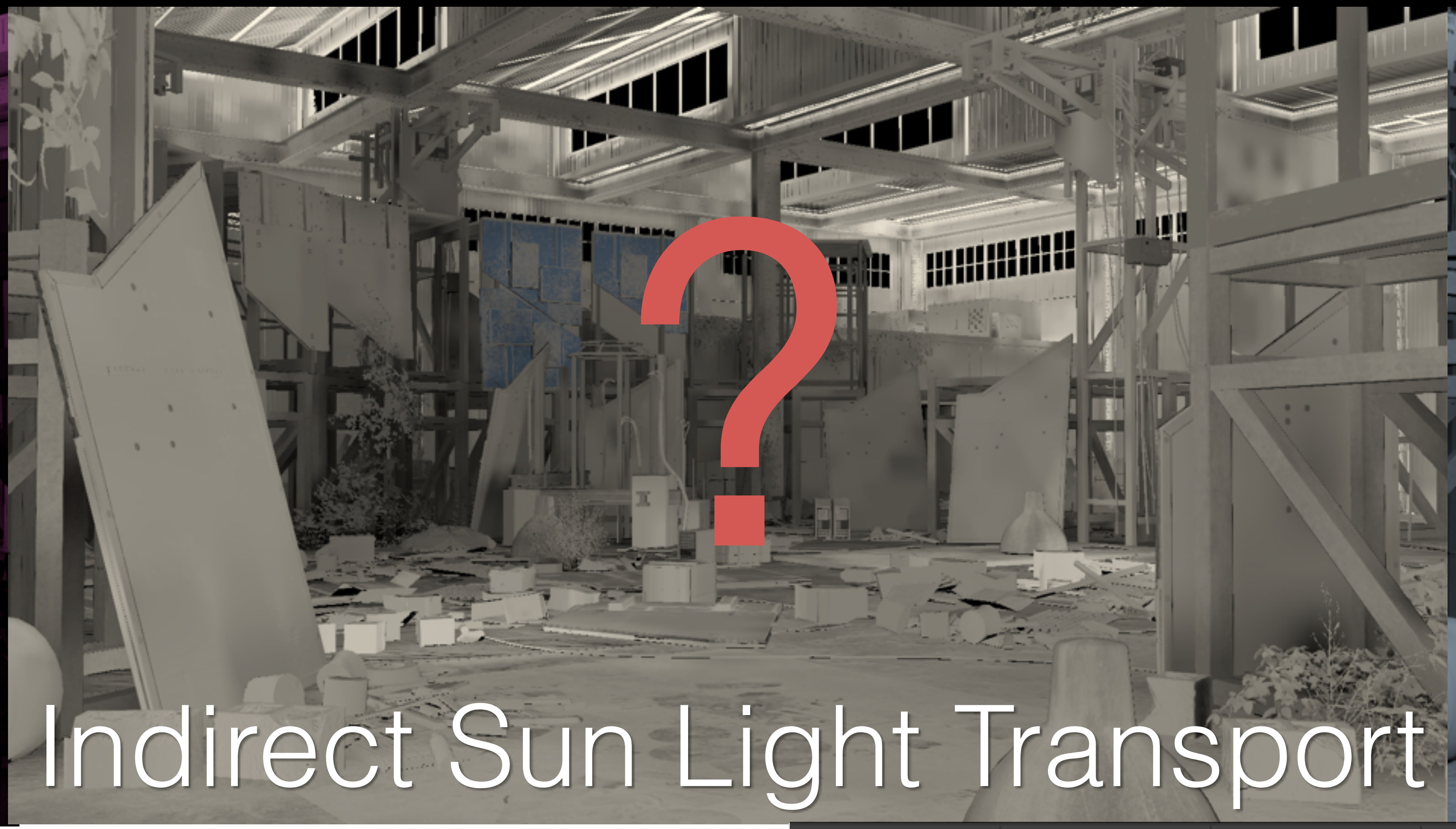
Probe Placement

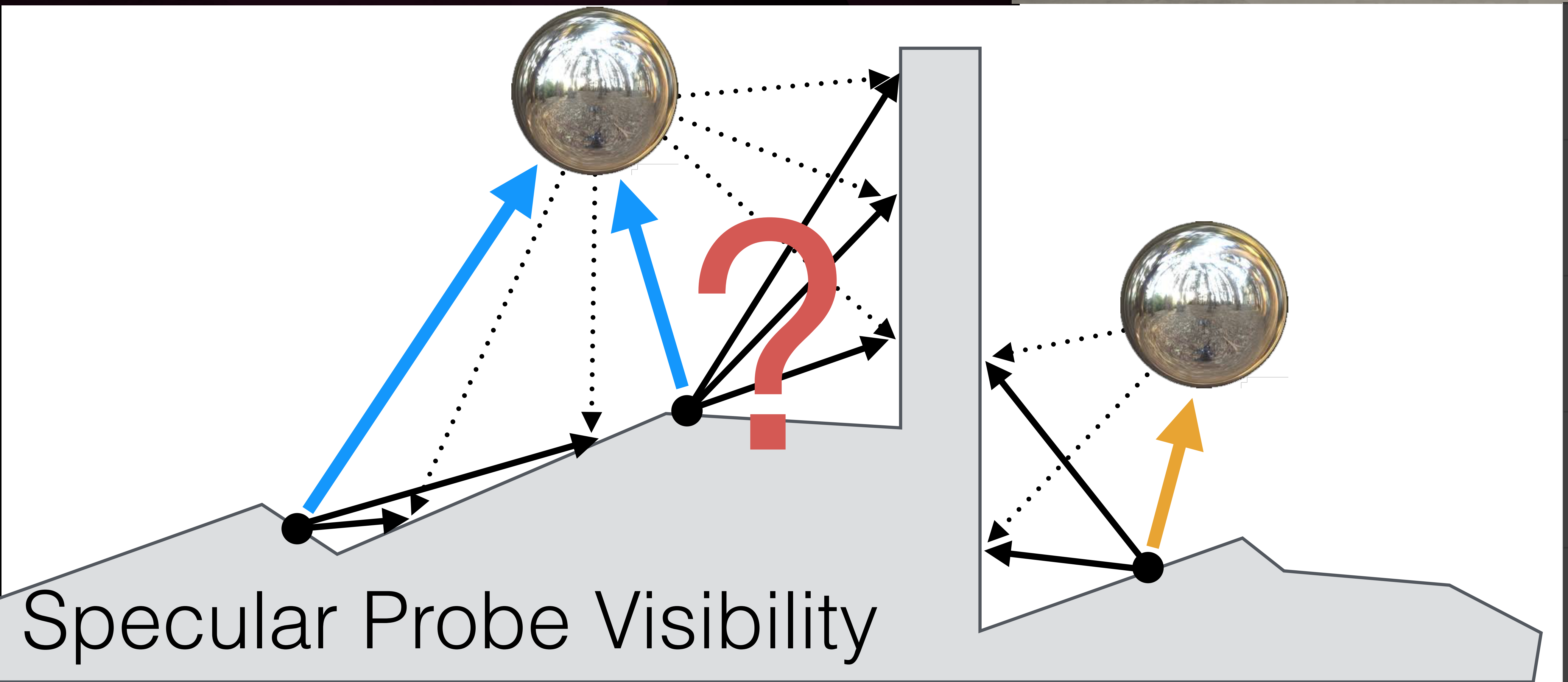
Global Illumination Data

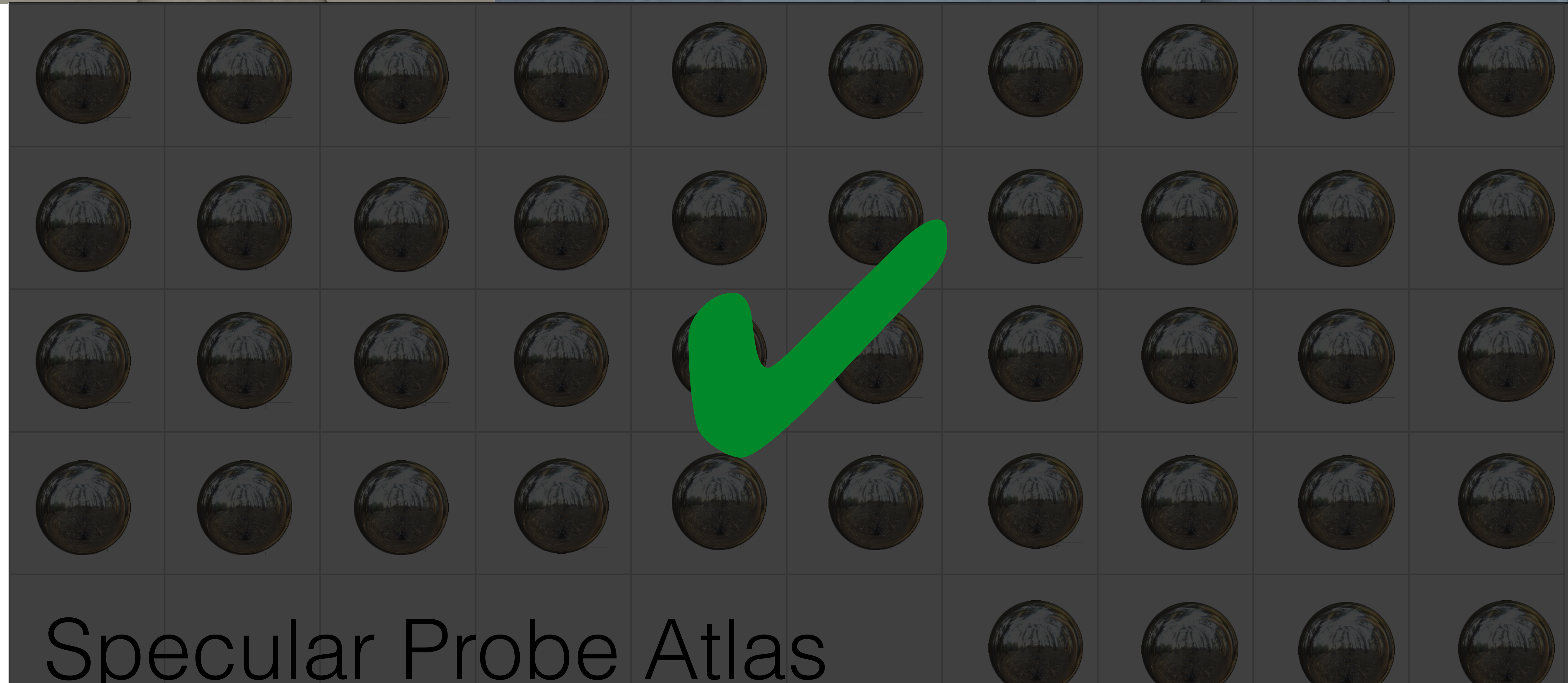




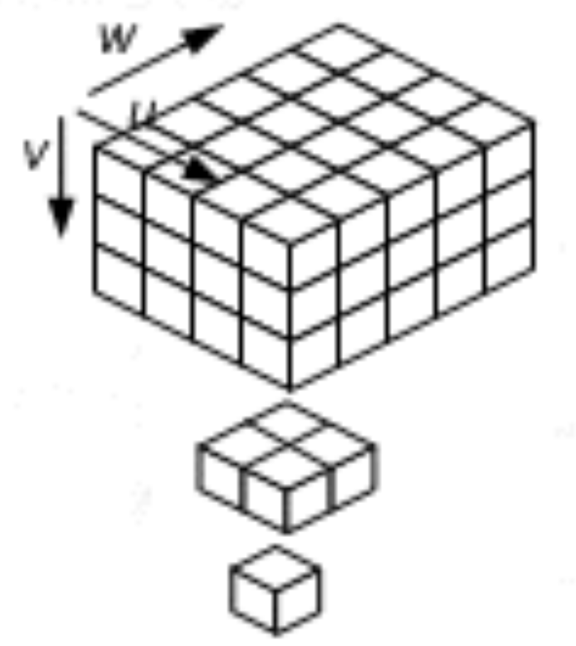
Global Illumination Data





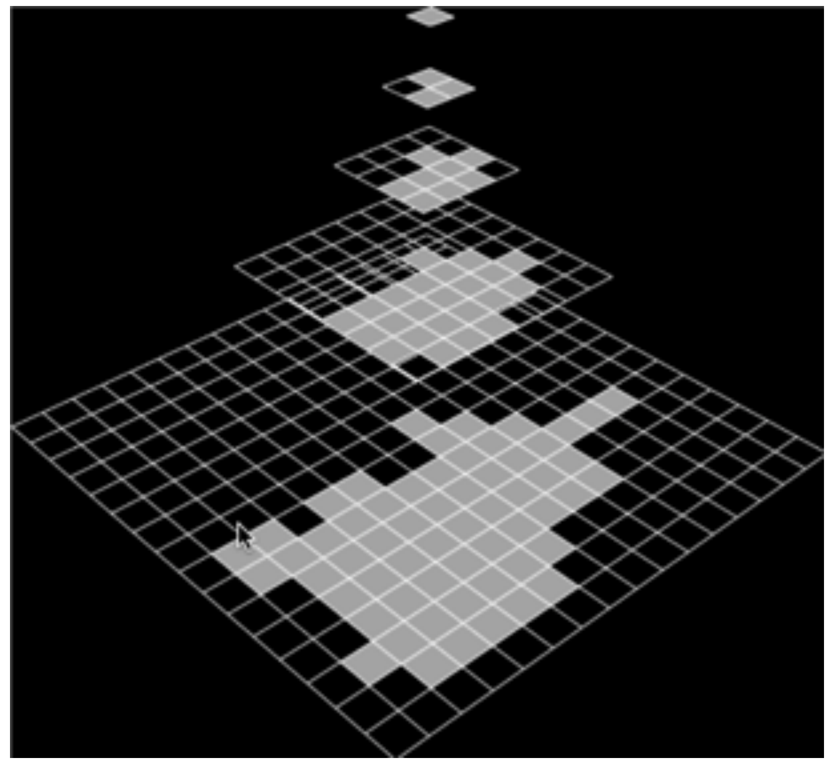


Related Work



GPU Volume Textures

— Can’t use native interpolation due to compression



GPU Sparse Textures

— Too large pages for fine grained tree structure

— May not be available on target platforms for future games

Related Work

Adaptive Volumetric Data Structures

— Irradiance Volumes [Greger98, Tatarchuk05]

— GigaVoxels [Crassin09]

— Sparse Voxel Octrees [Laine and Karras 2010]

— Tetrahedralization, e.g., [Cupisz12], [Bentley14], [Valient14]

— Sparse Voxel DAGs [Kämpe13]

— Open VDB [Museth13]

Adaptive Voxel Tree

Implicit spatial partitioning

Branching factor of 64

Multi-scale data

Adaptive Voxel Tree

Implicit spatial partitioning

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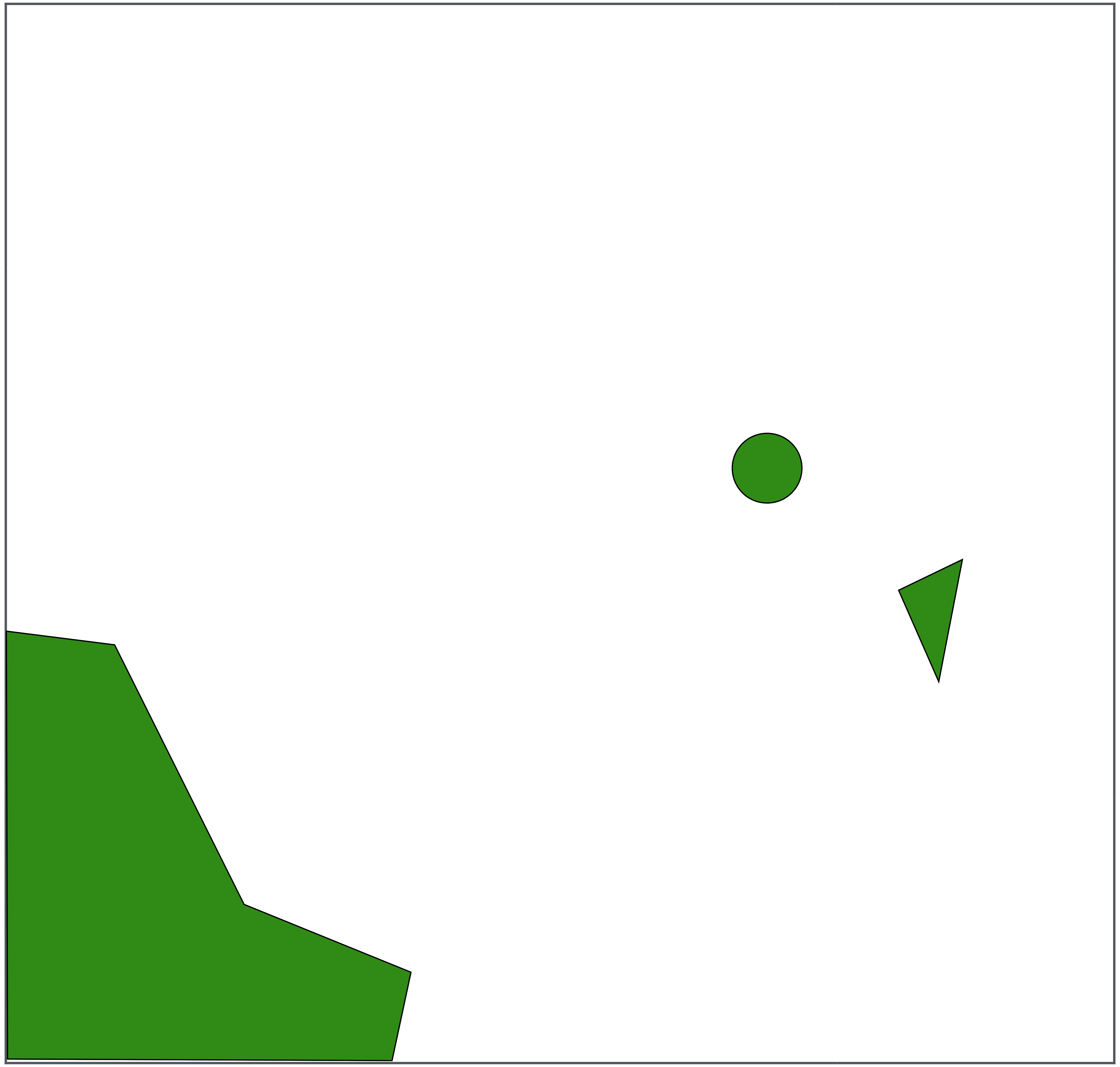

Adaptive Voxel Tree

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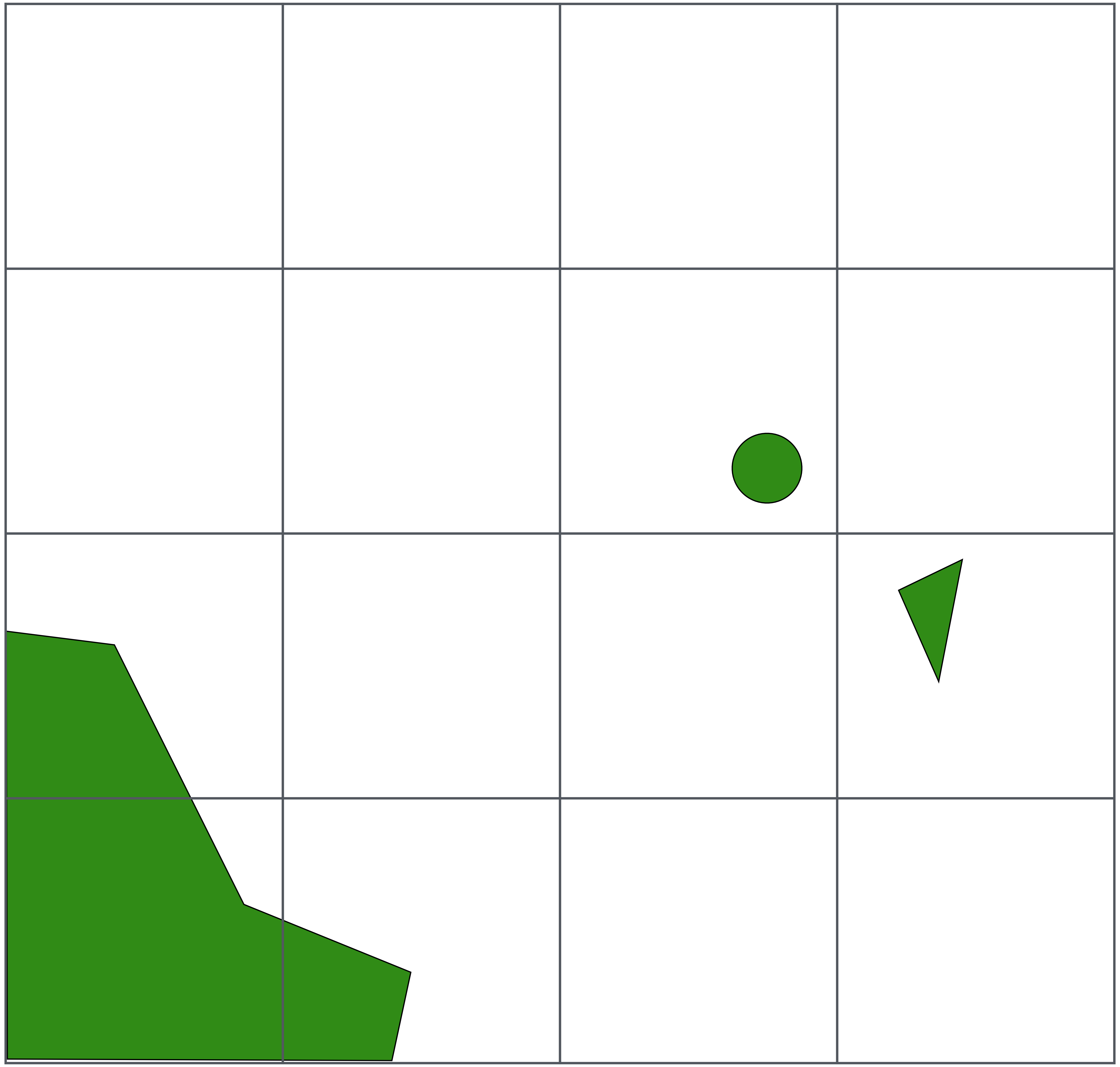

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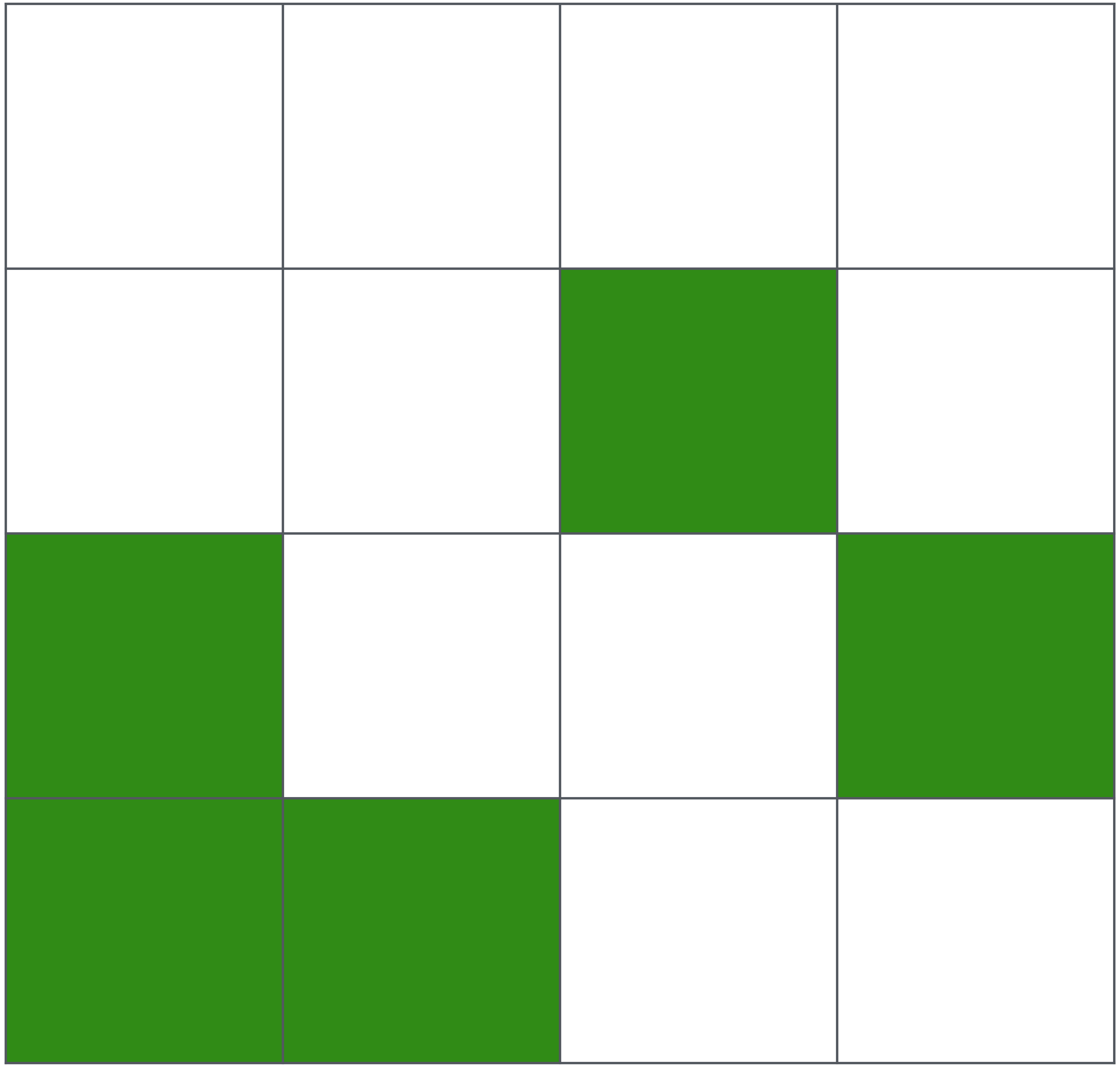

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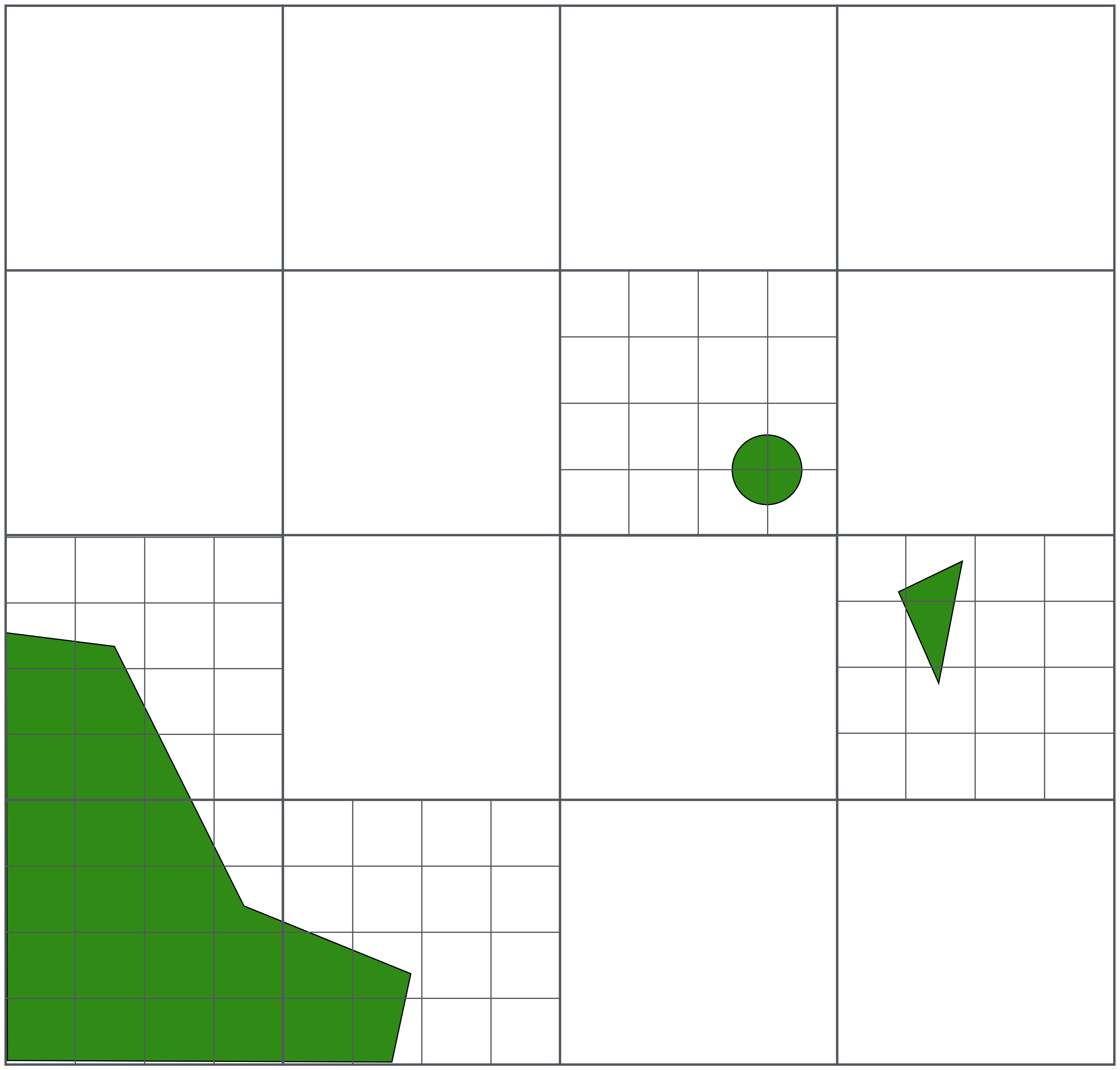

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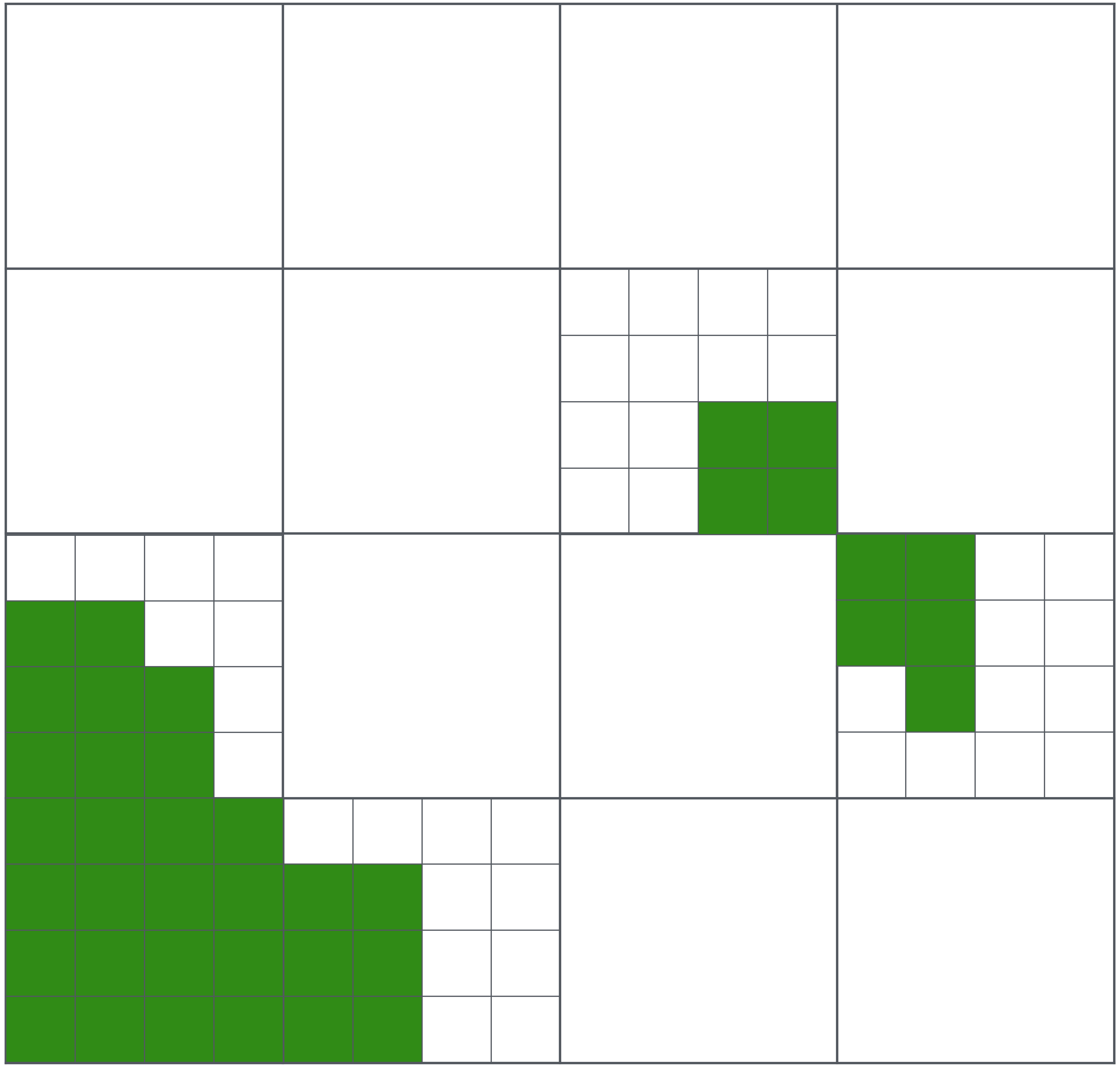
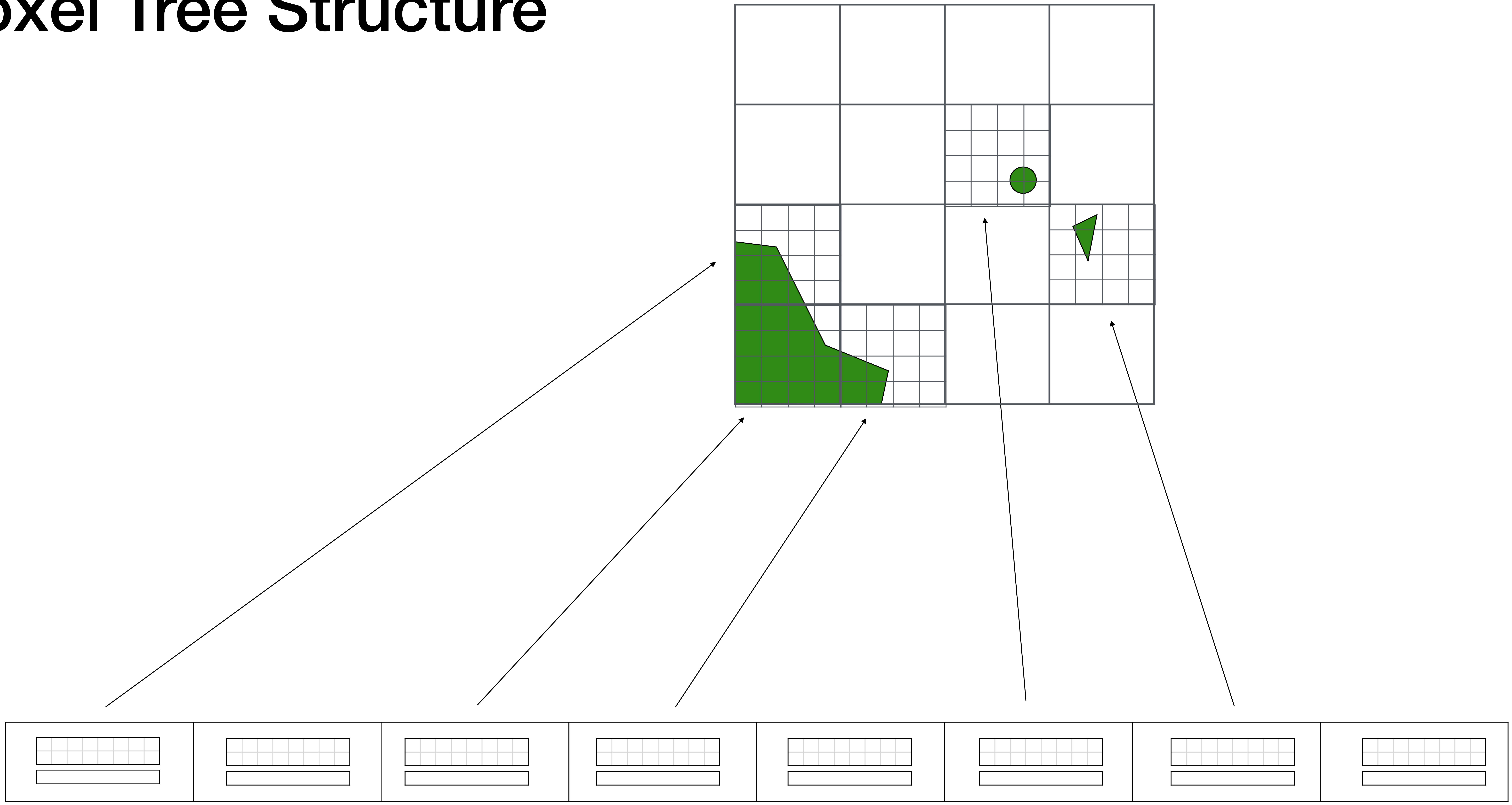
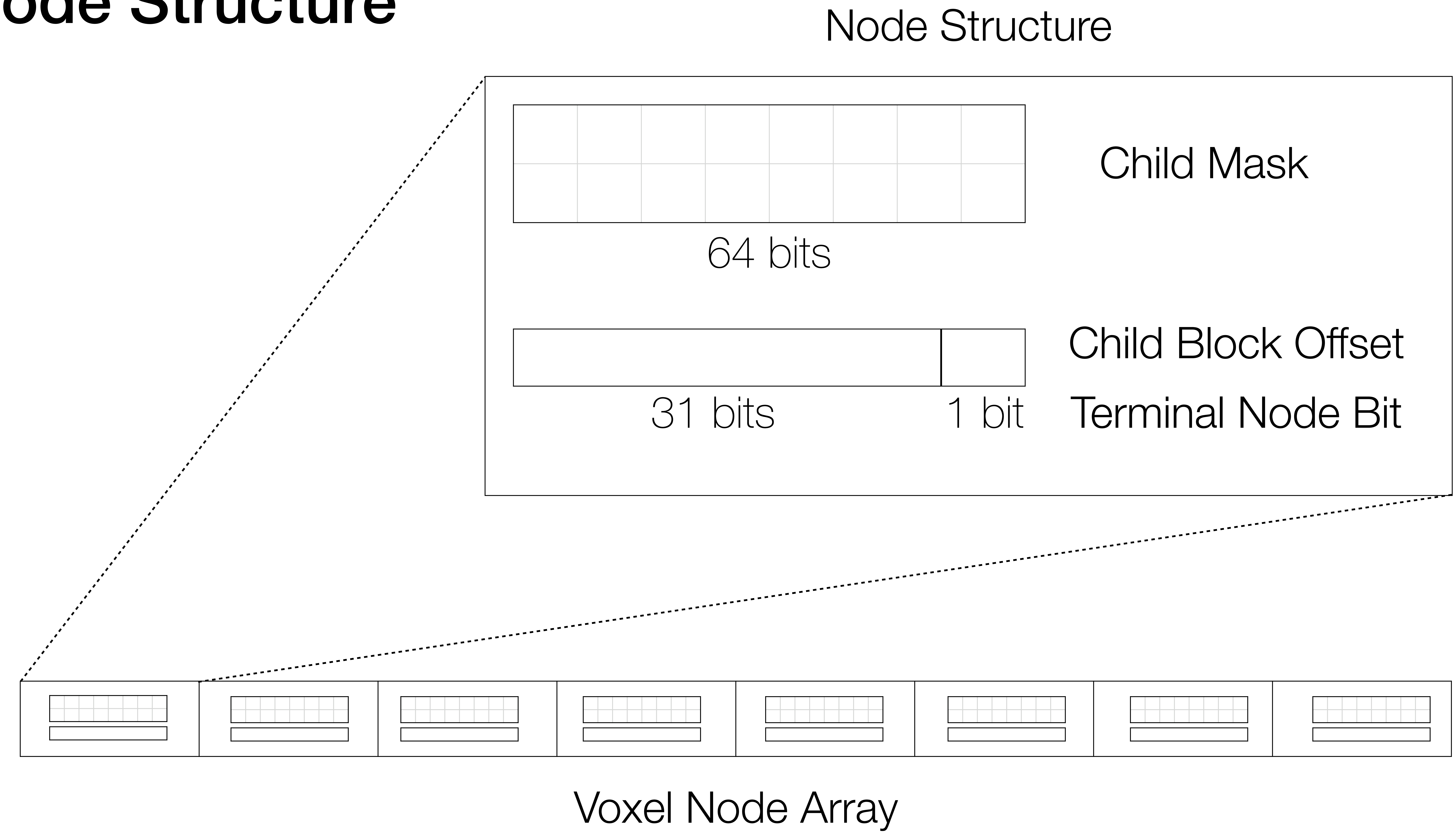


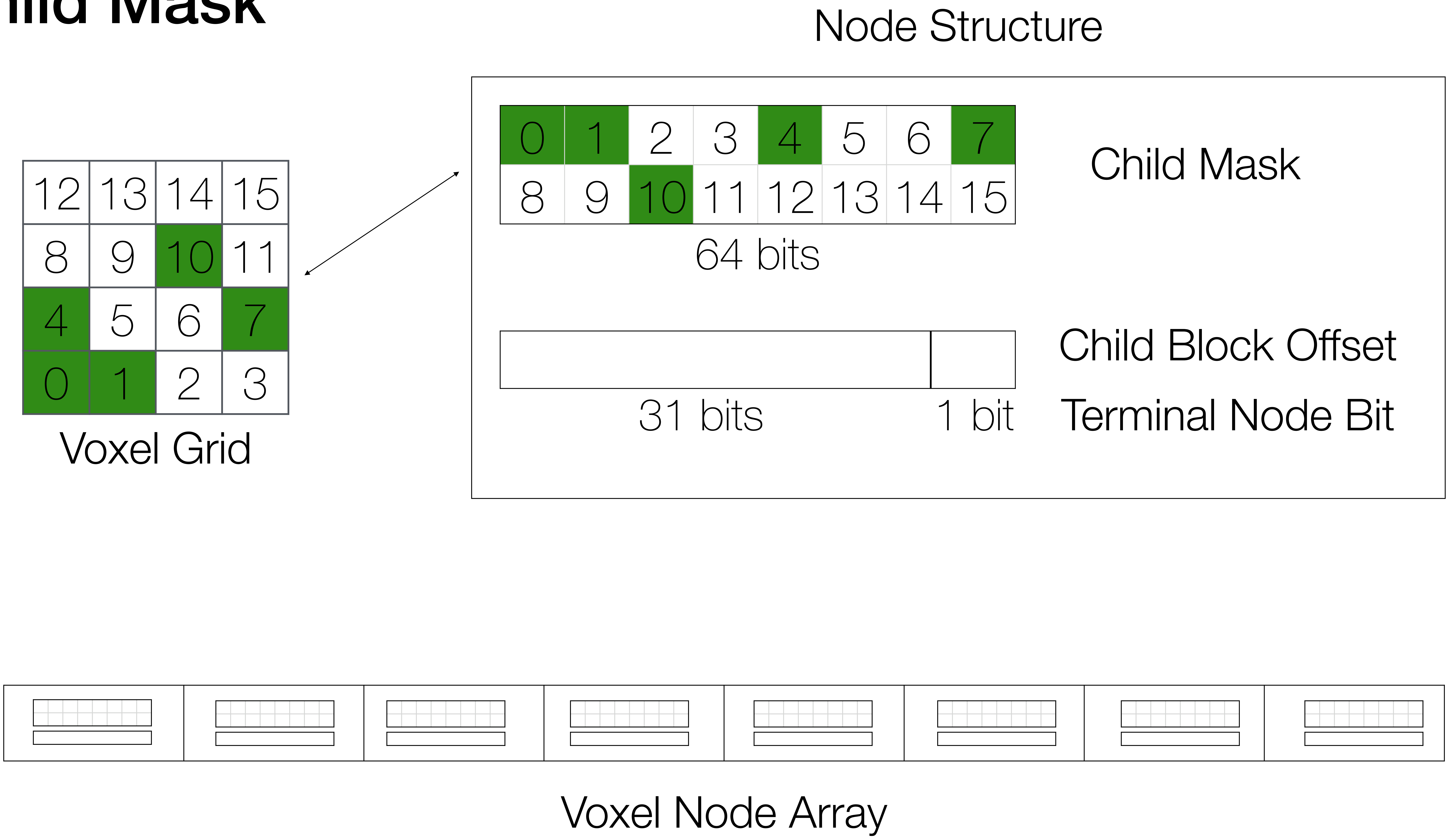
Voxel Tree Structure



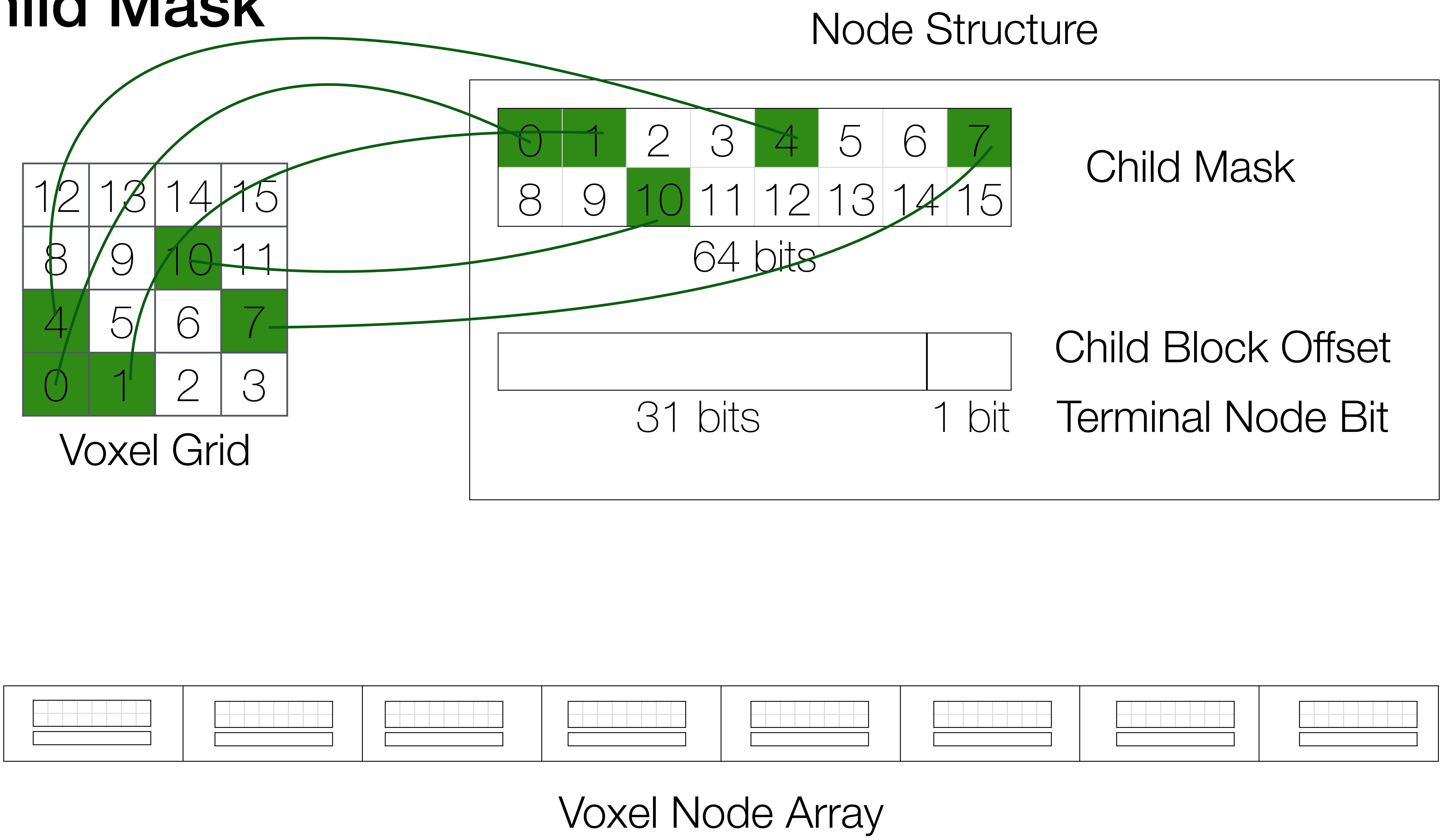
Node Structure



Child Mask


Node Structure
12 13 14 15
8 9 10 11
4 5 6 7
0 1 2 3
Voxel Grid
0 1 2 3 4 5 6 7
8 9 10 11 12 13 14 15
64 bits
Child Mask
Child Block Offset
31 bits
1 bit
Terminal Node Bit
Voxel Node Array

Child Mask



Node Structure
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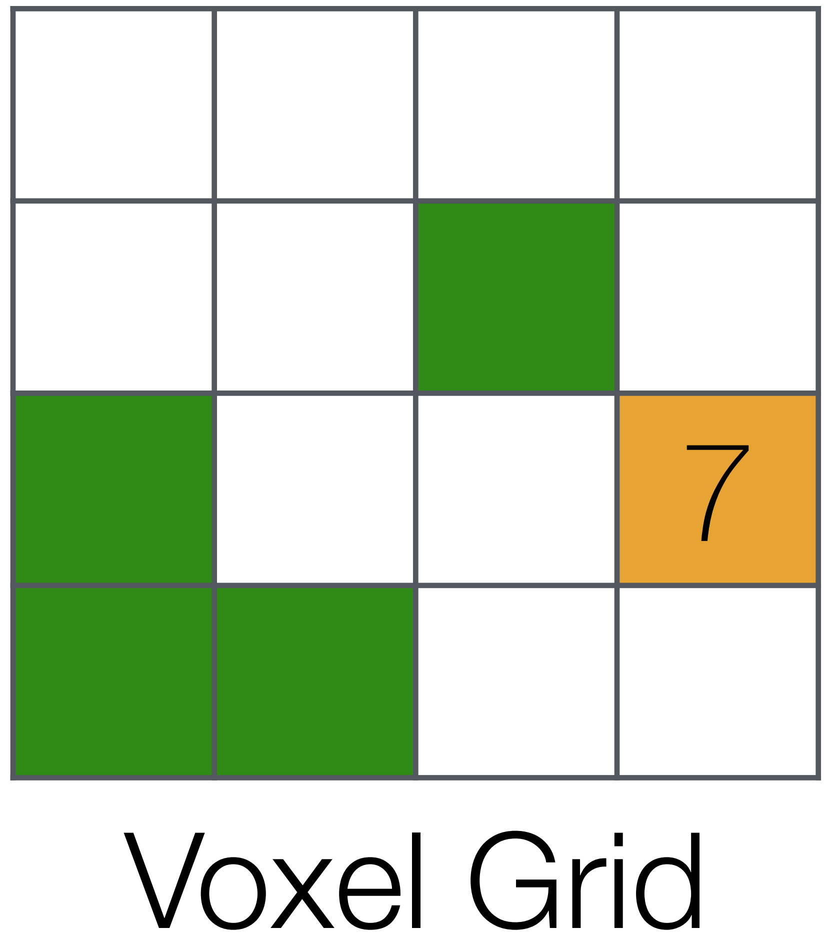
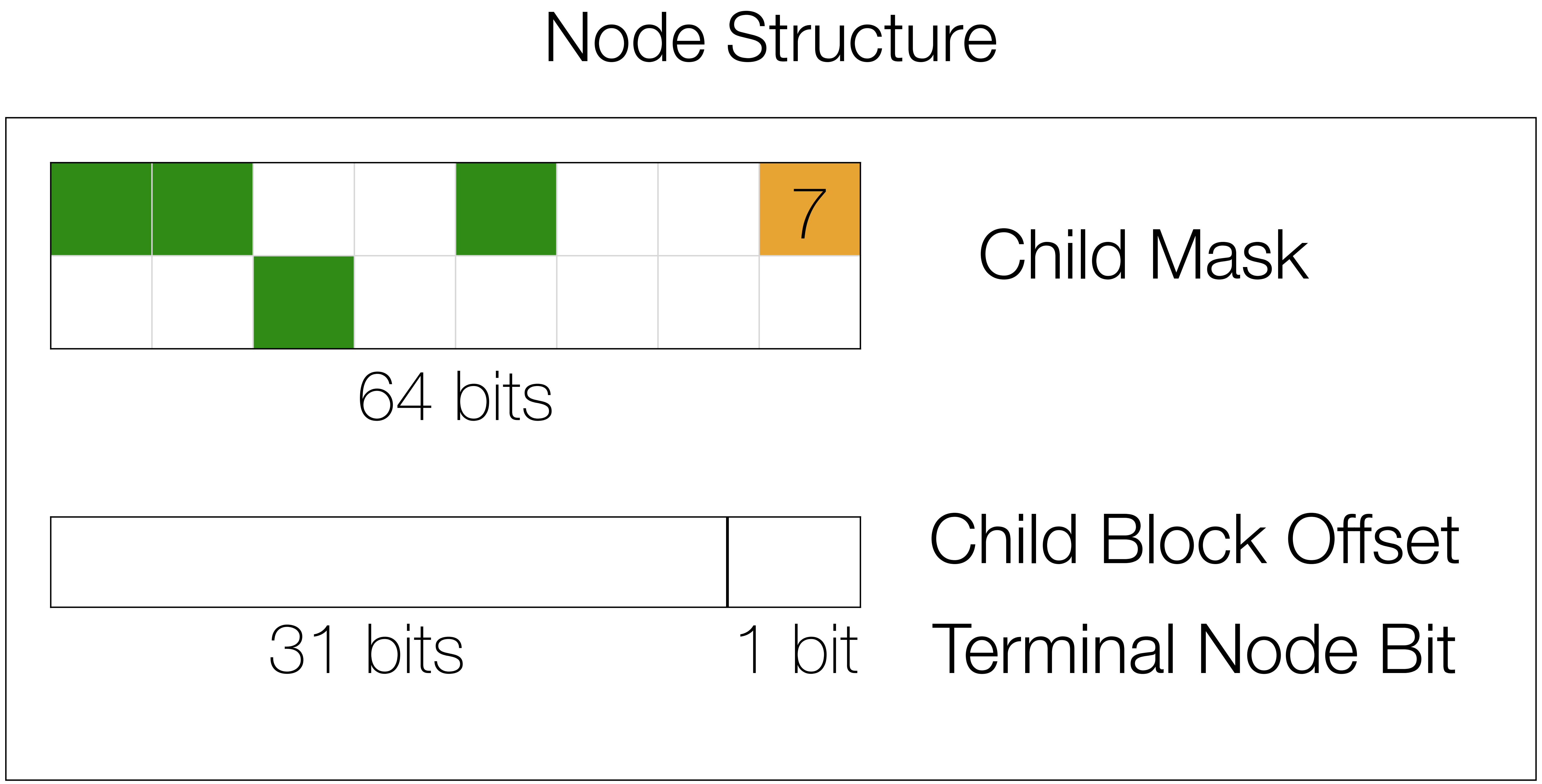
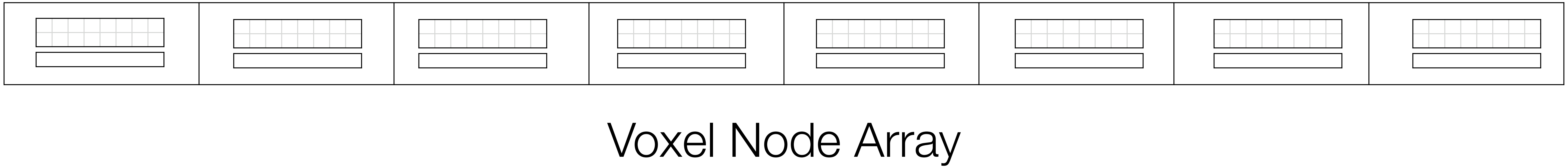
Voxel Node Array

Tree Traversal

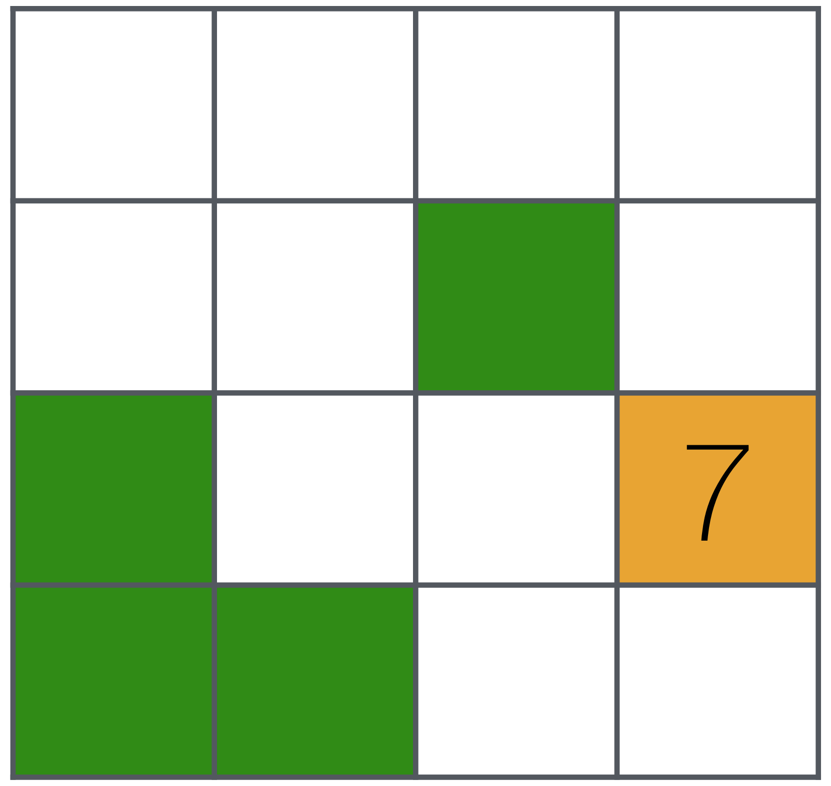




Child Index = ?

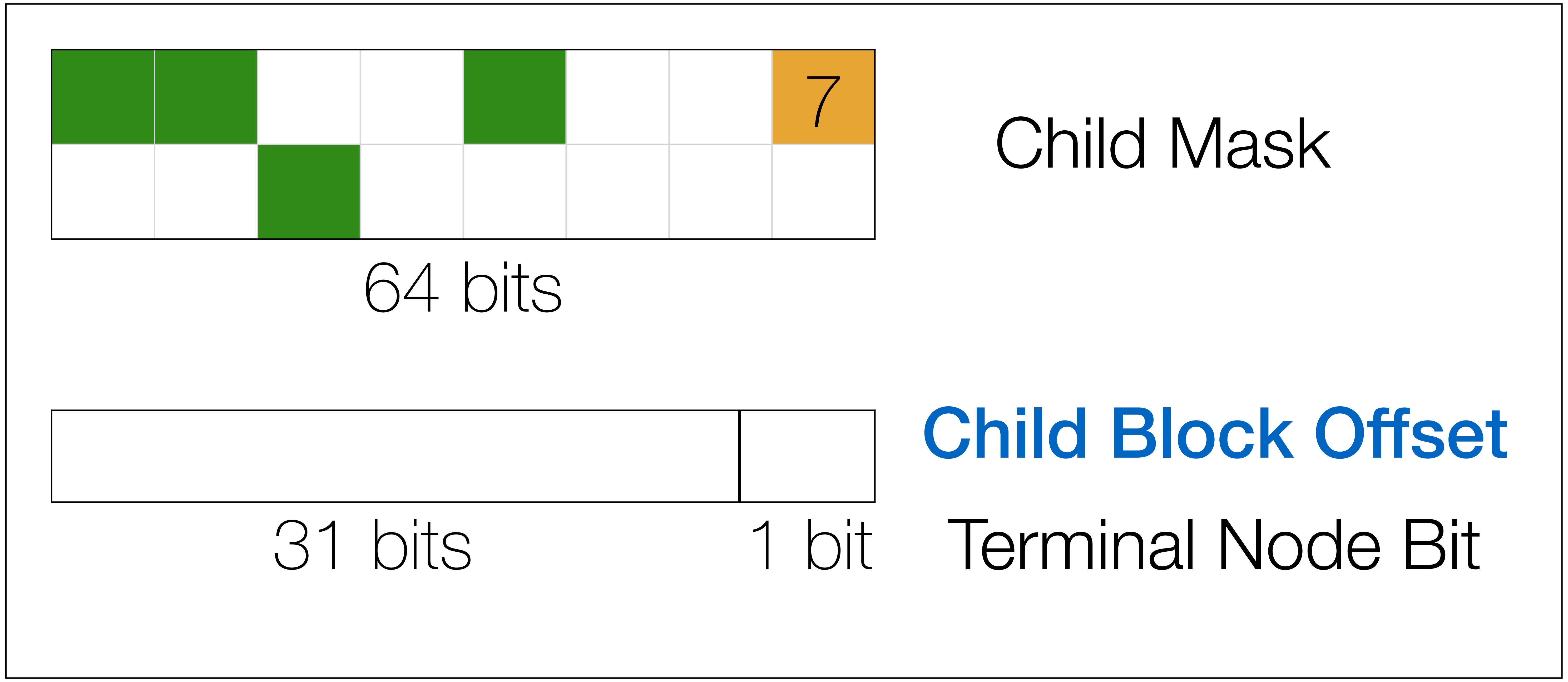


Tree Traversal

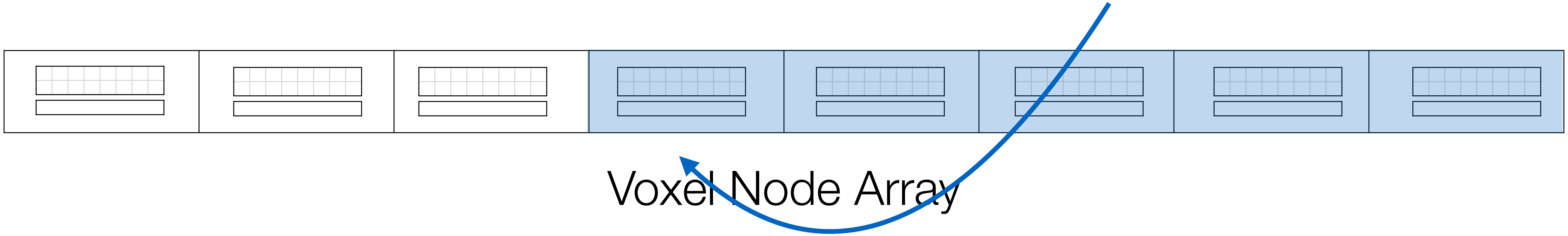


Voxel Grid

Node Structure

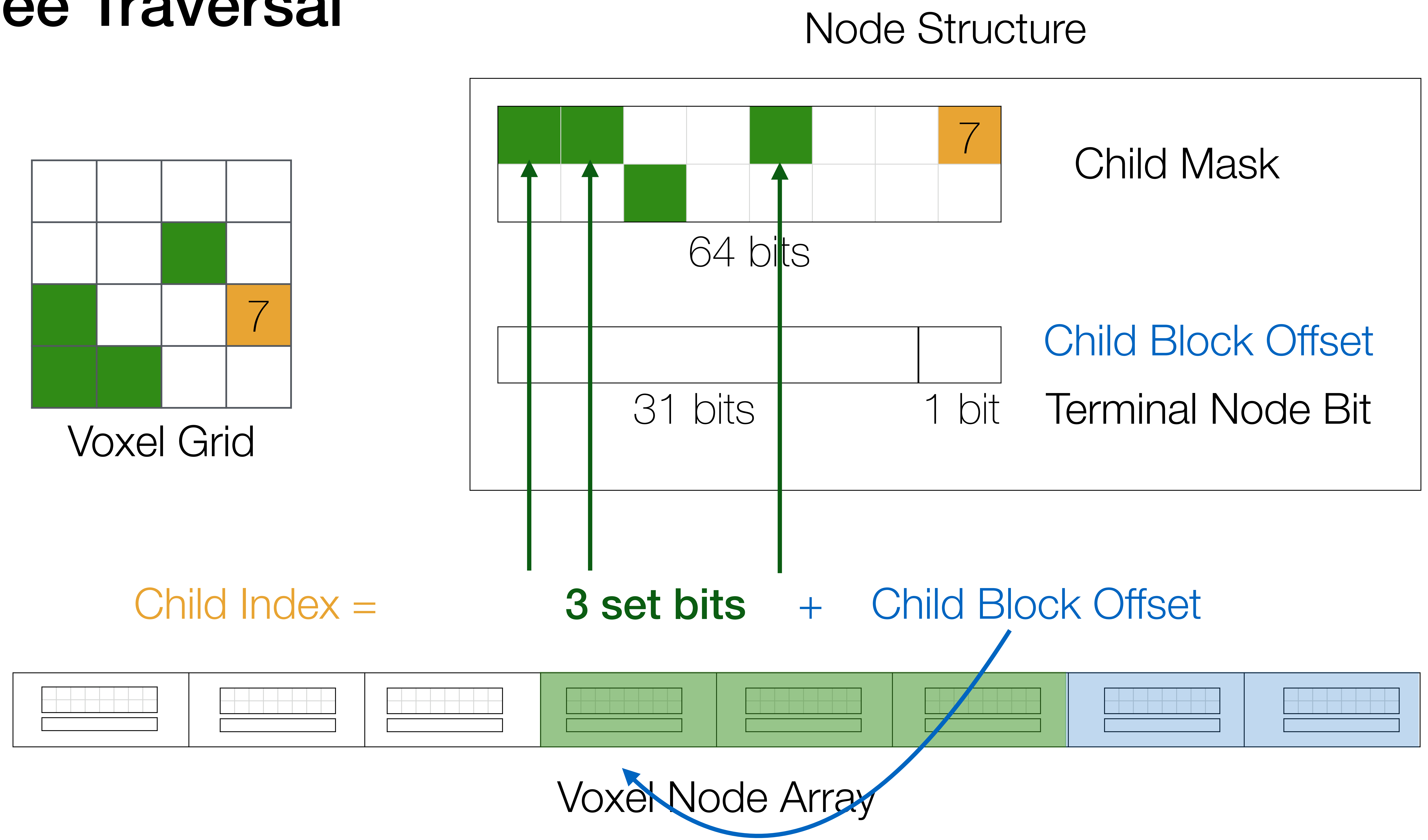


Child Index = + **Child Block Offset**

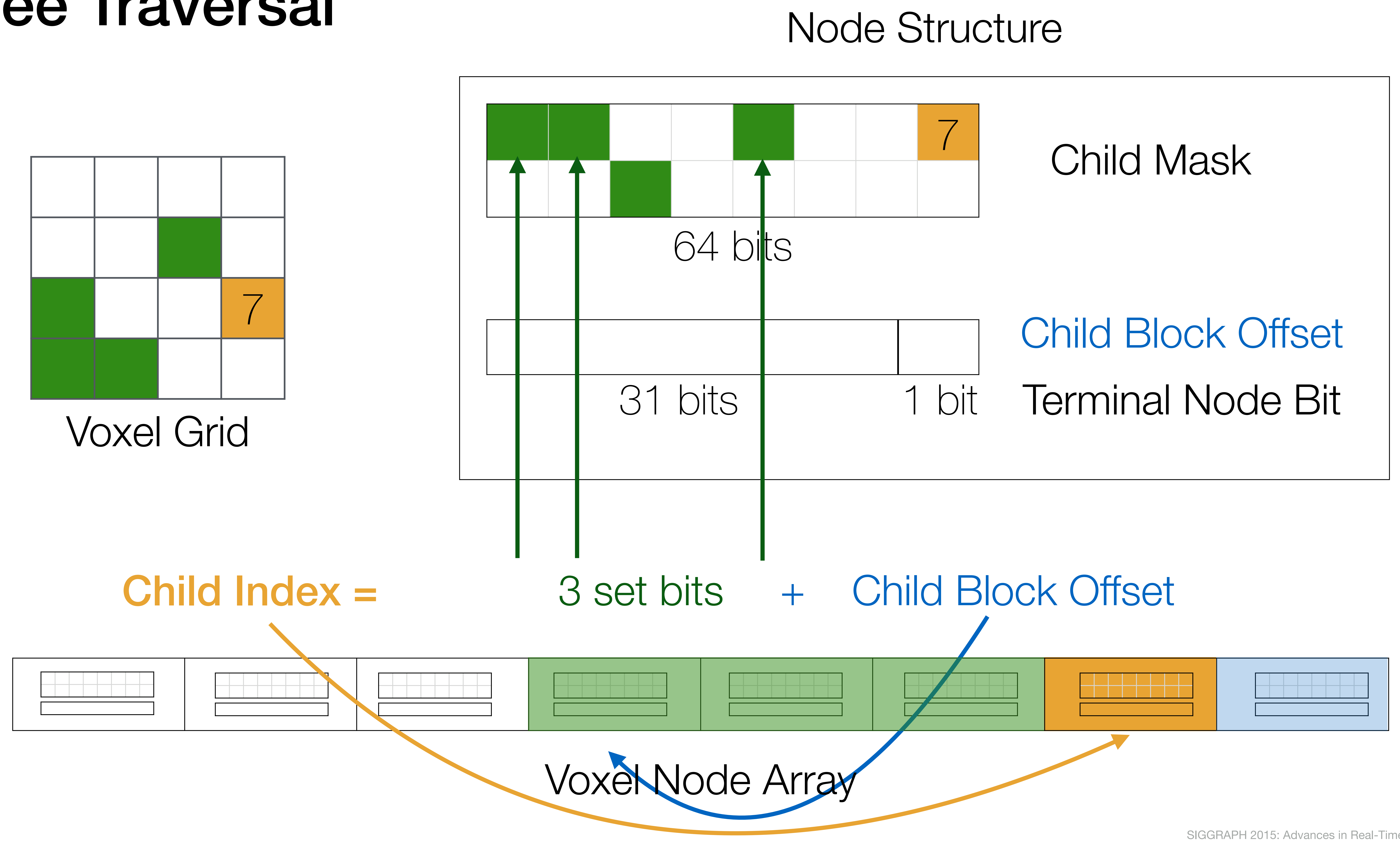


Voxel Node Array

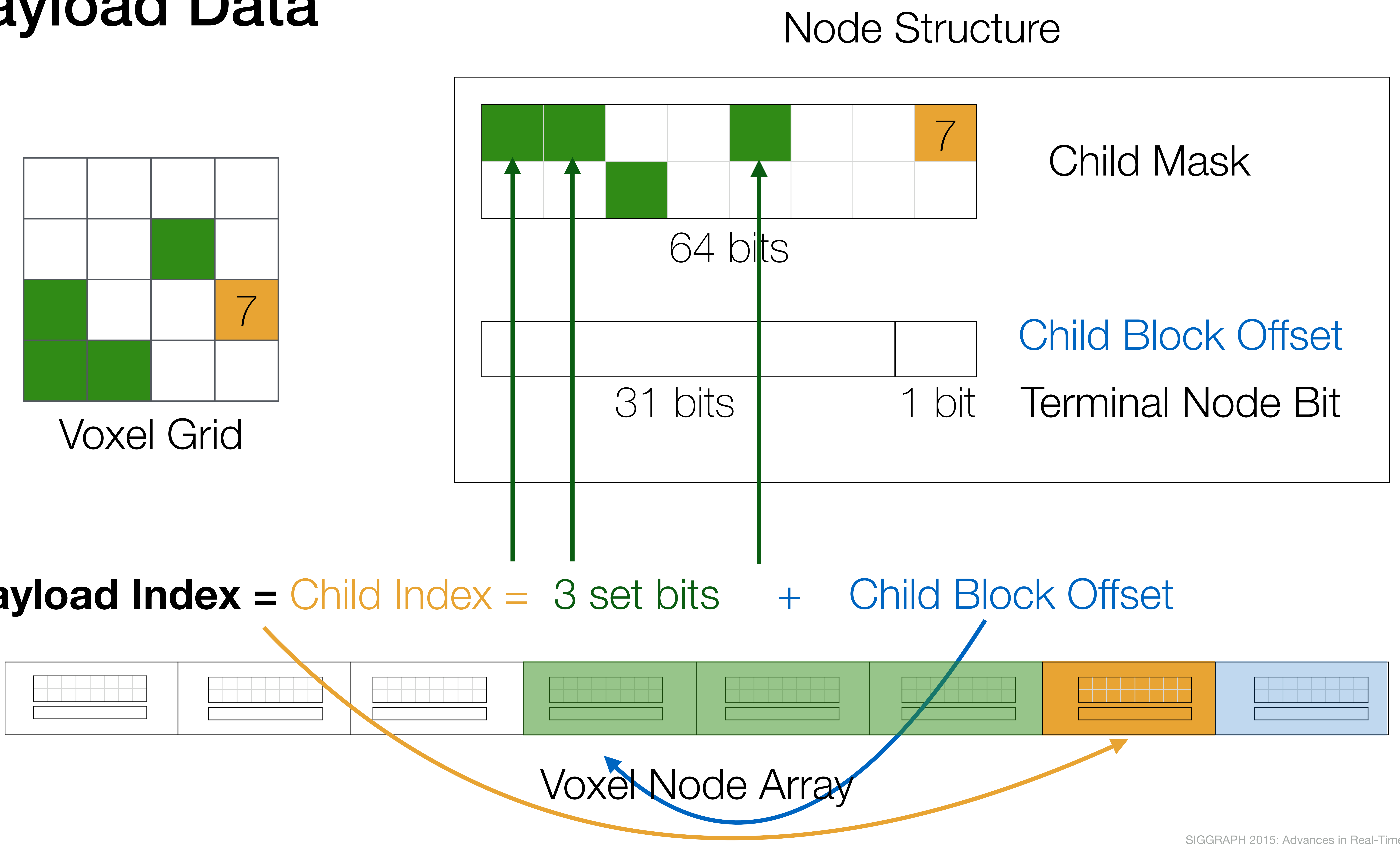
Tree Traversal



Tree Traversal



Payload Data



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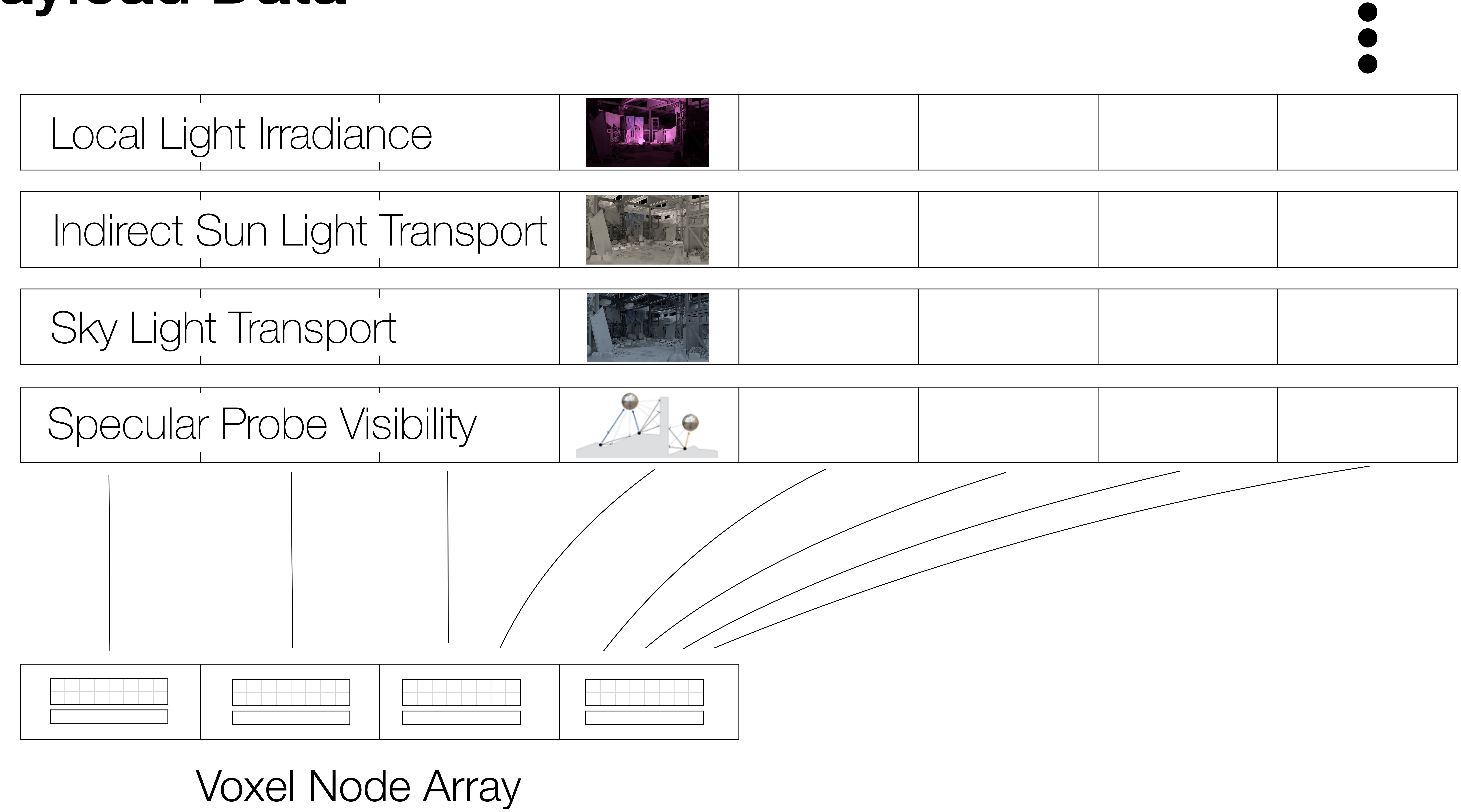


What About Leaf Nodes?

Leaf nodes are **implicit**: they only show up in the child masks of their parent voxels

Compact trees encoding only the **topology**

Only a **few hundred kilobytes** for an entire level

First Level Lookup

First level of the tree can have **arbitrary** dimensions

We use a **dense** grid of 8x8x8 meter cells to guarantee coverage for large dynamic objects

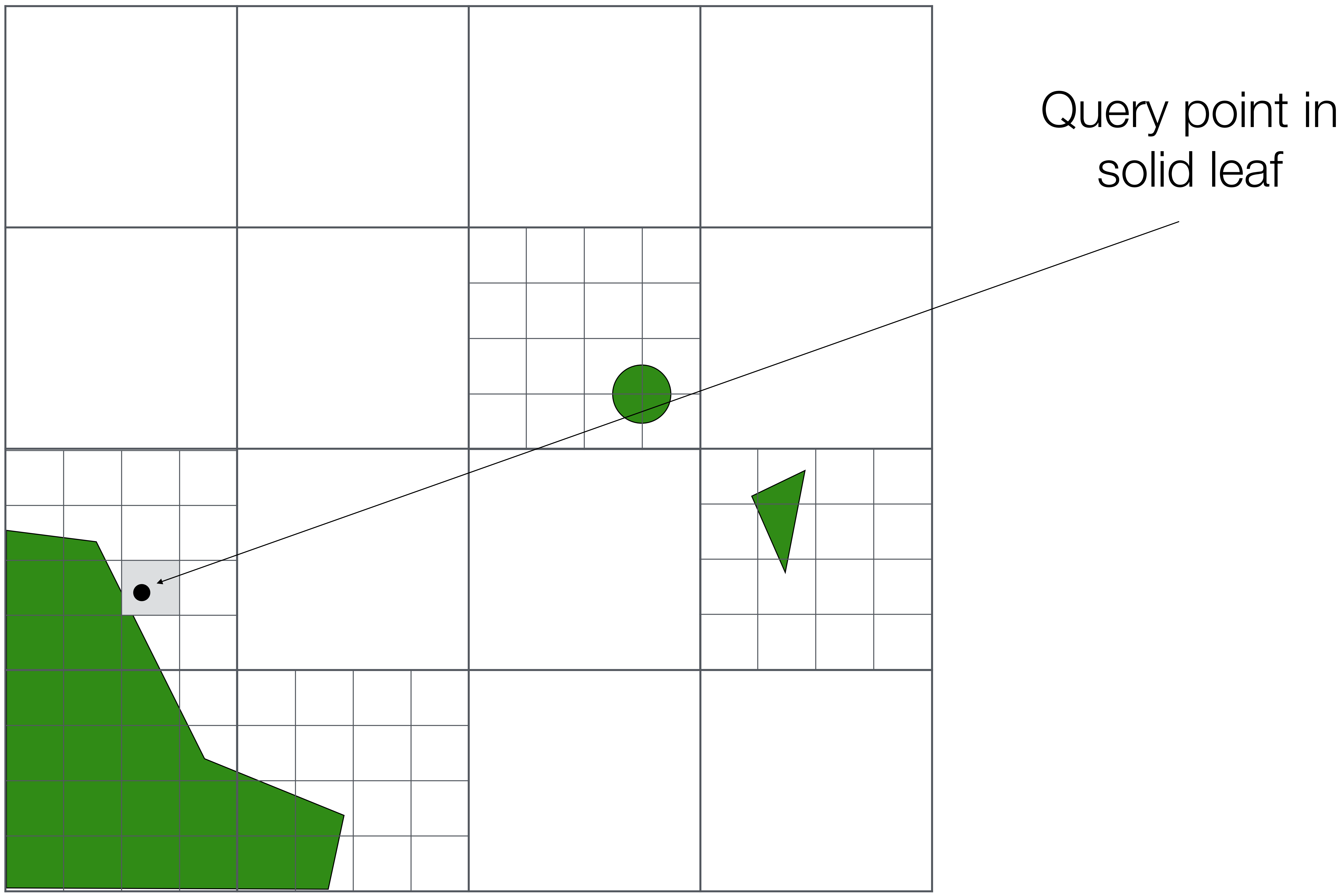
Voxel Tree Visualisation

Seamless Interpolation

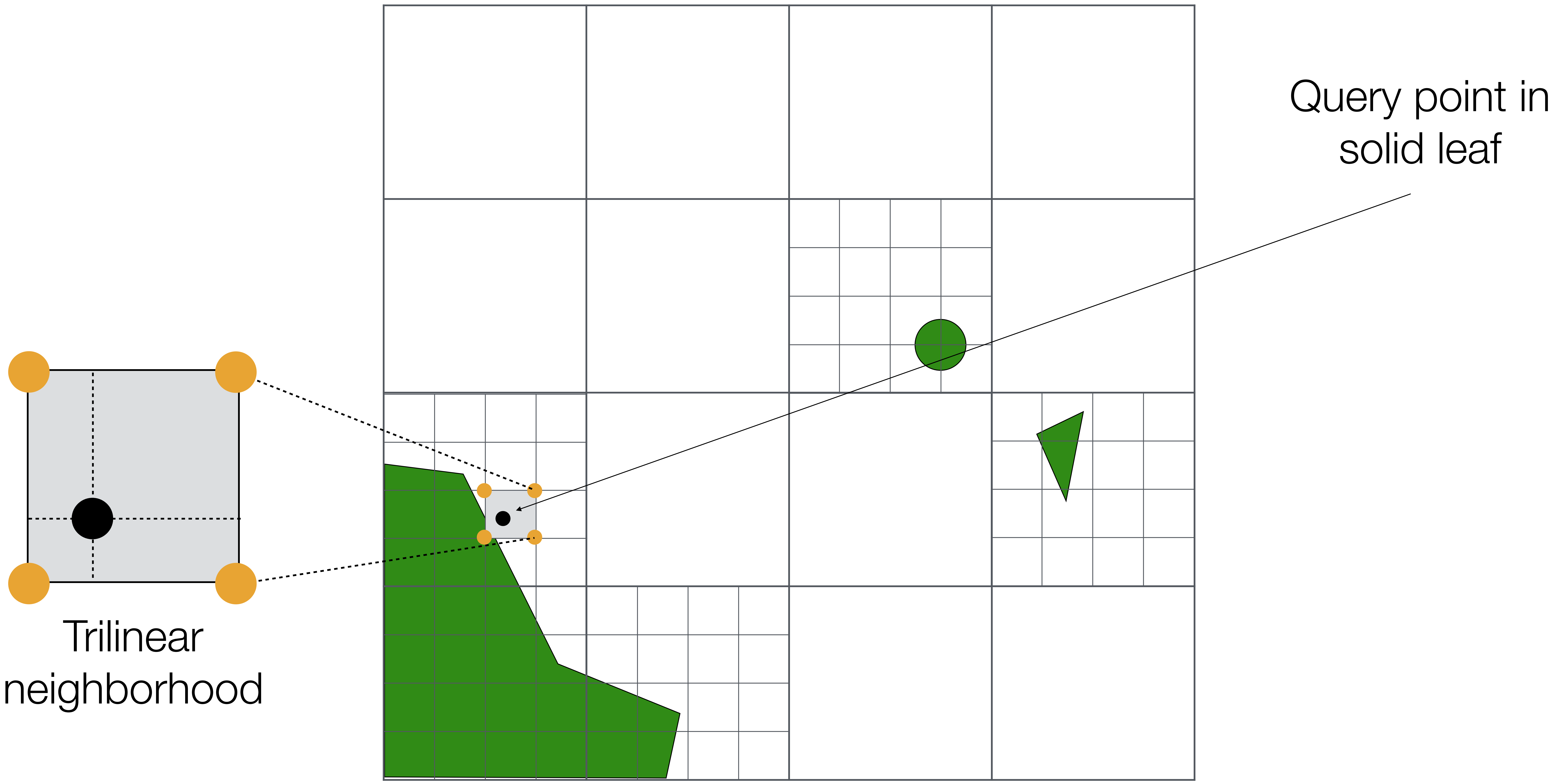
Dynamic and static objects lit by **same** data

Need **seamless** interpolation everywhere

Seamless Interpolation

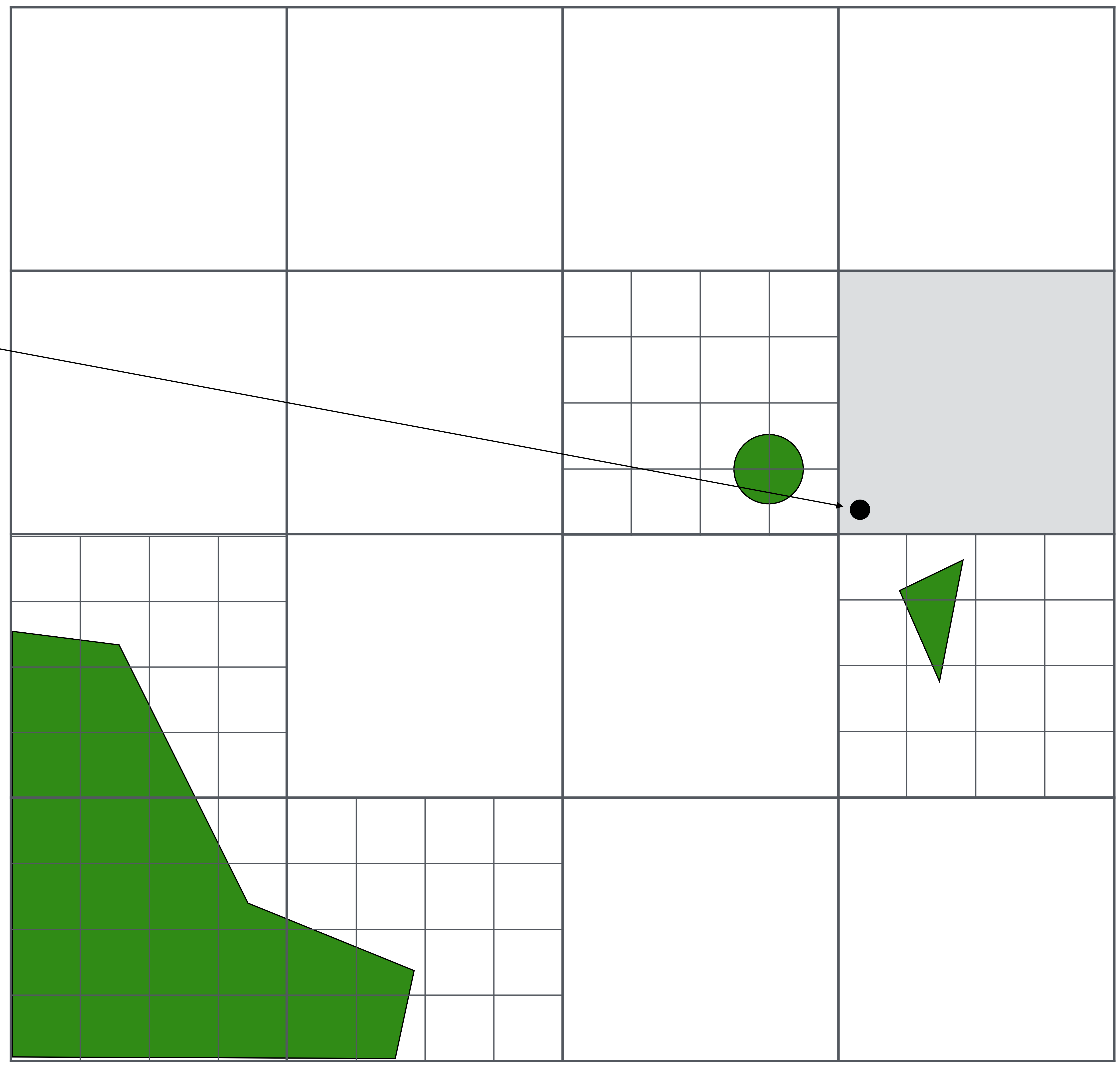


Seamless Interpolation



Seamless Interpolation

Query point in
empty leaf



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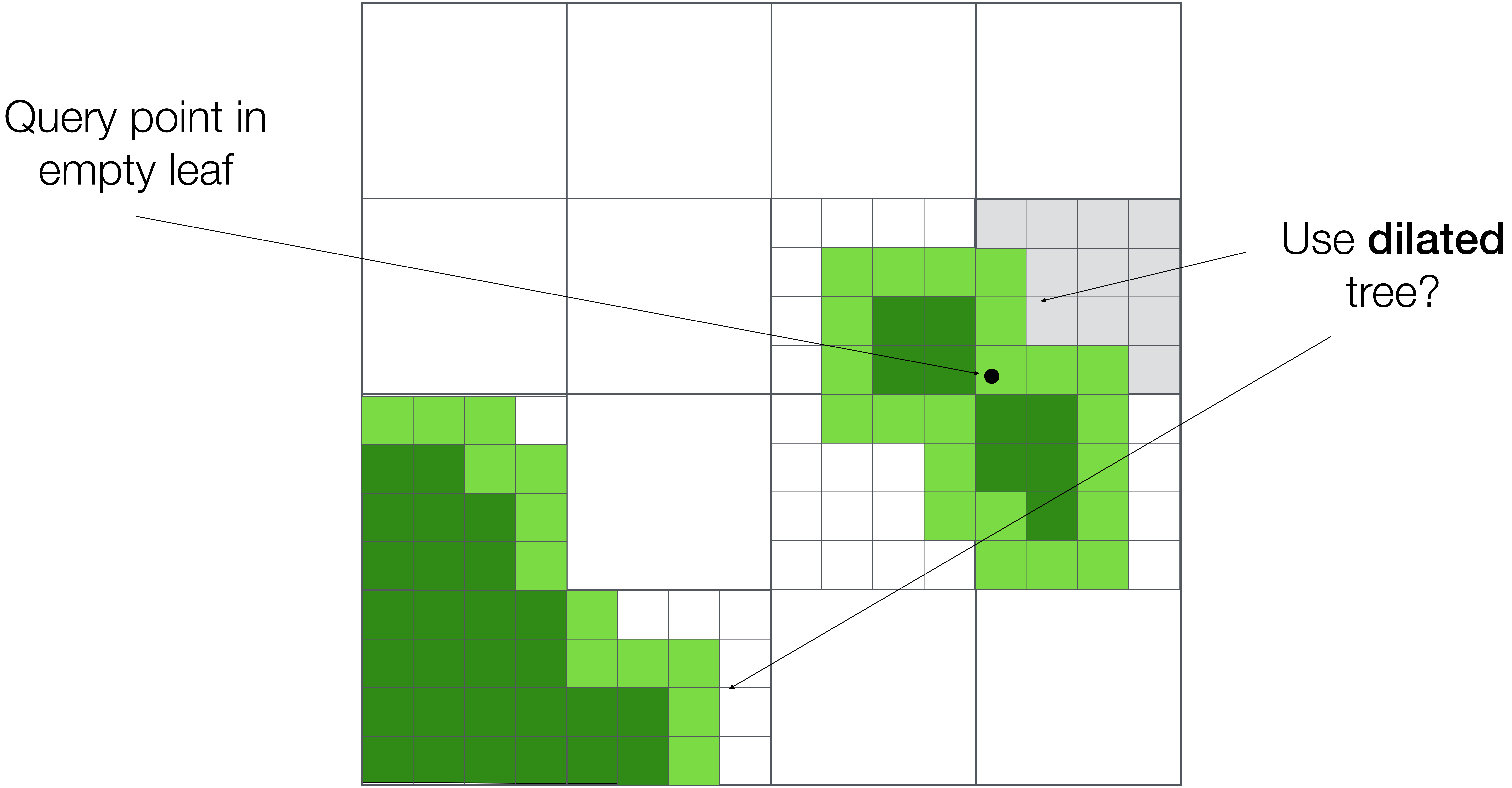

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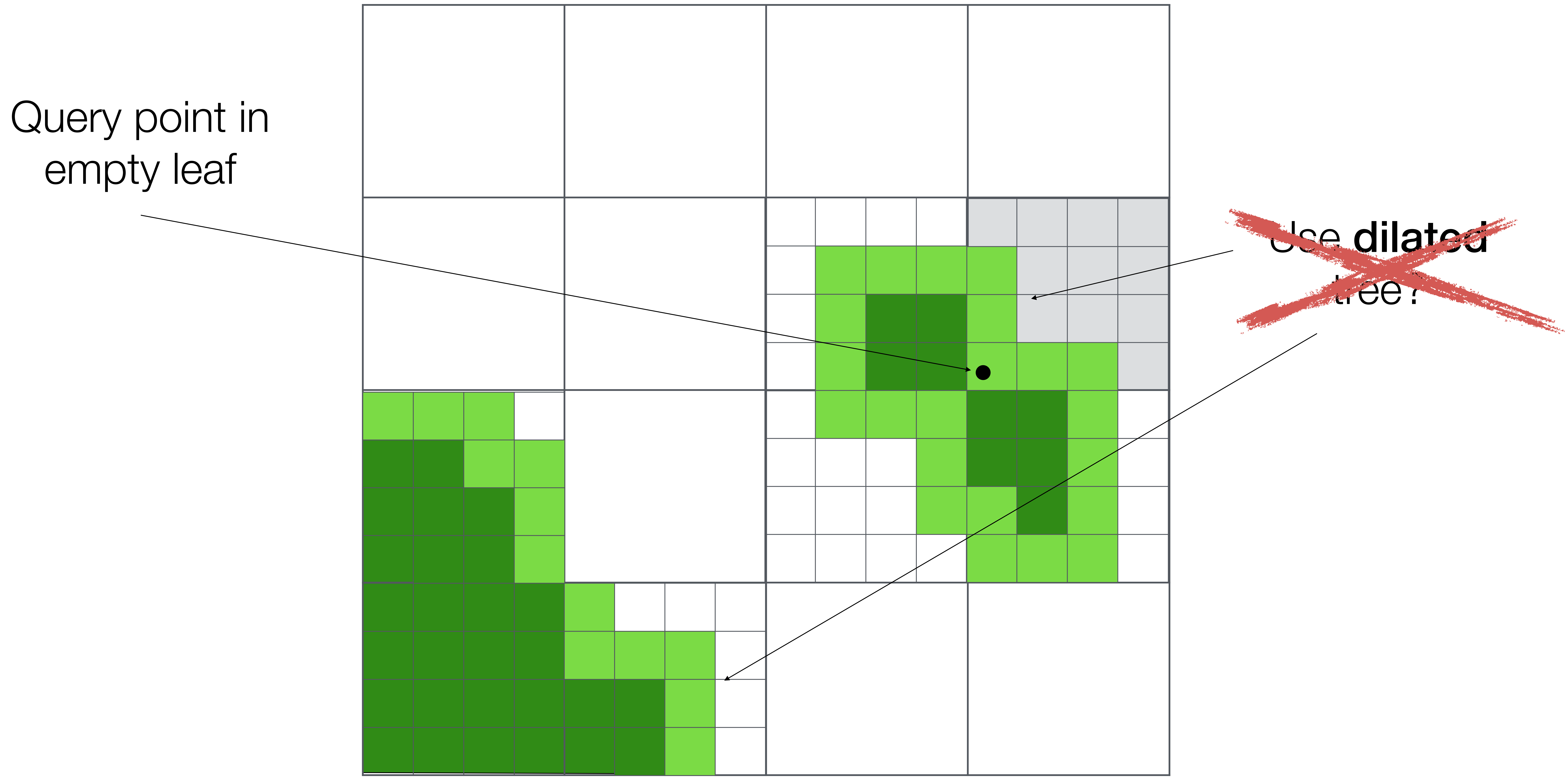
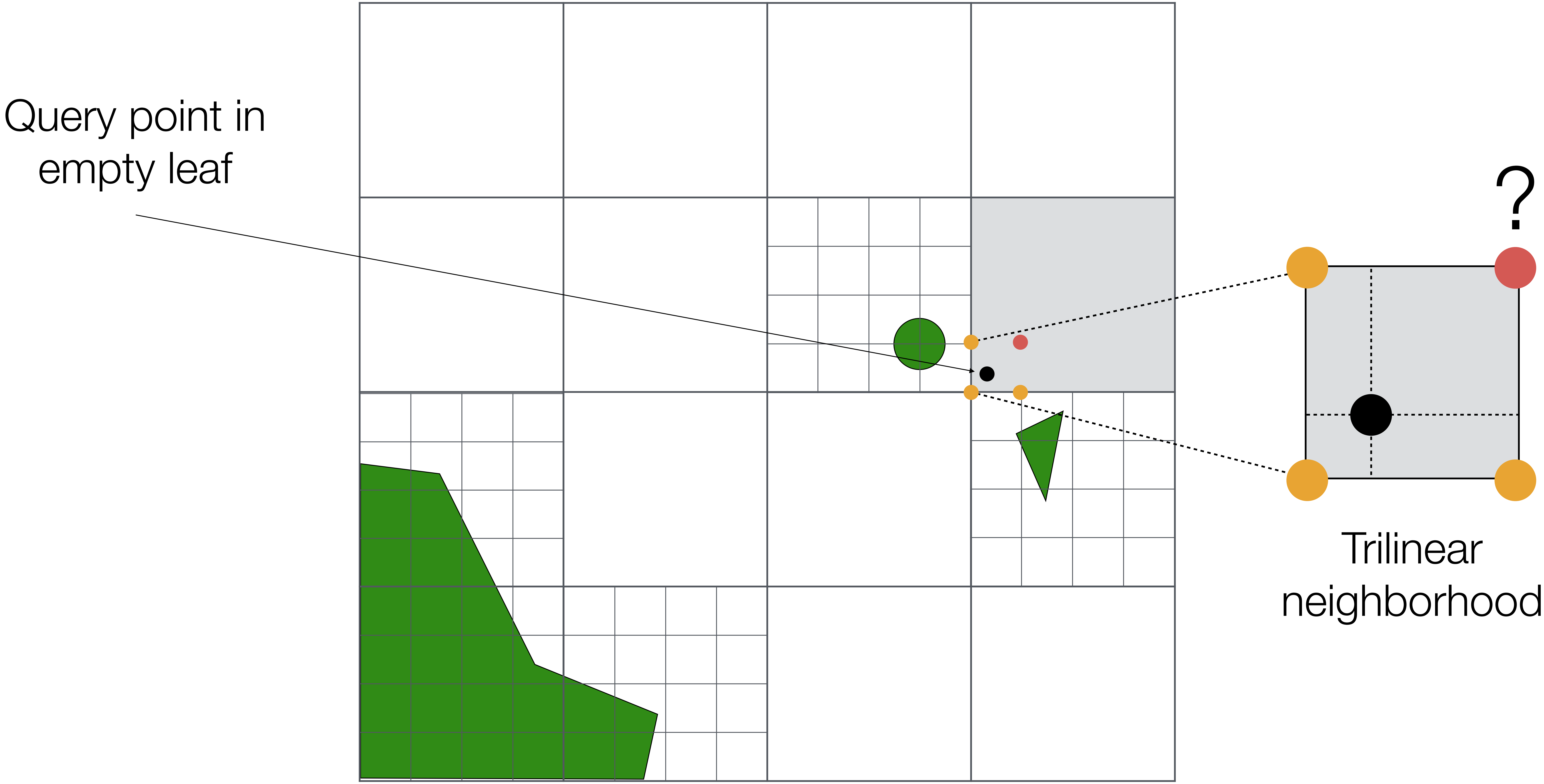


Seamless Interpolation



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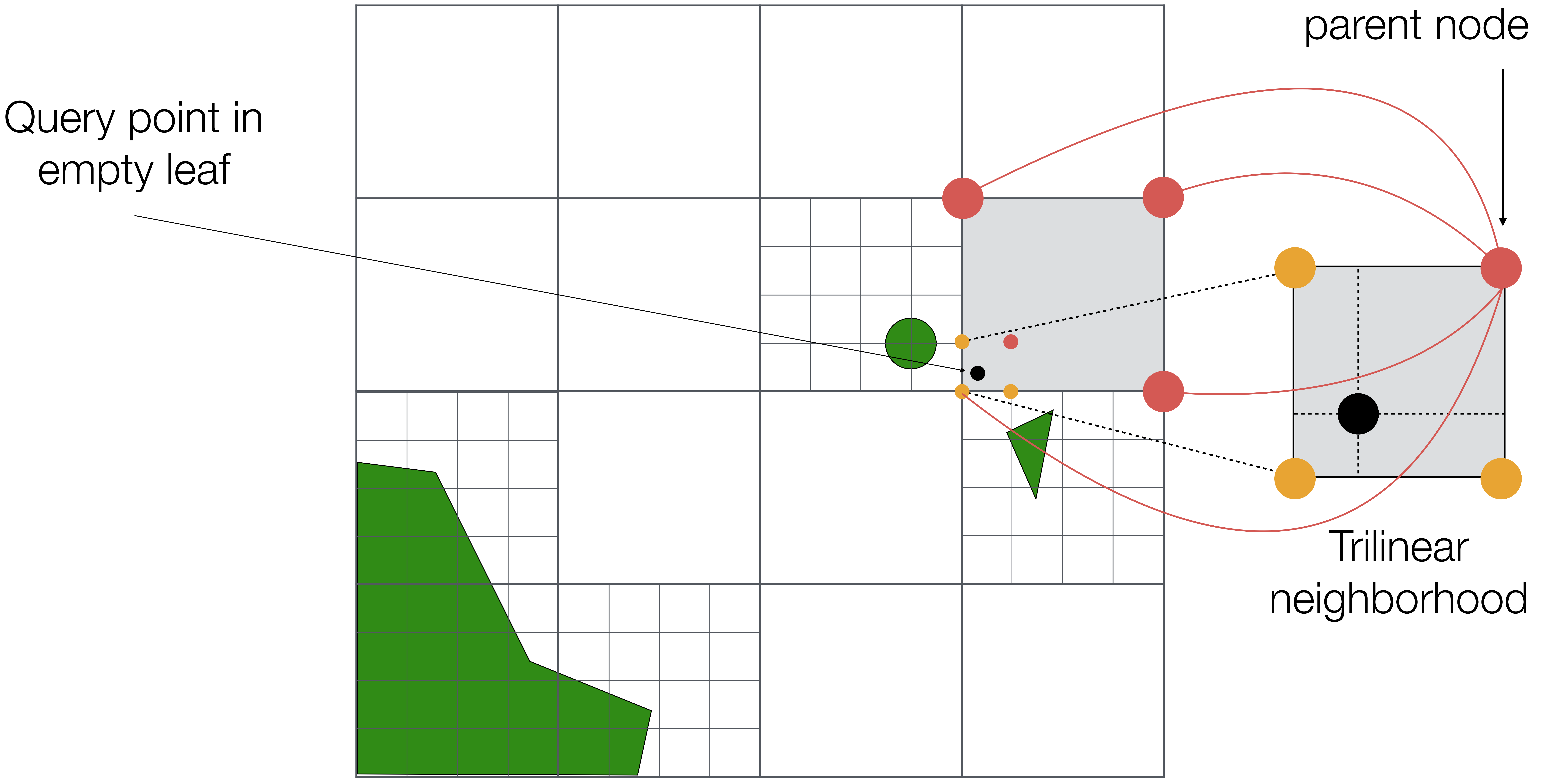

Seamless Interpolation

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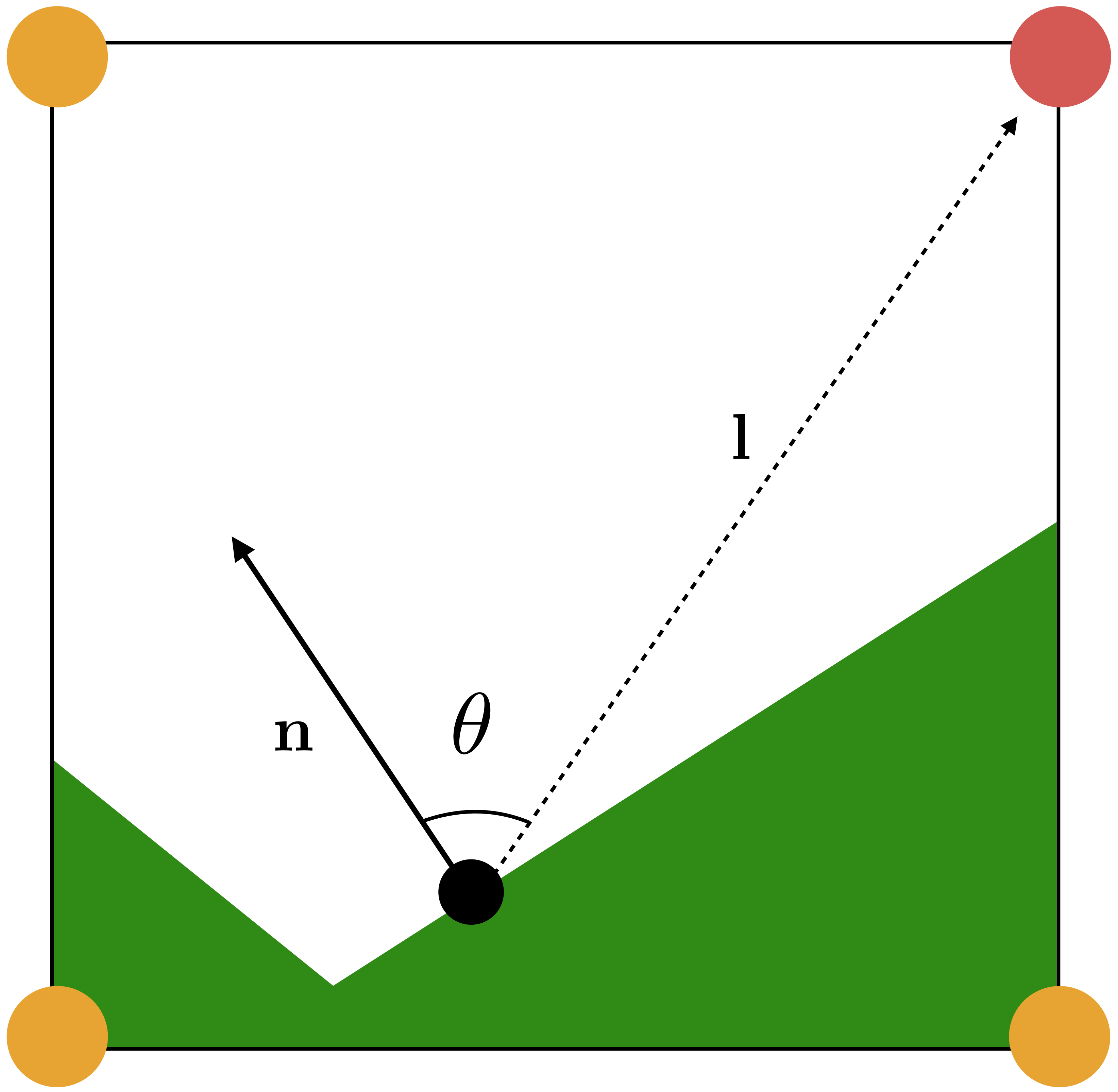
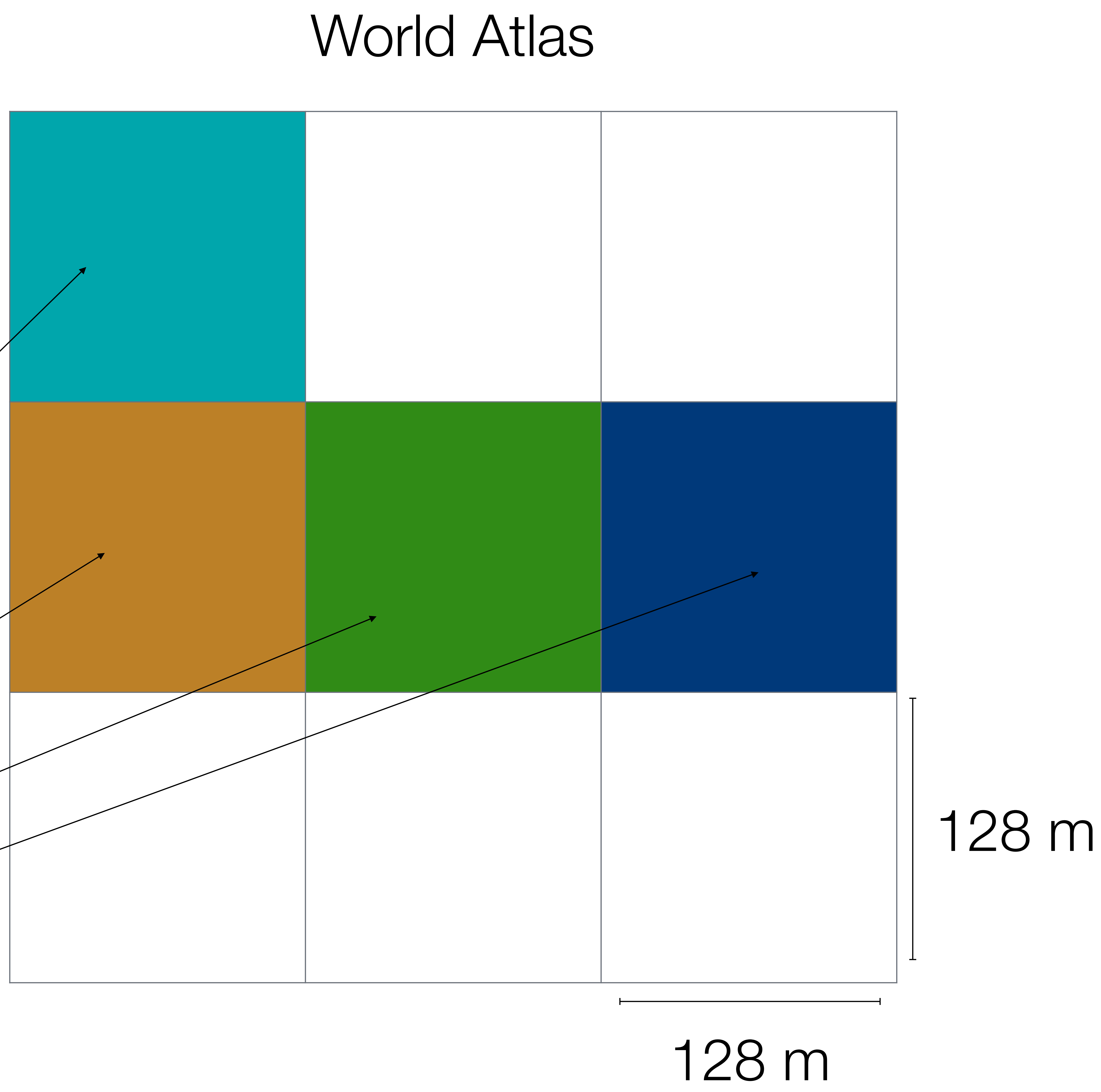
Geometry Weights



Multiply trilinear weight with $\max(0, \cos\theta)$

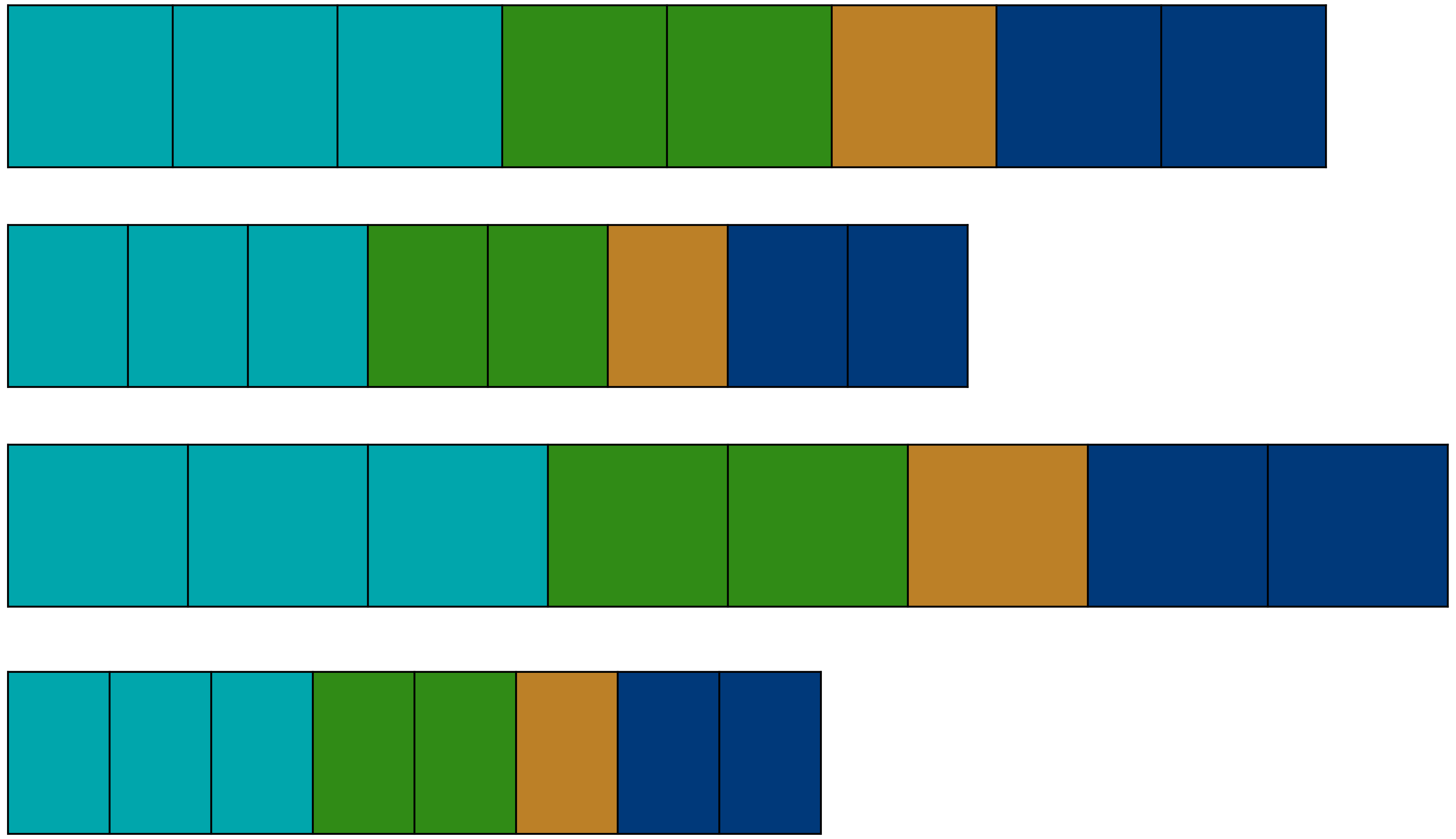
Scaling to Large Scenes

World is divided into a **cell grid** for streaming



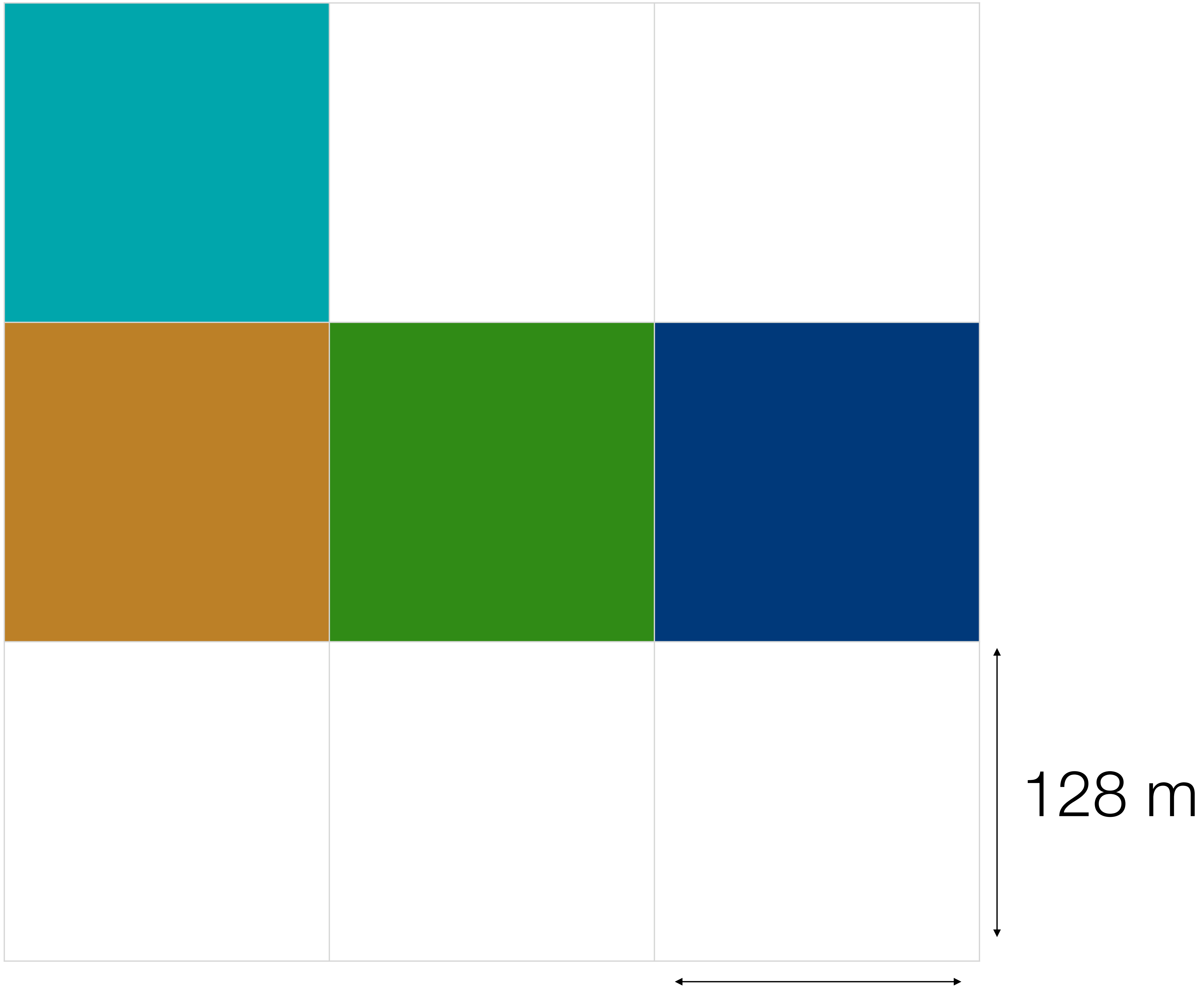
Per cell voxel tree

Scaling to Large Scenes



Linear GPU arrays

World Atlas



Global Illumination

Screen Space + Ambient


Global Illumination
Screen-Space + Ambient


Global Illumination
Screen-Space + Ambient

Performance

Each world cell has max 65K diffuse GI data points

Comparable to **256x256** light map

Performance

Use **reflector lights**
to avoid dynamic fill lights

Local Irradiance


Direct Only
Global Illumination
Reference Indirect
Real-Time Indirect

Volumetric Global Illumination


Global Illumination
Constant Ambient
SIGGRAPH 2015: Advances in Real-Time Rendering course


Global Illumination


Constant Ambient

Summary

Unified approach to large scale lighting

Fully **automatic** specular probe system

Talk Outline

Part I: Large-scale lighting

Part II: Screen space lighting

Screen-Space Techniques

Requirements

— Occlude larger scale lighting
— Fill in with screen-space sampled lighting

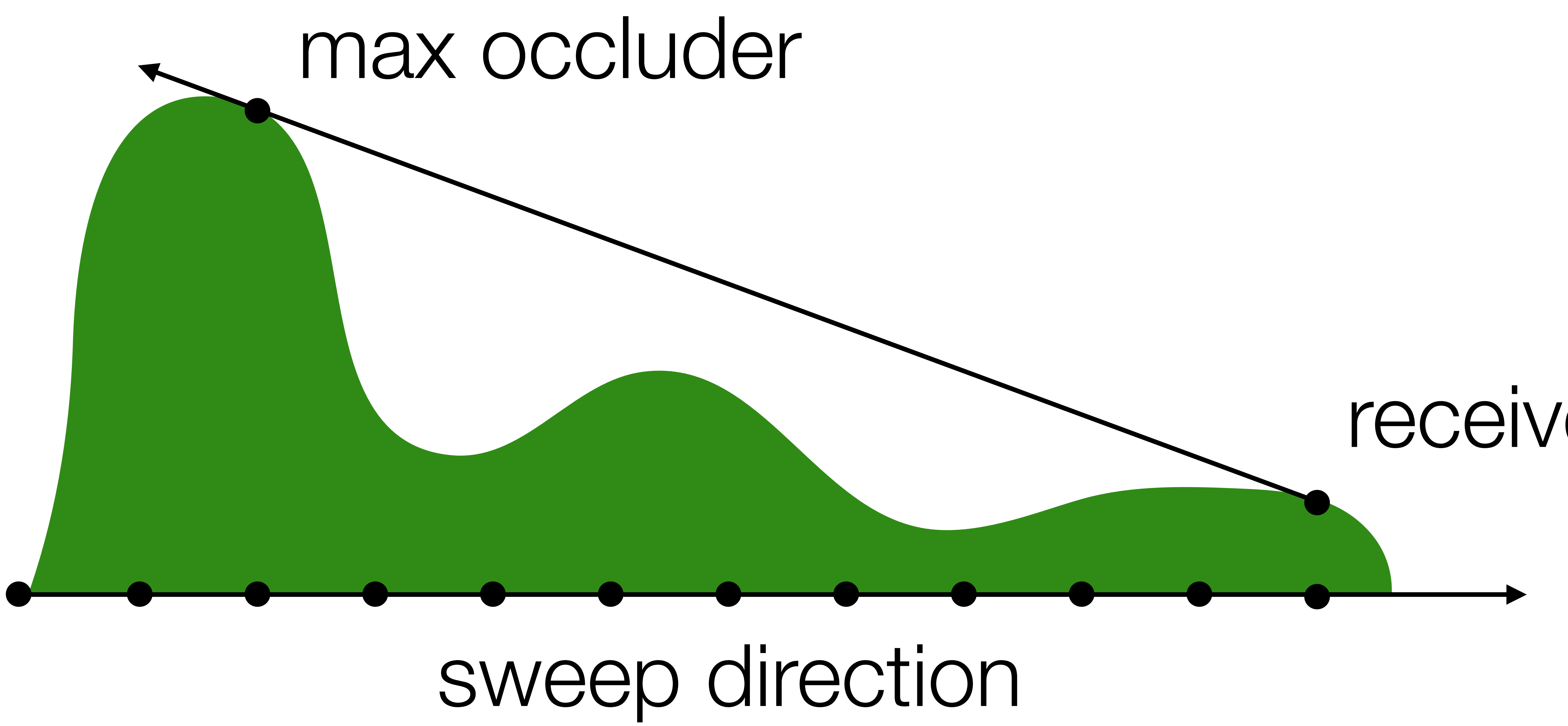
Screen-Space Ambient Occlusion and Diffuse


GI diffuse occlusion


Screen-Space Diffuse

Screen-Space Ambient Occlusion

Based on Line-Sweep Ambient Obscurance [Timonen2013]:
LSAO locates most contributing occluders

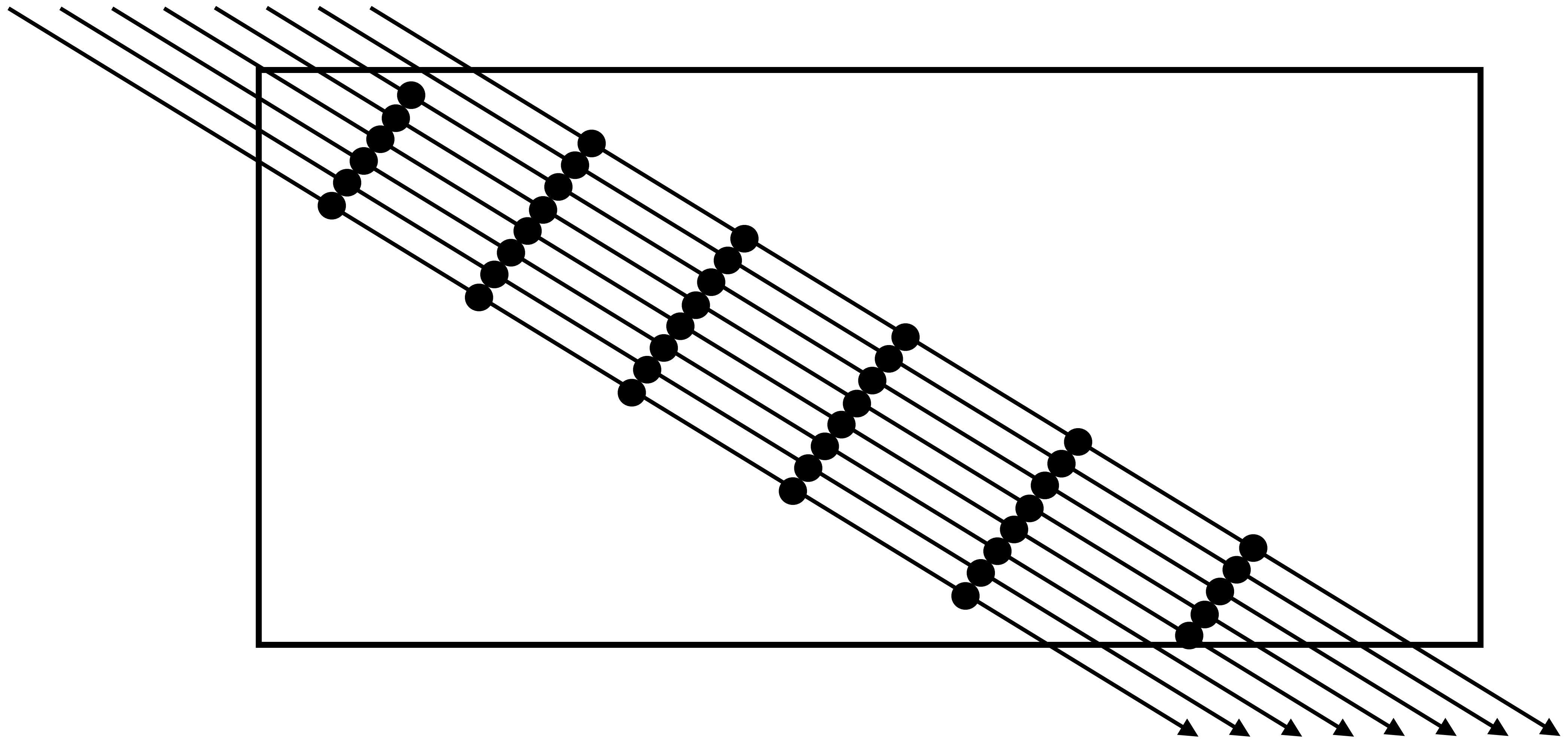


Screen-Space Ambient Occlusion

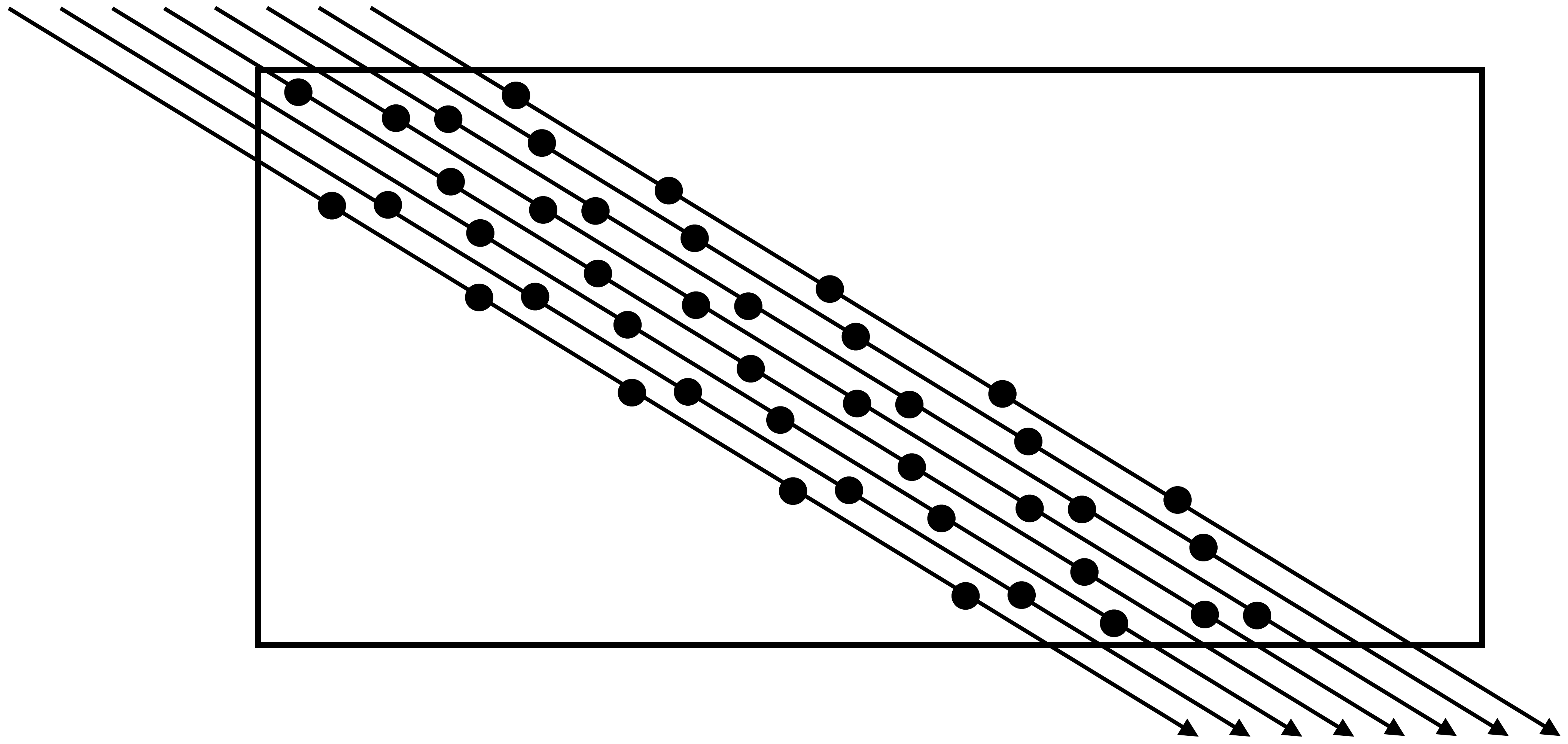
We scan in 36 directions, long steps (~10px) and short line spacing (~2px apart)

— Scheduling friendly for the GPU
— Scan is 0.75ms on Xbox One at 720p

Screen-Space Ambient Occlusion



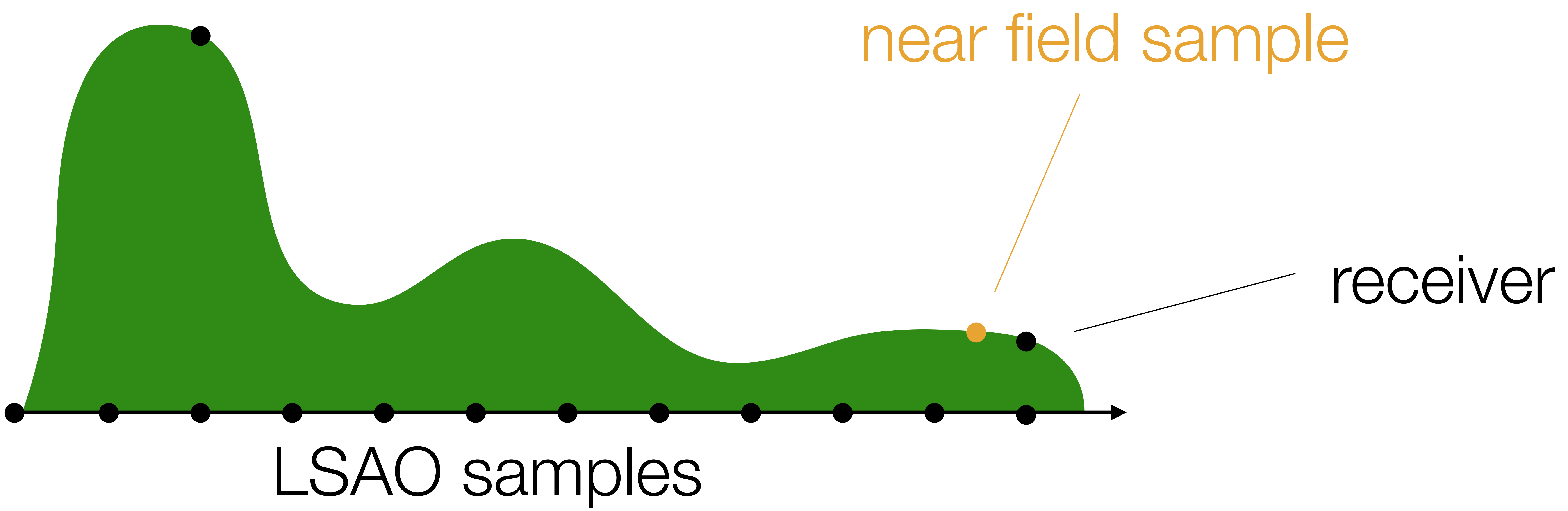
regular



jittered

Screen-Space Ambient Occlusion

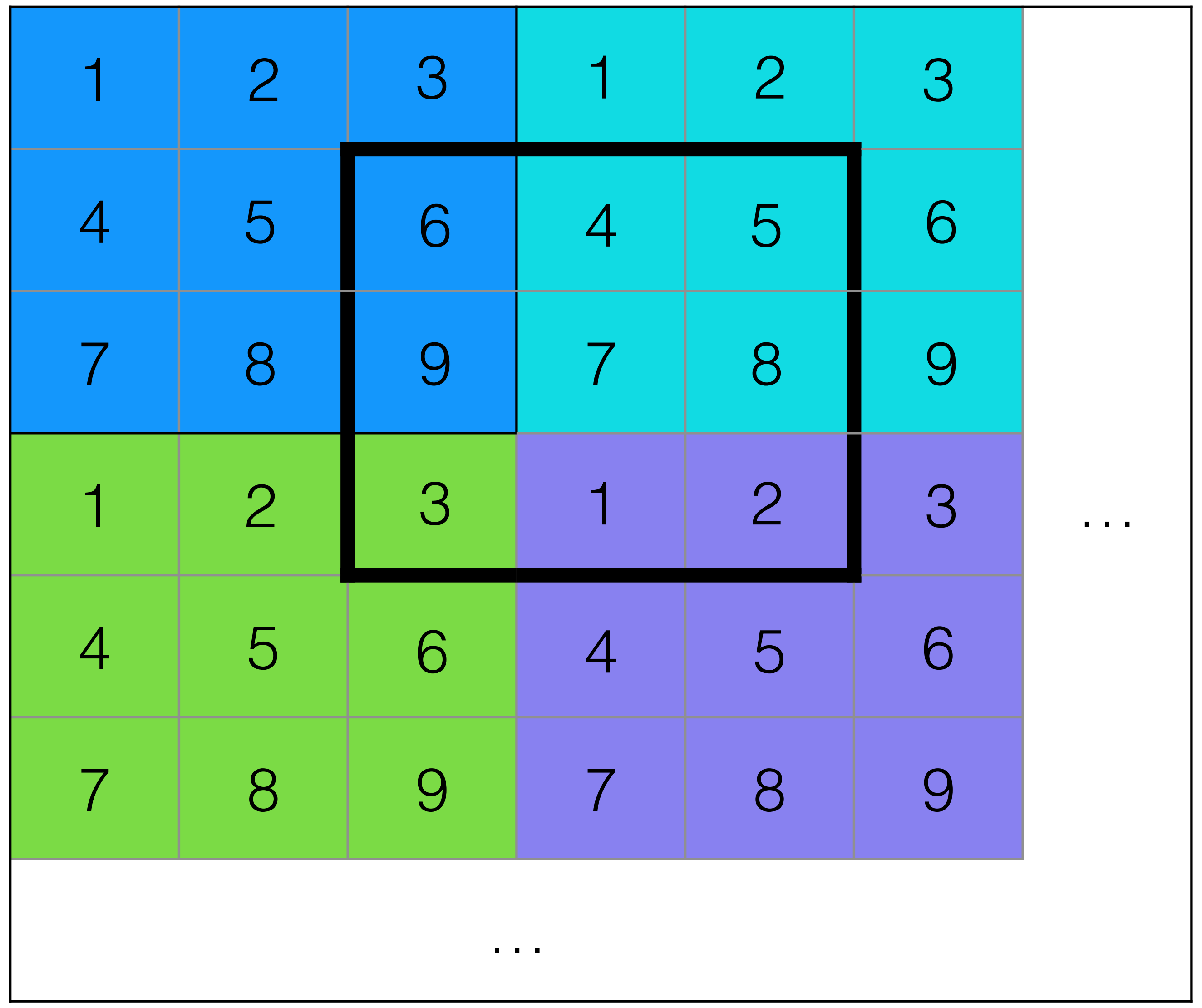
- An additional near field sample (at ~2px distance)
- Sample normal to clamp occluders



Screen-Space Ambient Occlusion

36 directions too expensive to gather per pixel

— Interleave on a 3x3 neighborhood (4 dirs/pixel)
— Gather using a depth and normal aware 3x3 box filter



Screen-Space Ambient Occlusion — 1.4ms @ 720p on XB1


Screen-Space Ambient Occlusion — 1.4ms @ 720p on XB1

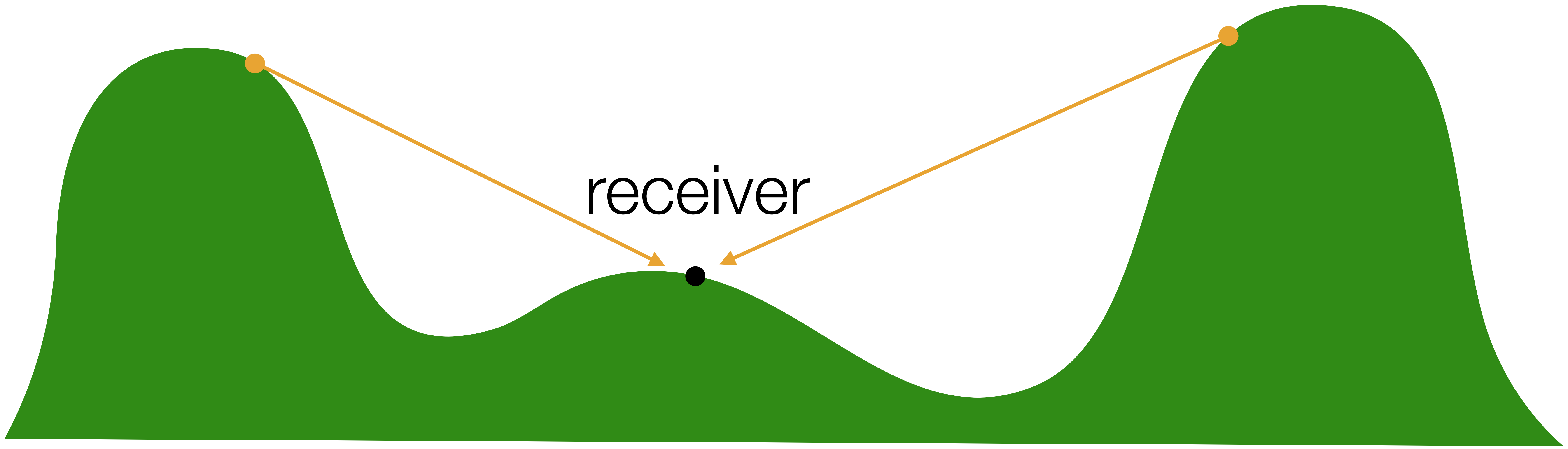

Single frame 36 dirs
Temporal 4x36 dirs

Screen-Space Diffuse Lighting

Screen-Space Diffuse Lighting

LSAO samples are “the most visible”

— Good candidates to sample incident light
— Can’t be occluded by definition (providing self-occlusion)



Screen-Space Diffuse — 0.45ms

Final image


Screen-Space Ambient Occlusion OFF
Screen-Space Diffuse Lighting OFF


Screen-Space Ambient Occlusion ON
Screen-Space Diffuse Lighting OFF


Screen-Space Ambient Occlusion ON
Screen-Space Diffuse Lighting ON


Screen-Space Ambient Occlusion OFF
Screen-Space Diffuse Lighting OFF


Screen-Space Ambient Occlusion ON
Screen-Space Diffuse Lighting OFF

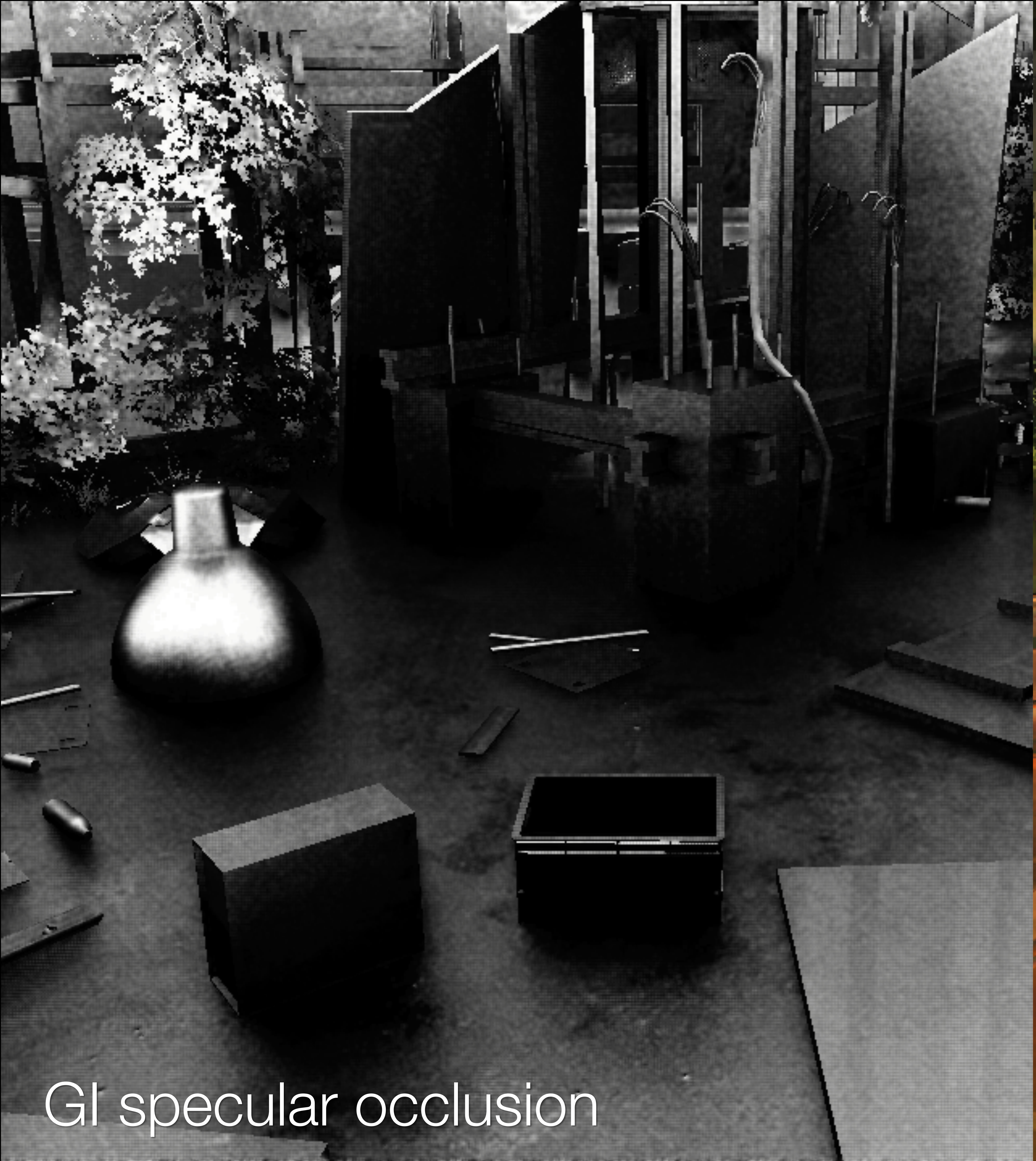
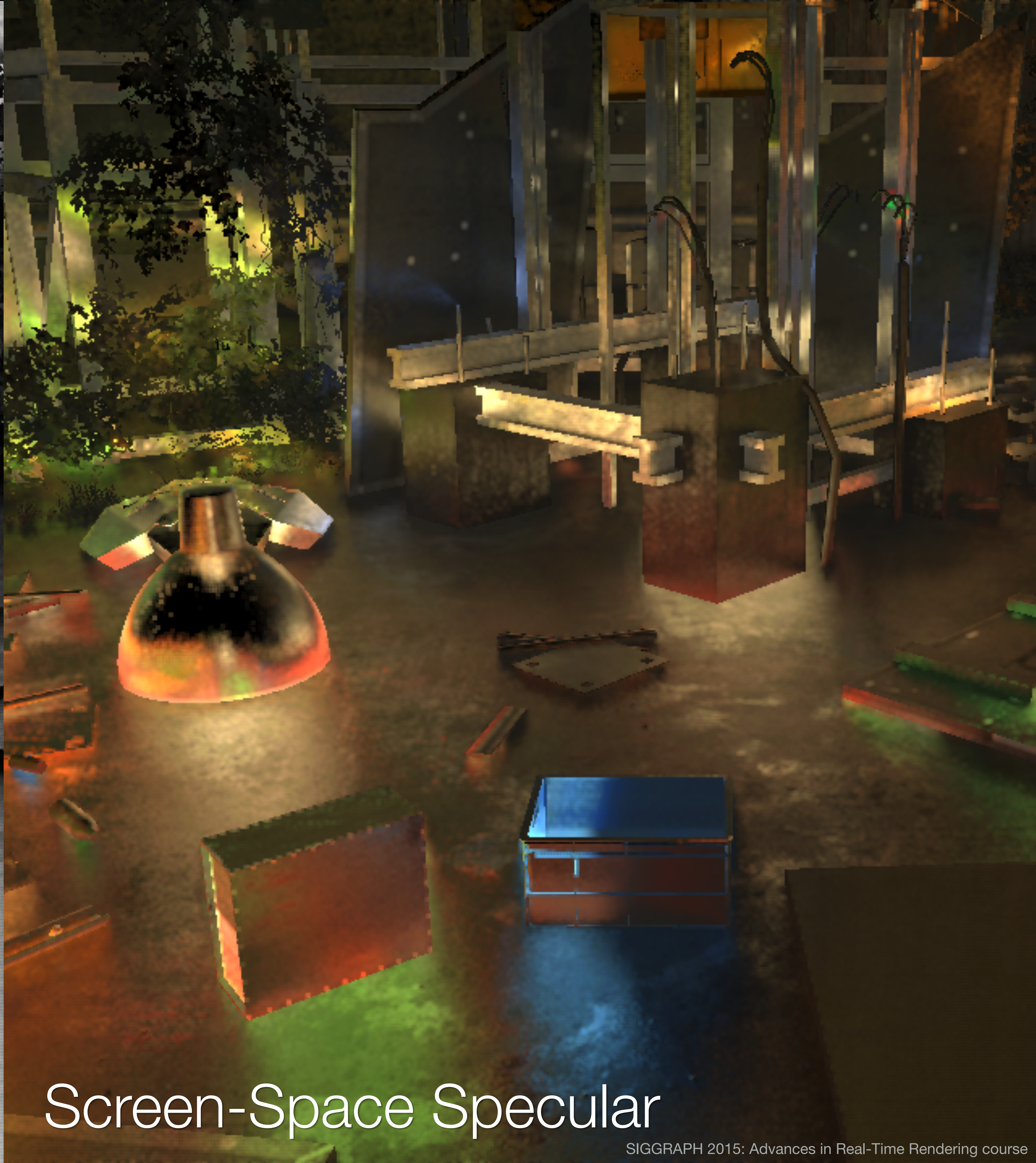

Screen-Space Ambient Occlusion ON
Screen-Space Diffuse Lighting ON


Screen-Space Ambient Occlusion OFF
Screen-Space Diffuse Lighting OFF


Screen-Space Ambient Occlusion ON
Screen-Space Diffuse Lighting OFF


Screen-Space Ambient Occlusion ON
Screen-Space Diffuse Lighting ON

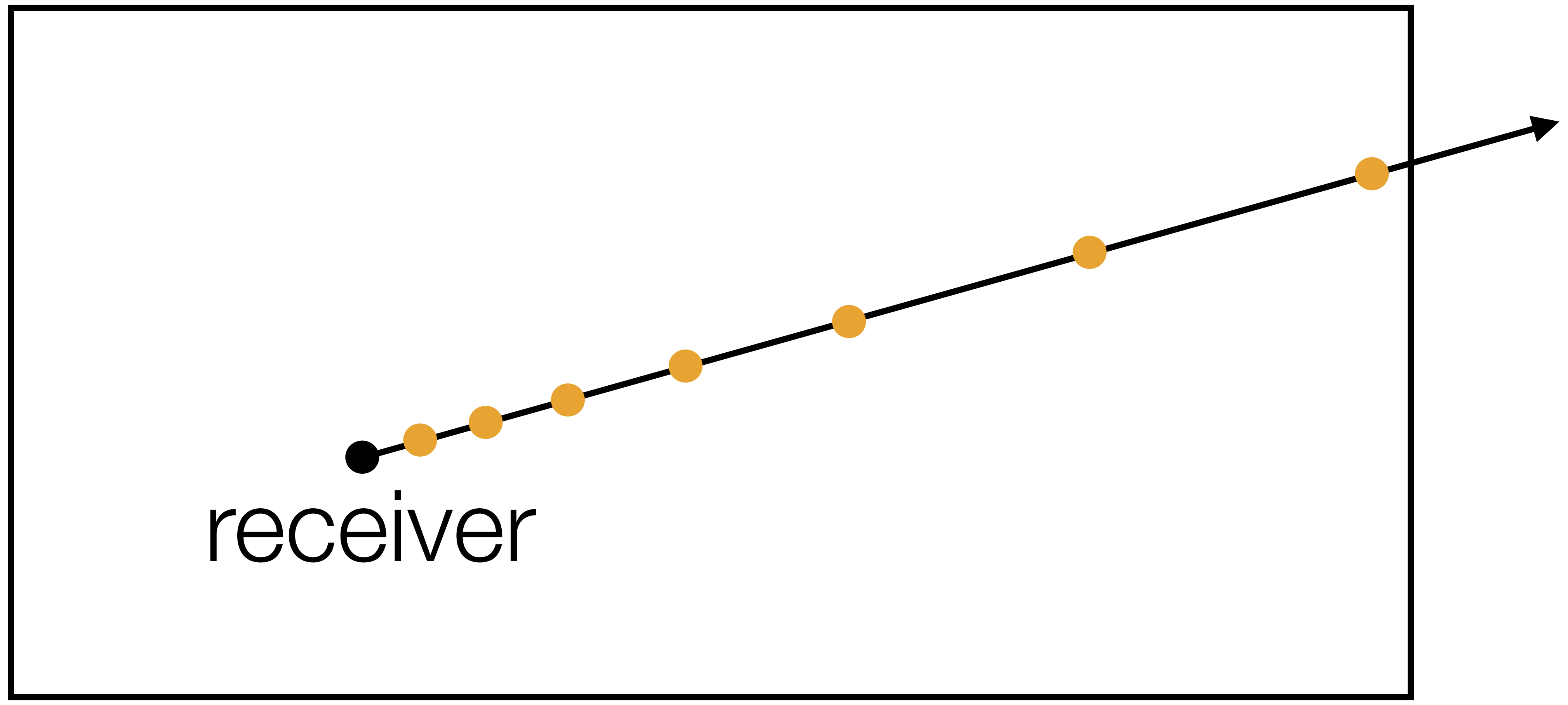
Screen-Space Reflections and Occlusion


GI specular occlusion

Screen-Space Specular

Screen-Space Reflections

1 ray per pixel from GGX distribution, evaluated for all surfaces

— Linear search (7 steps)
— Step distances form a geometric series



Screen-Space Reflections

Treating the depth buffer samples

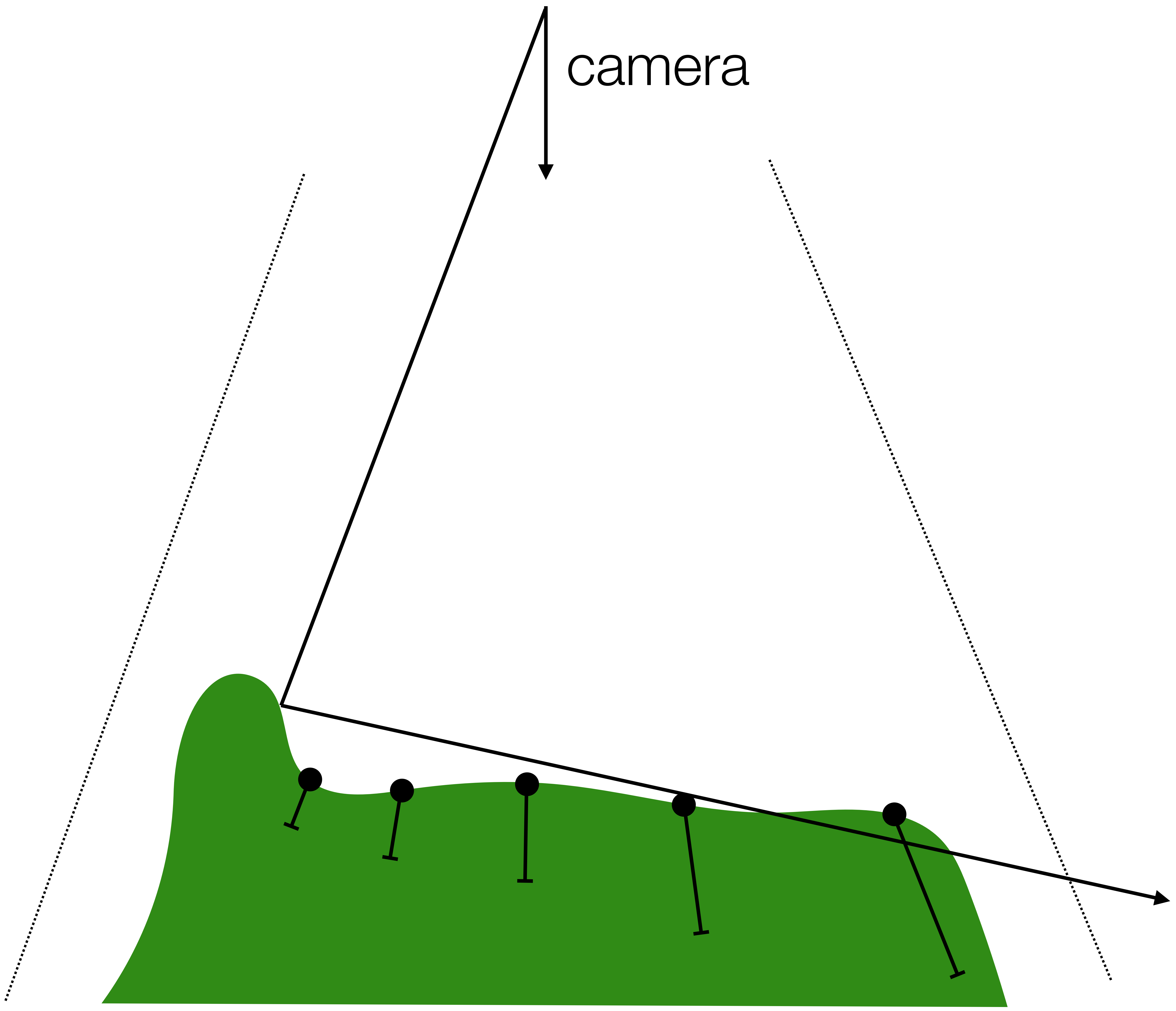
Need to support varying roughness
— Calculate cone coverage

Need to suit both occlusion and color sampling
— Also find a single color sample location

Screen-Space Reflections

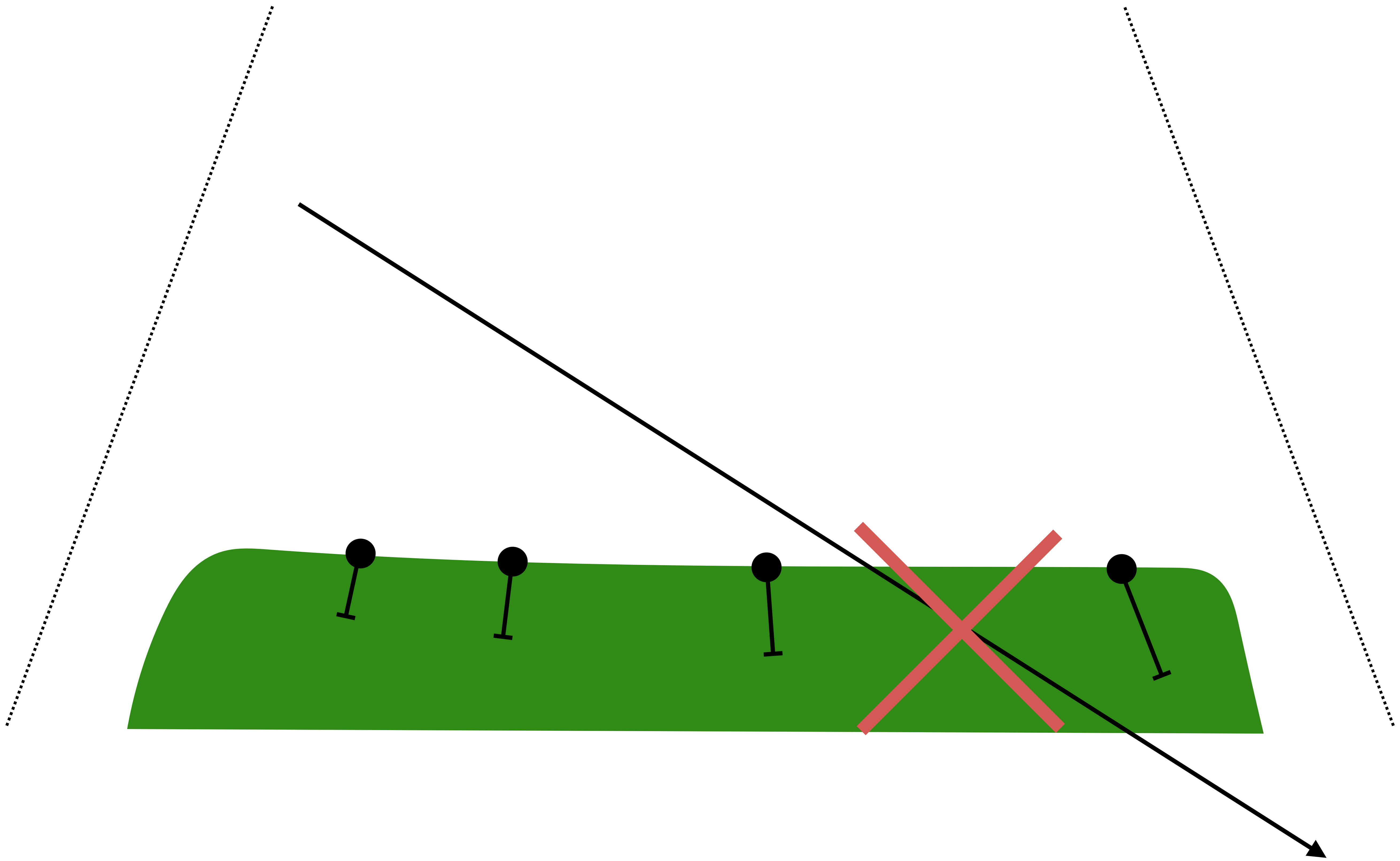
Depth thickness =
a + b*(distance along the ray)

Depth field extends to/from camera, not along view z!



Screen-Space Reflections

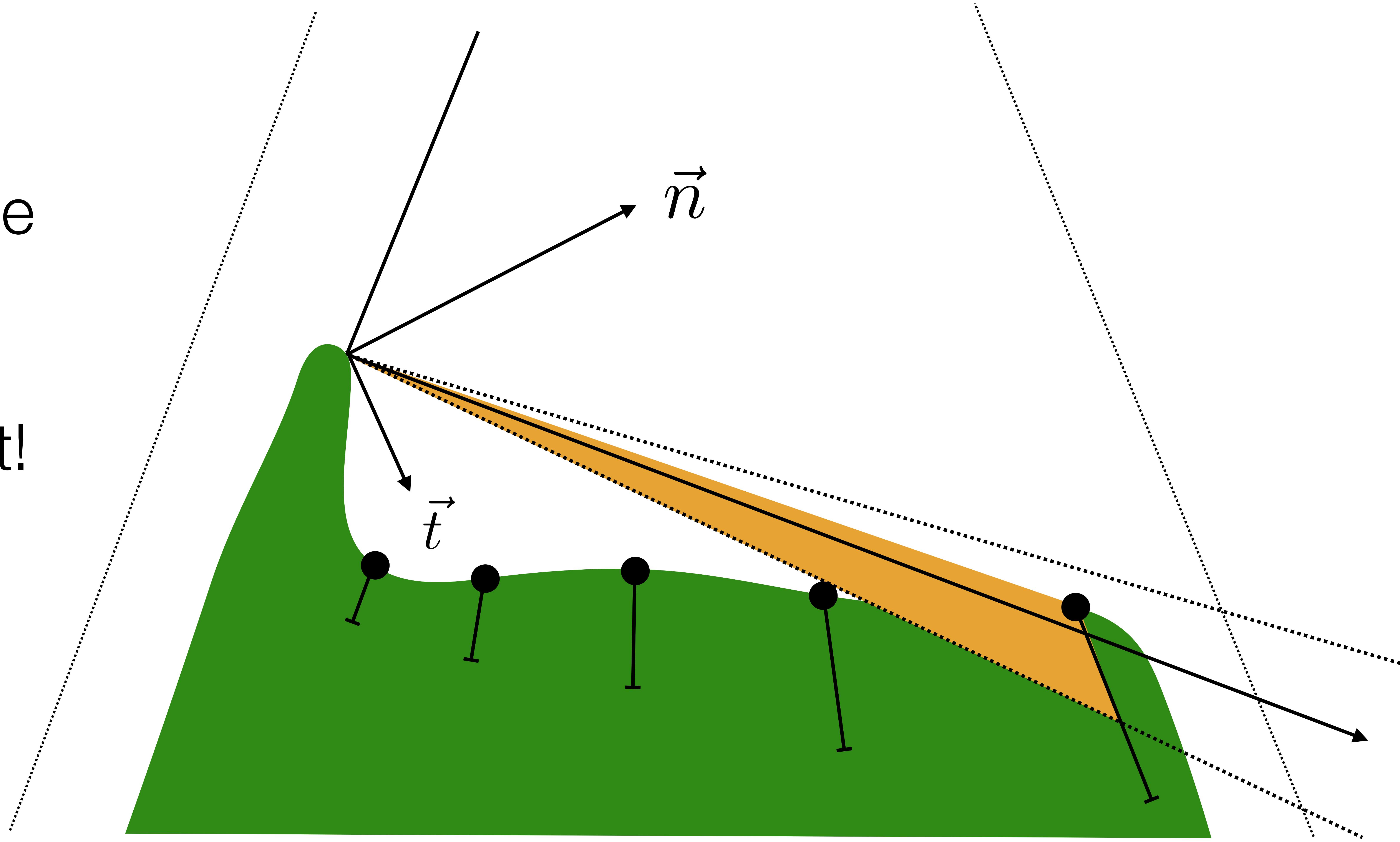
Match the linear term to step size in view space.
Otherwise holes on solid geometry:



Screen-Space Reflections

For occlusion, calculate max coverage of the cone

Clamp the cone's lower bound to surface tangent!

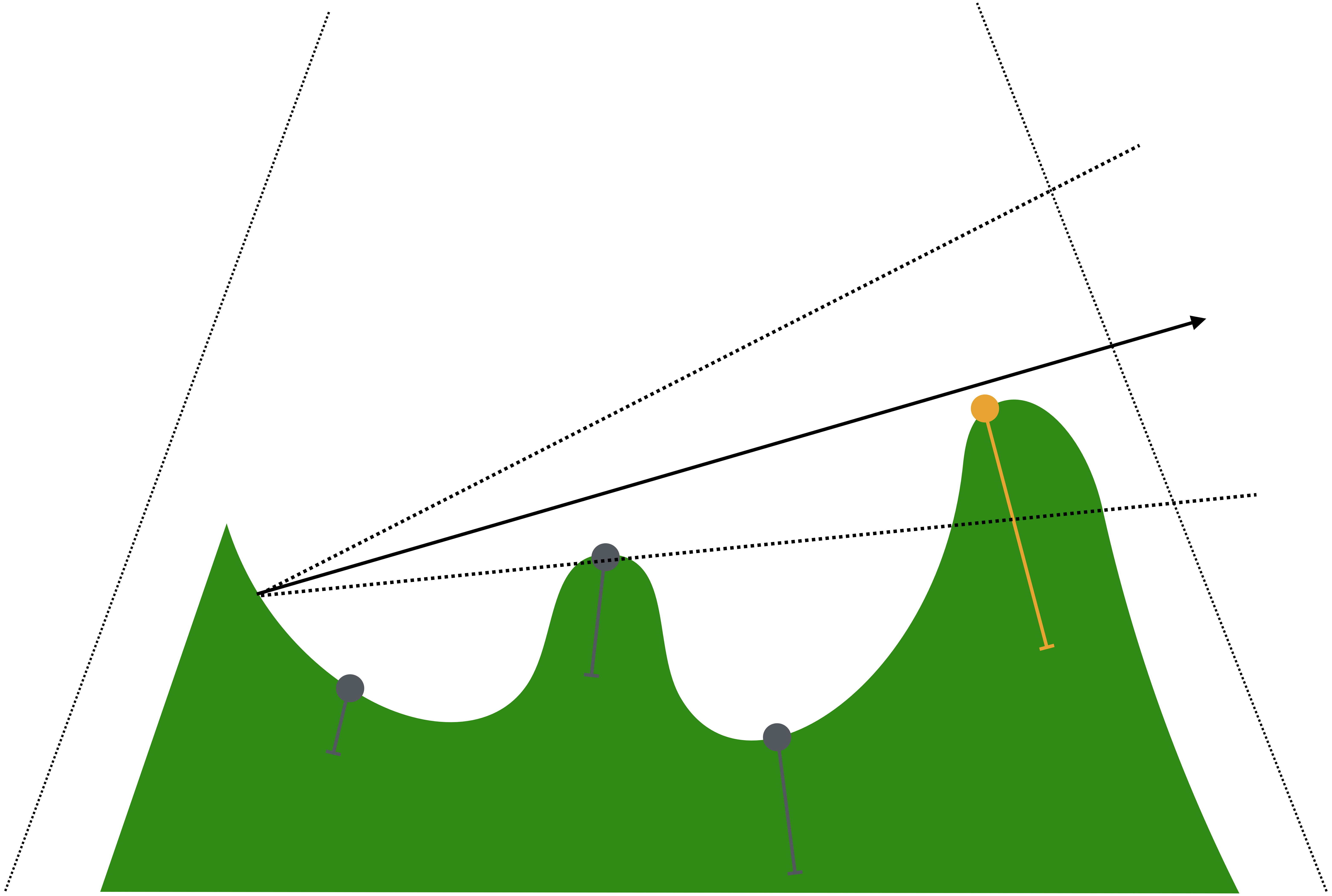



Screen-Space Reflection Occlusion — 0.8 ms @ 720p on XB1
SIGGRAPH 2015: Advances in Real-Time Rendering course

Screen-Space Reflections

For **color**, we need a single sample location

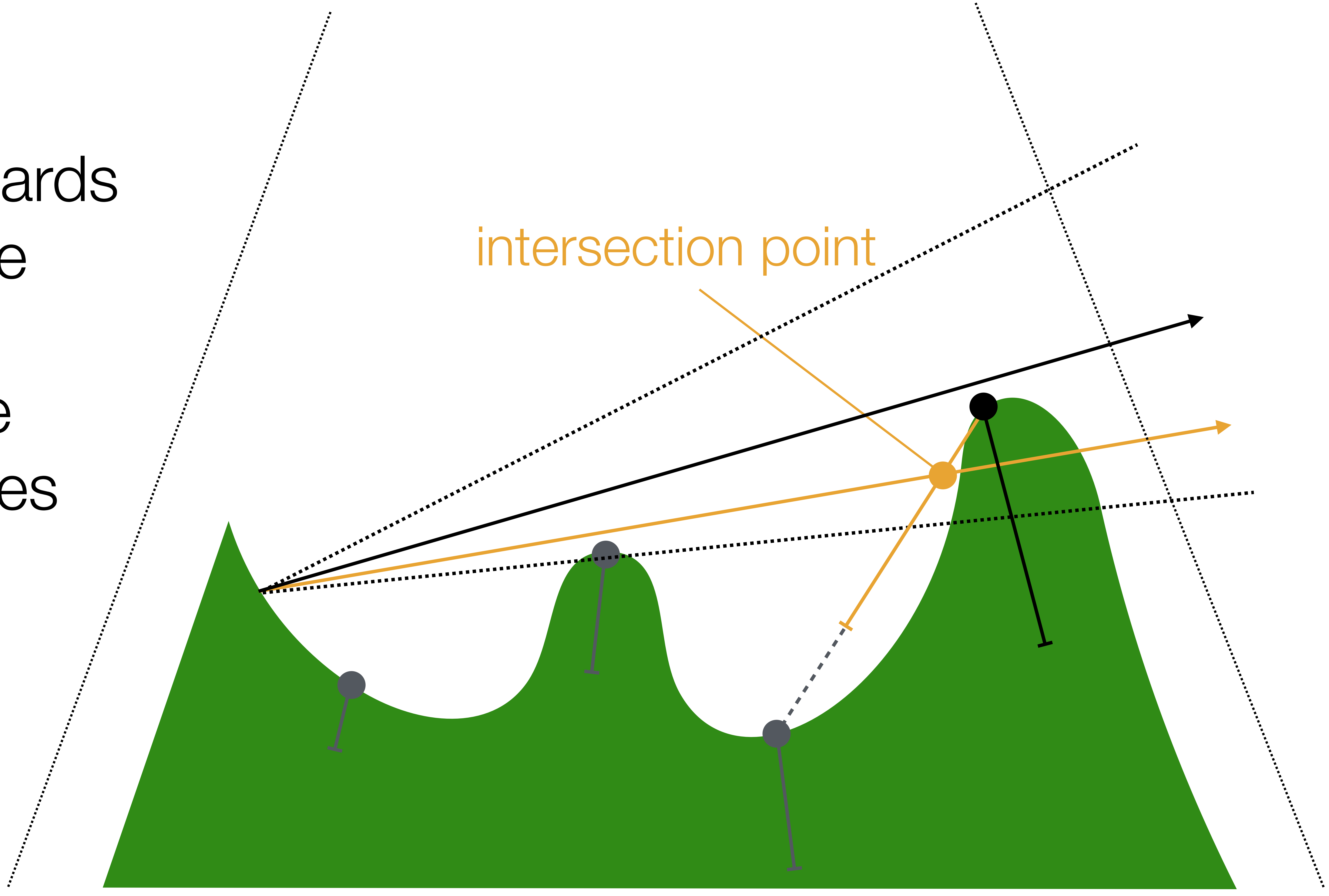
First, we pick the sample that covered most of the cone



Screen-Space Reflections

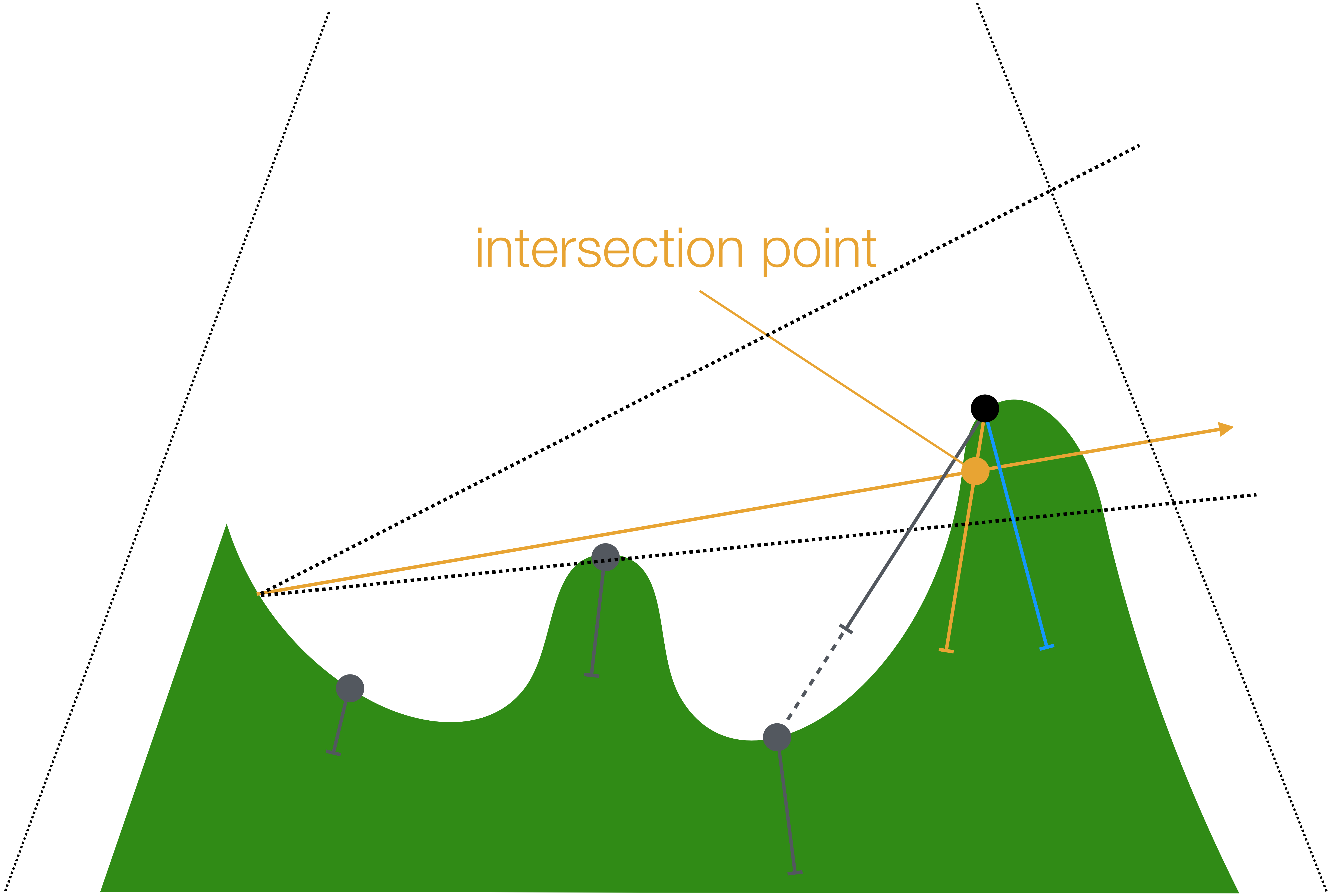
Aim the reflection ray towards the center of the coverage

And intersect with the line between the last 2 samples



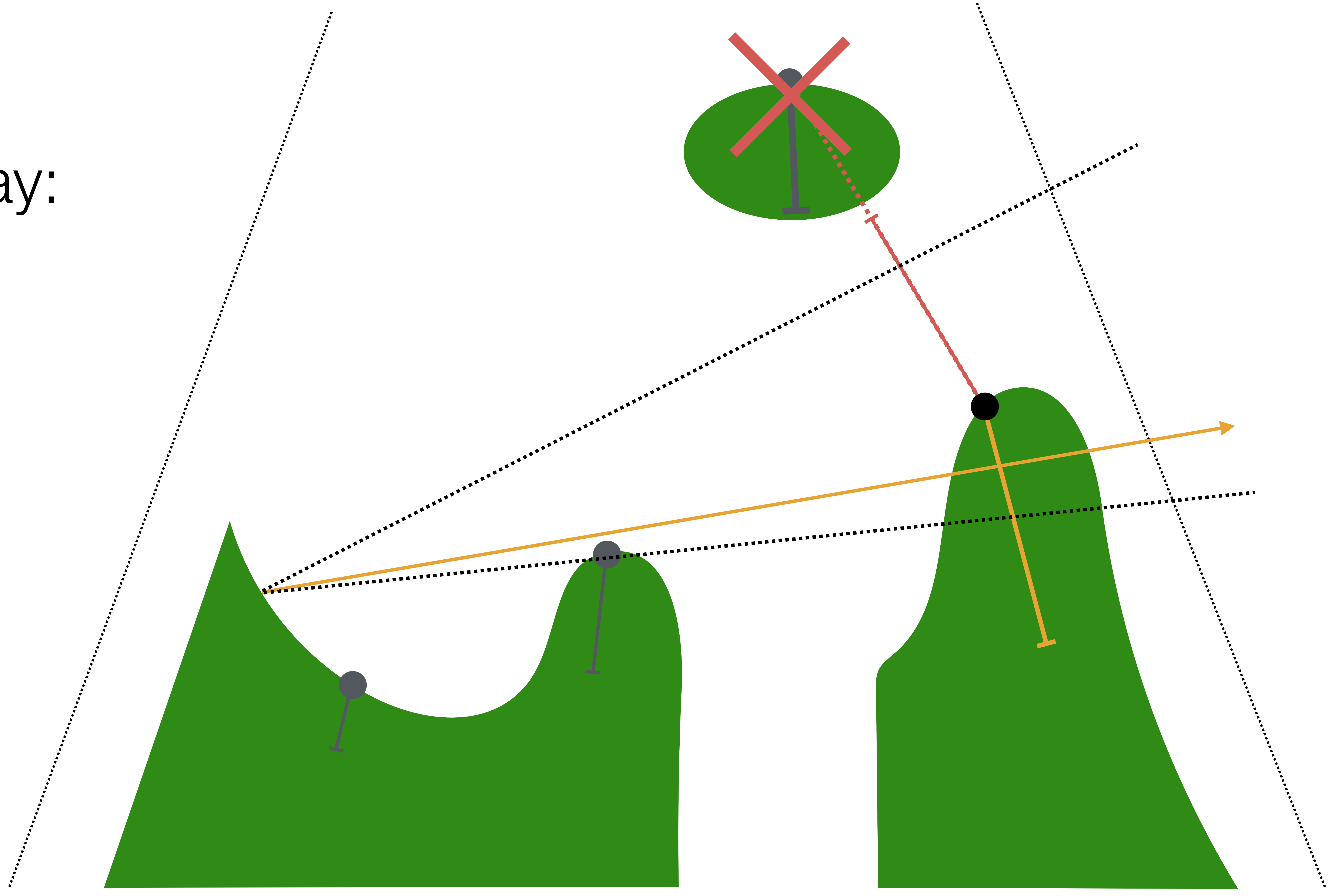
Screen-Space Reflections

Low sample density:
interpolate towards
camera direction (in blue)



Screen-Space Reflections

Previous sample above ray:
don't interpolate




Screen-Space Reflections — 0.5 ms @ 720p on XB1


Final image


Screen-Space Reflection Occlusion OFF
Screen-Space Reflections OFF


Screen-Space Reflection Occlusion ON
Screen-Space Reflections OFF

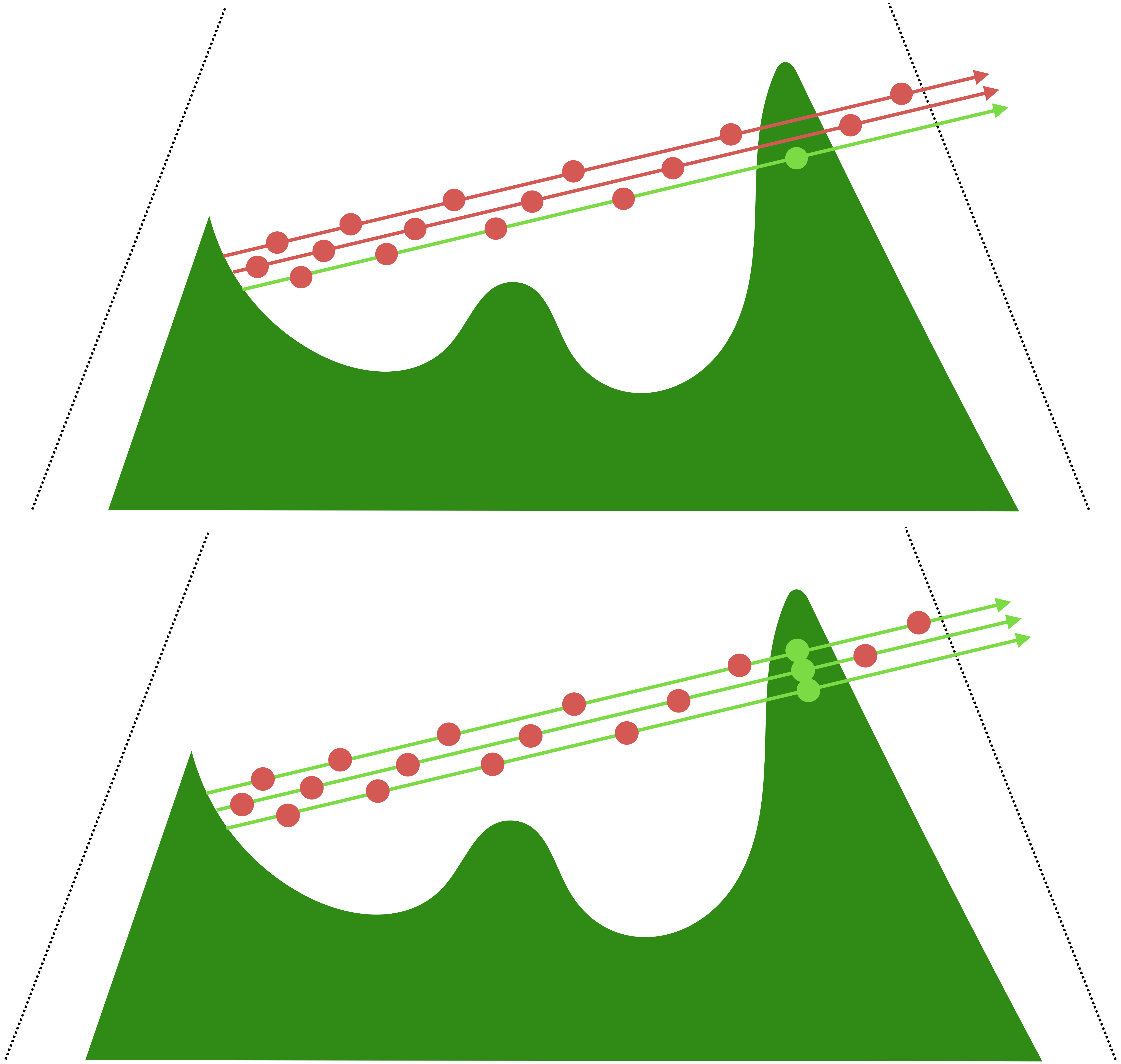

Screen-Space Reflection Occlusion ON
Screen-Space Reflections ON


smooth
rough

Refining the intersections

If neighboring rays have the same direction

— Interleave search
— Take nearest hit distance




Independent rays
2x2 shared

Thank You!

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SIGGRAPH2015

REMEDY

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