Multi-Resolution Screen-Space Ambient Occlusion

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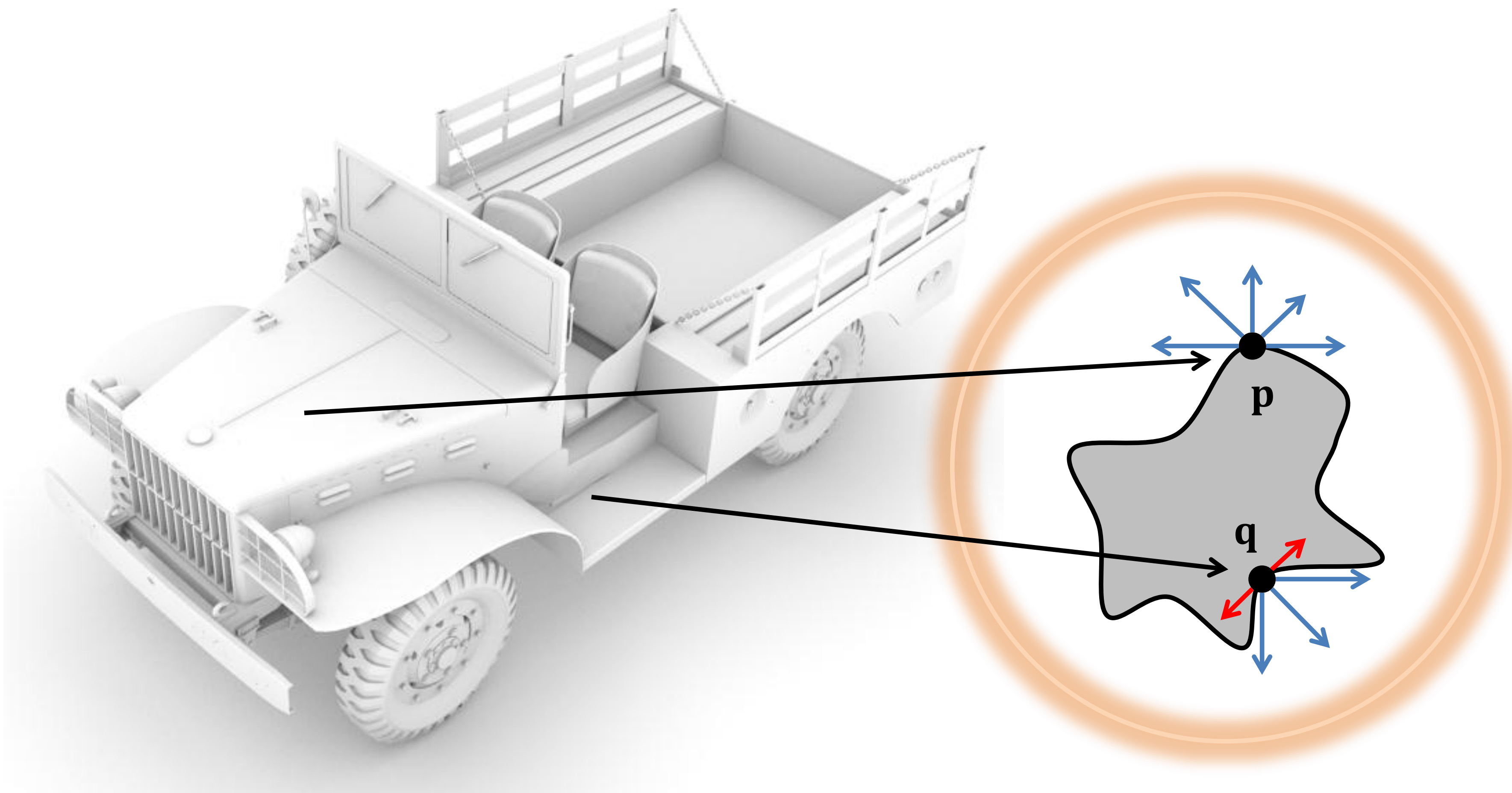
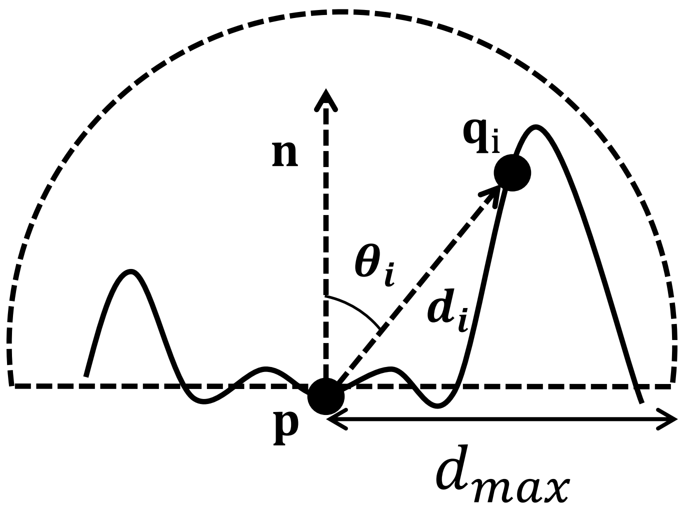
Ambient Occlusion (AO)



AO

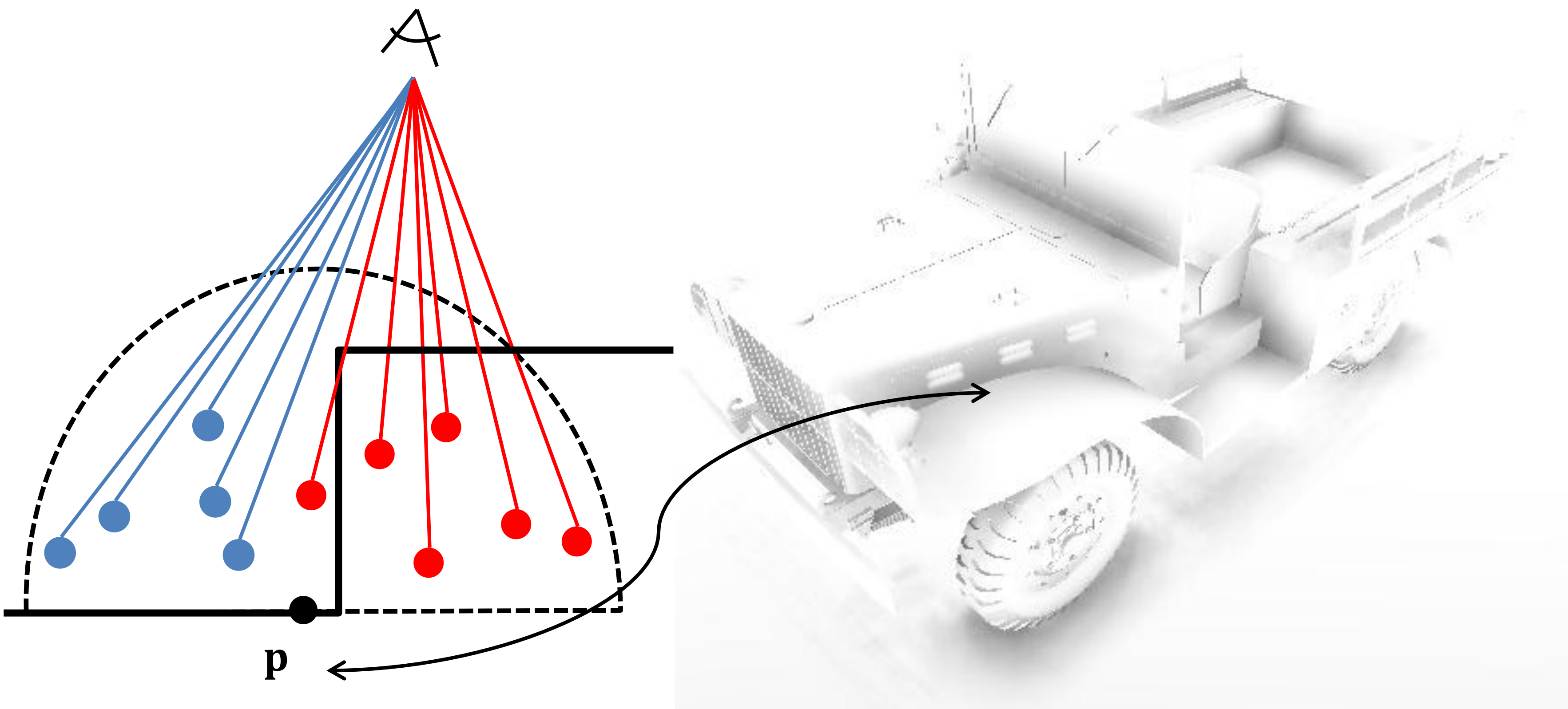


Cosine-weighted fraction of a tangent hemisphere that is occluded

$$AO(\mathbf{p}) = \frac{1}{\pi} \int_{\Omega} \rho(\mathbf{p}, d_i) \cos\theta_i \, dw_i$$

$$\begin{aligned} d_i &\geq d_{max} : \rho = 0 \\ d_i &= 0 \quad\quad : \rho = 1 \end{aligned}$$

Screen-Space AO (SSAO)



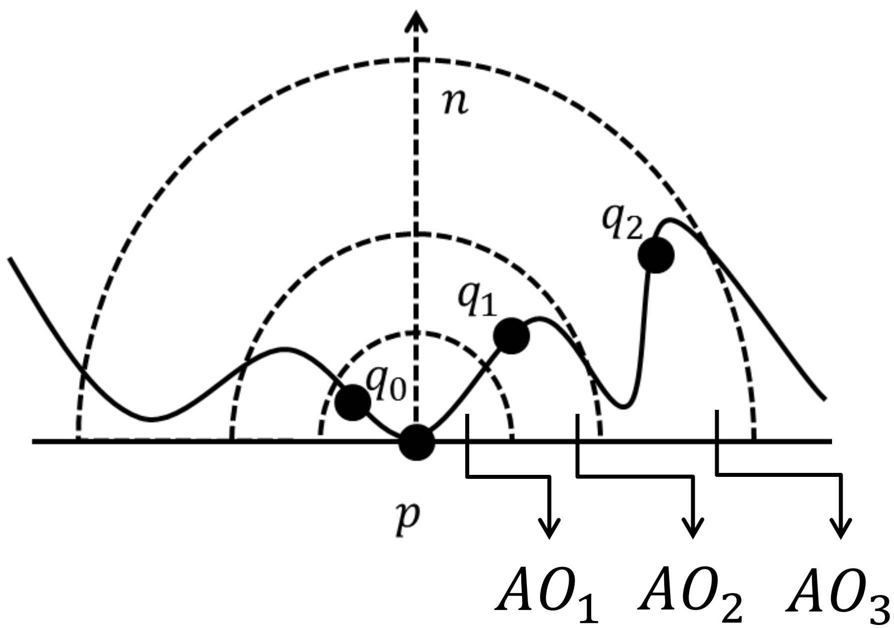
Volumetric AO [SKUT10]

SSAO (Dis)Advantages

- ✖ Inaccurate
  - ✖ Local AO
  - ✖ Over/underestimated AO
- ✖ Low quality
  - ✖ Noise
  - ✖ Blur

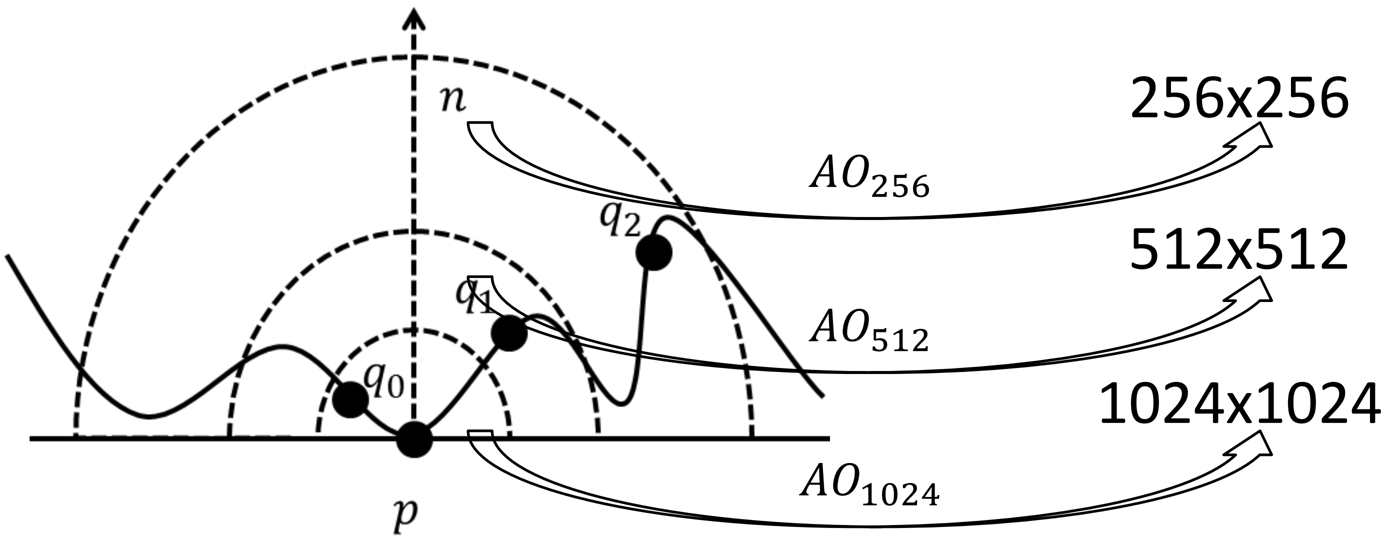
- ✓ Simple
- ✓ Fast
- ✓ General
- ✓ Easy to integrate

Multi-Resolution AO (MSSAO) Intuition



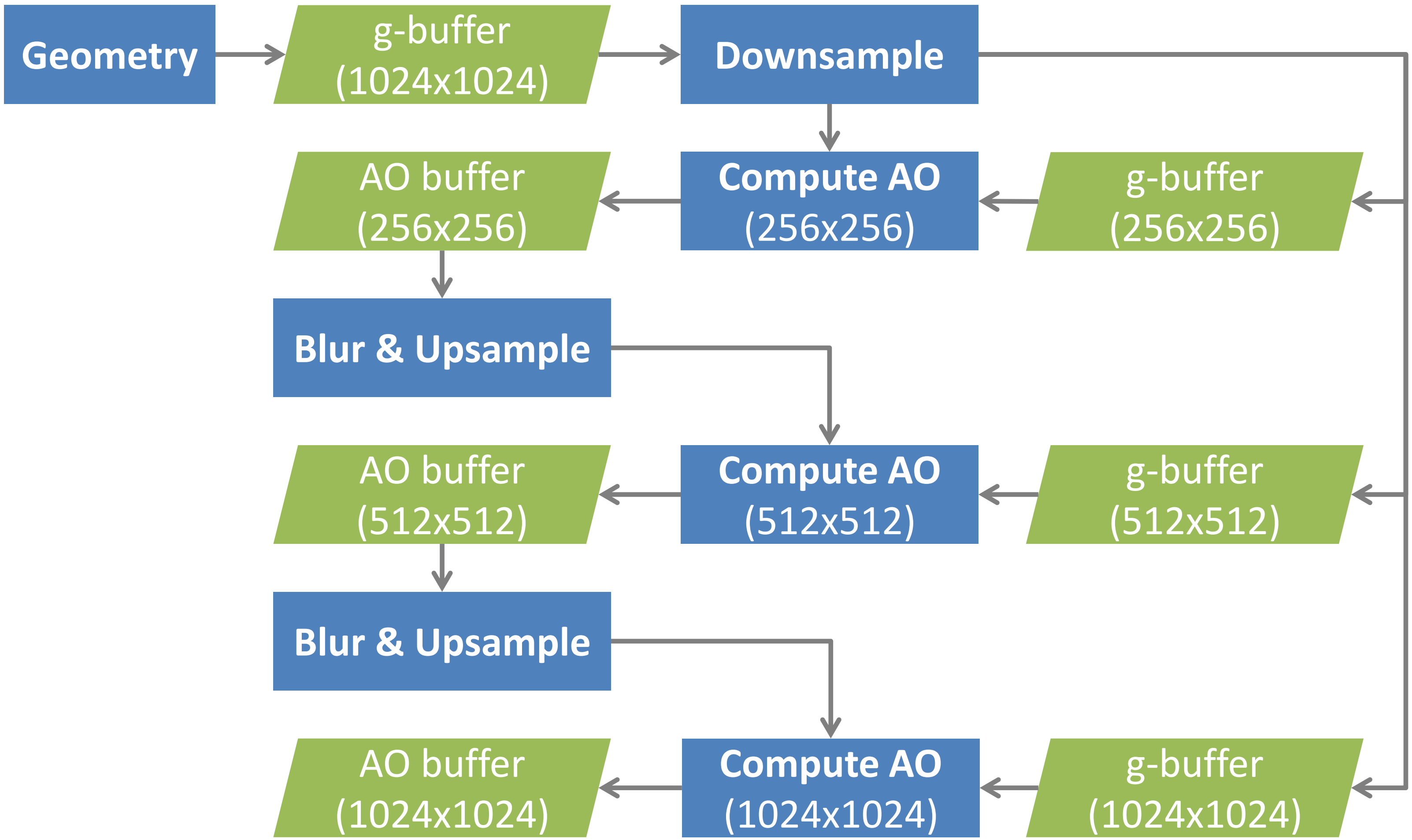
$$AO_{final} = \max(AO_i)$$

Multi-Resolution AO (MSSAO) Intuition

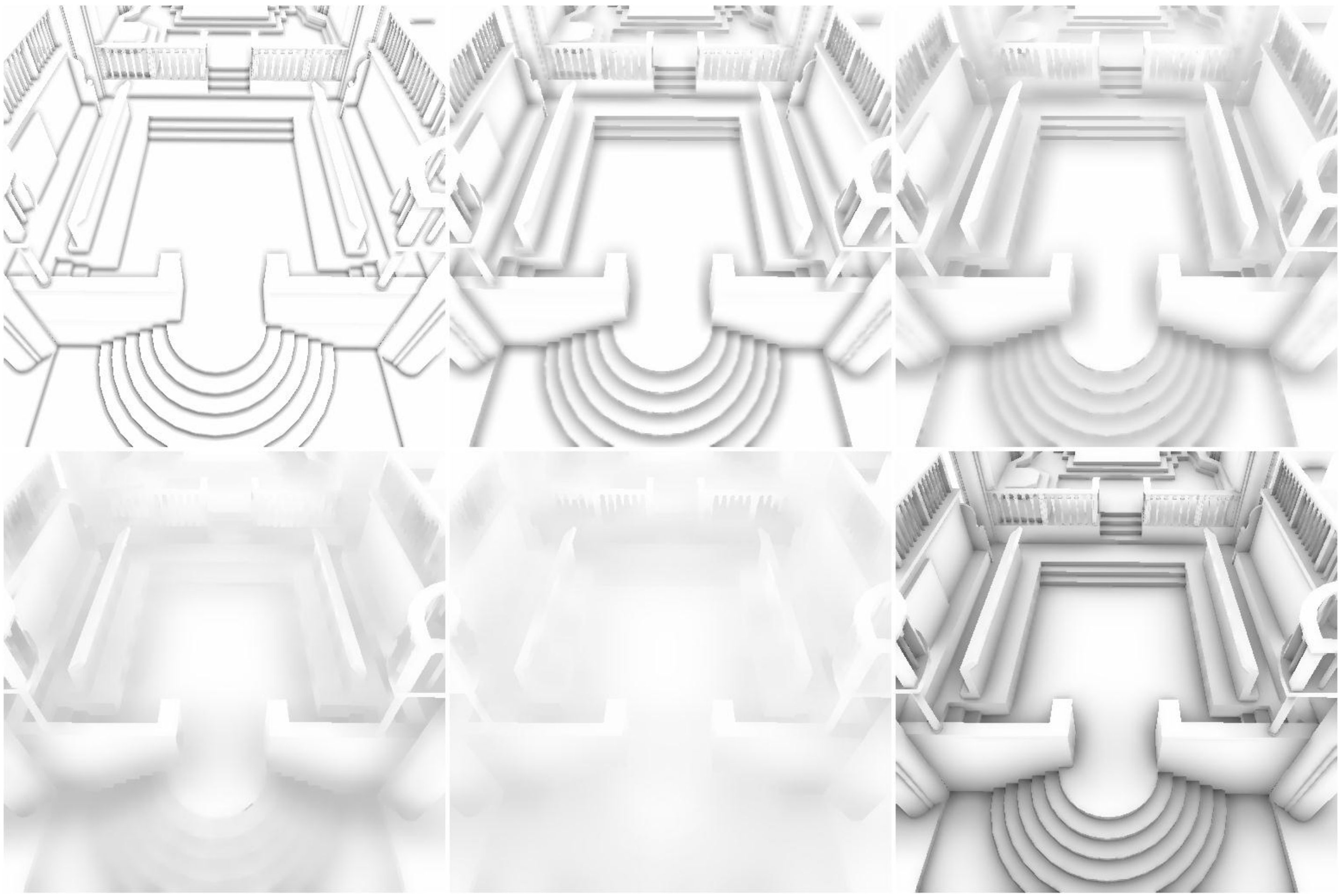


$$AO_{final} = \mathrm{f}\left(\max(AO_i), \mathrm{average}(AO_i)\right)$$
$$AO_{final} \geq \max(AO_i)$$
$$AO_{final} \propto \mathrm{average}(AO_i)$$

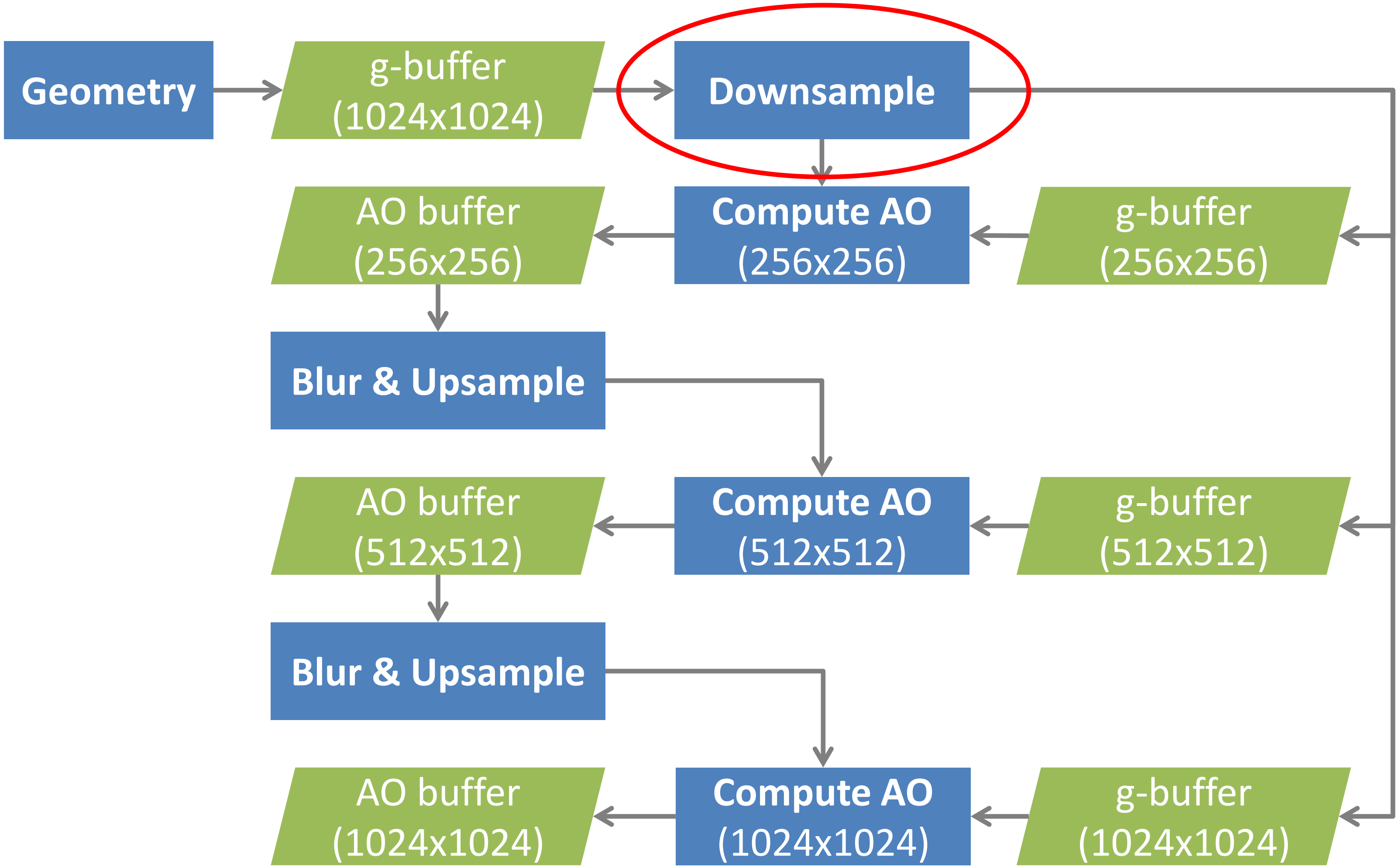
MSSAO Overview



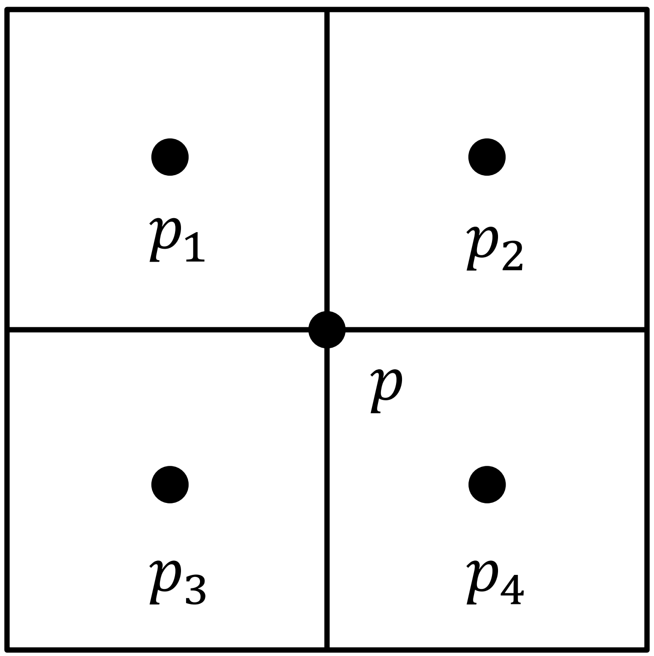
MSSAO
AO from Multiple Resolutions



MSSAO Overview



MSSAO
Downsampling



$$\mathbf{p}_1^z \le \mathbf{p}_2^z \le \mathbf{p}_3^z \le \mathbf{p}_4^z$$

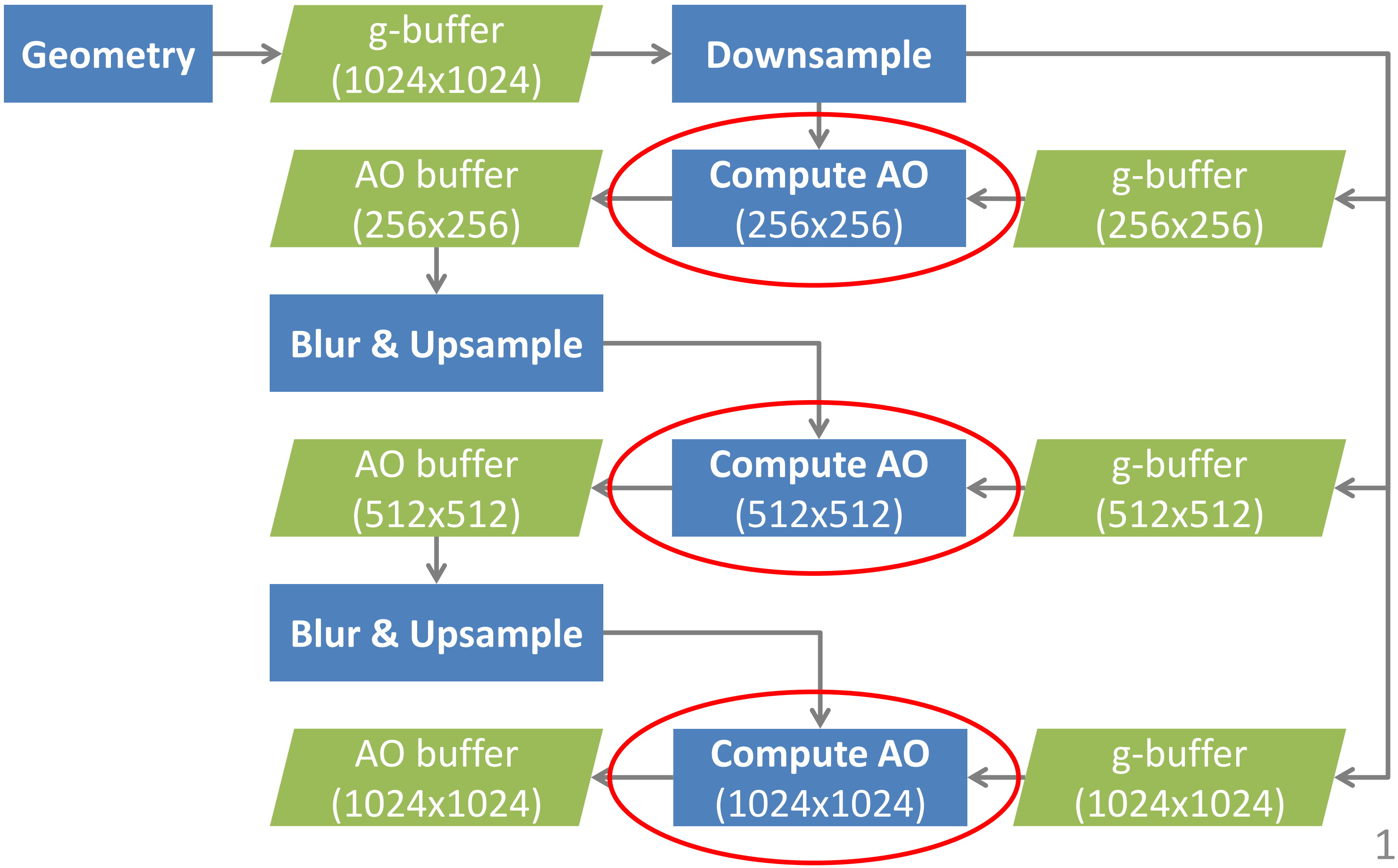
if $\mathbf{p}_4^z - \mathbf{p}_1^z \le d_{threshold}$

$$\mathbf{p} \leftarrow (\mathbf{p}_2 + \mathbf{p}_3)/2$$
$$\mathbf{n} \leftarrow (\mathbf{n}_2 + \mathbf{n}_3)/2$$

else

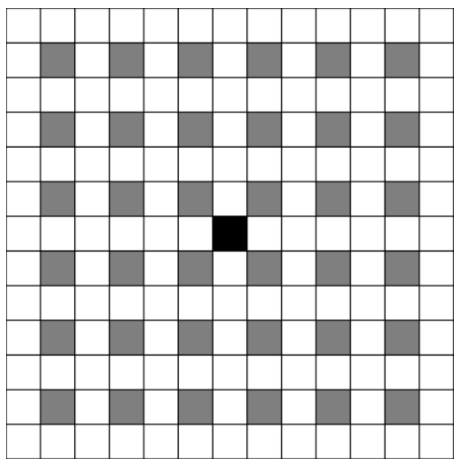
$$\mathbf{p} \leftarrow \mathbf{p}_2$$
$$\mathbf{n} \leftarrow \mathbf{n}_2$$

MSSAO Overview

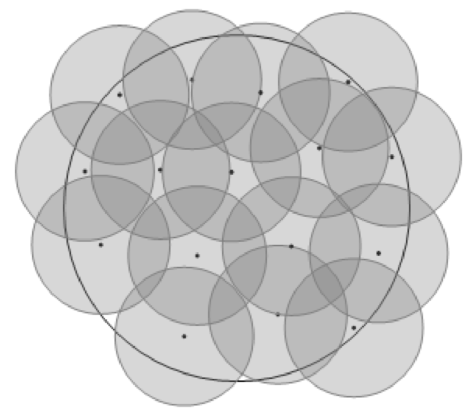


MSSAO
Neighborhood Sampling

- Project the AO radius of influence to screen space at each pixel p at resolution Res_i to get $r_i(p)$ (in terms of pixels)
- Cap $r_i(p)$ to some value r_{max} (typical value is 5)



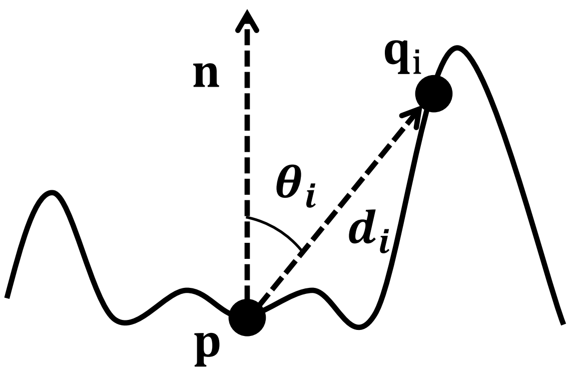
512x512
256x256



1024x1024
16-point Poisson disk

Works well with a 3x3 Gaussian filter

MSSAO
Computing AO



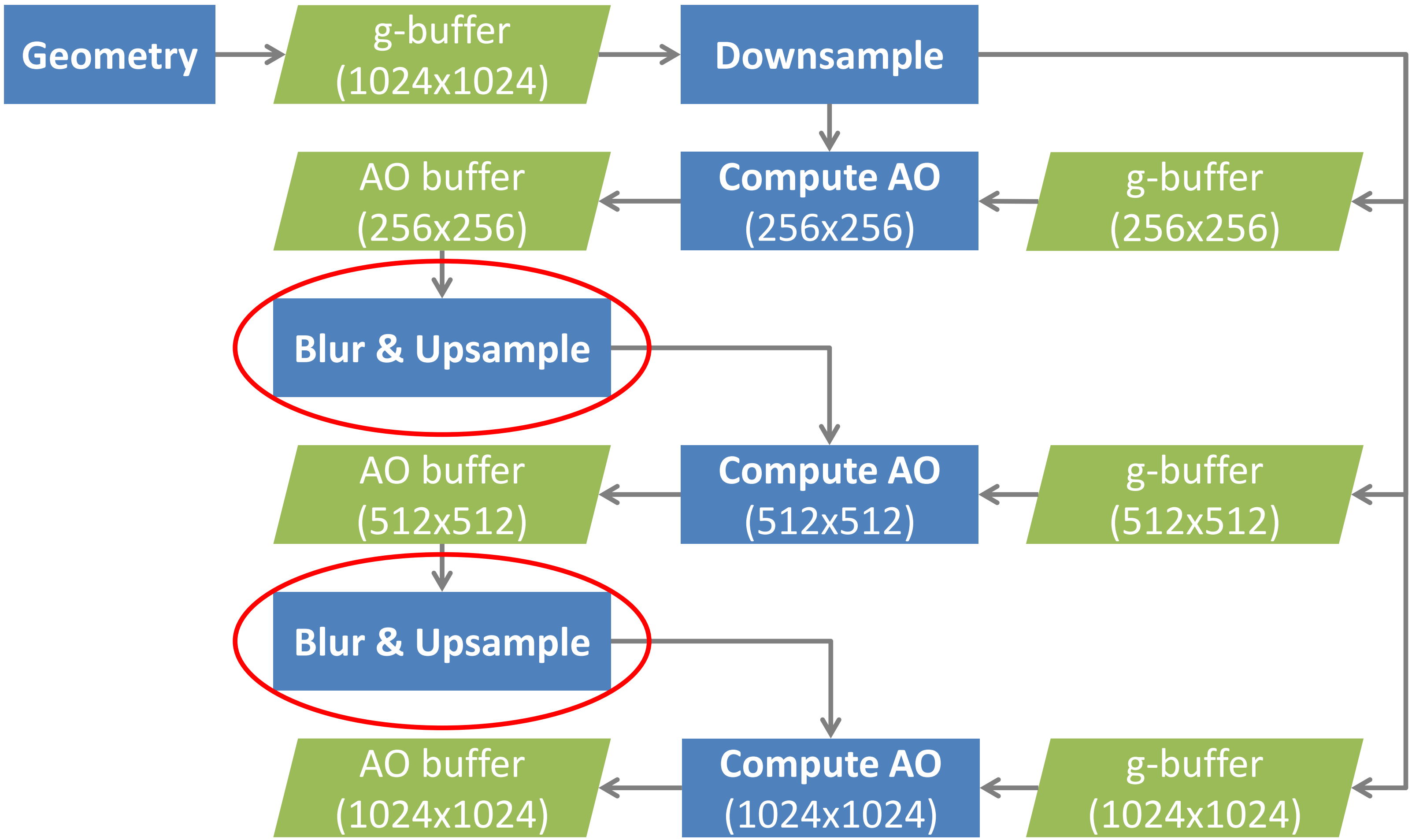
- ✓ Low-variance
- ✓ Cheap
- ✗ Biased

$$AO(\mathbf{p}) = \frac{1}{N}\sum_{i=1}^{N} \rho(\mathbf{p}, d_i)\overline{(\mathbf{n} \cdot \widehat{\mathbf{q}_i - \mathbf{p}})}$$

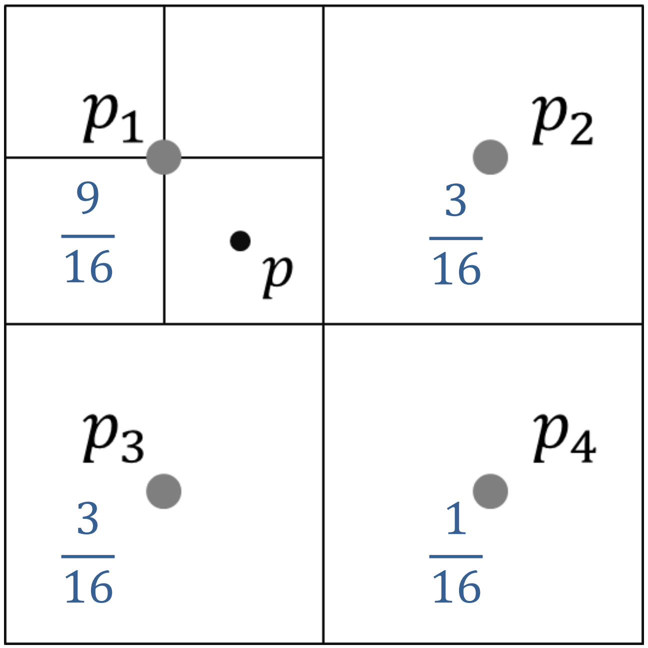
model after the Monte-Carlo approximation of

$$AO(\mathbf{p}) = \frac{1}{\pi}\int_{\Omega} \rho(\mathbf{p}, d_i) \cos\theta_i \, d\omega_i$$

MSSAO Overview



MSSAO
Bilateral Upsampling



- Bilinear weights w_b
- Depth weights

$$w_z(p_i) = \left(\frac{1}{1 + |z_i - z|}\right)^{t_z}$$

- Normal weights

$$w_n(p_i) = \left(\frac{\mathbf{n} \cdot \mathbf{n}_i + 1}{2}\right)^{t_n}$$

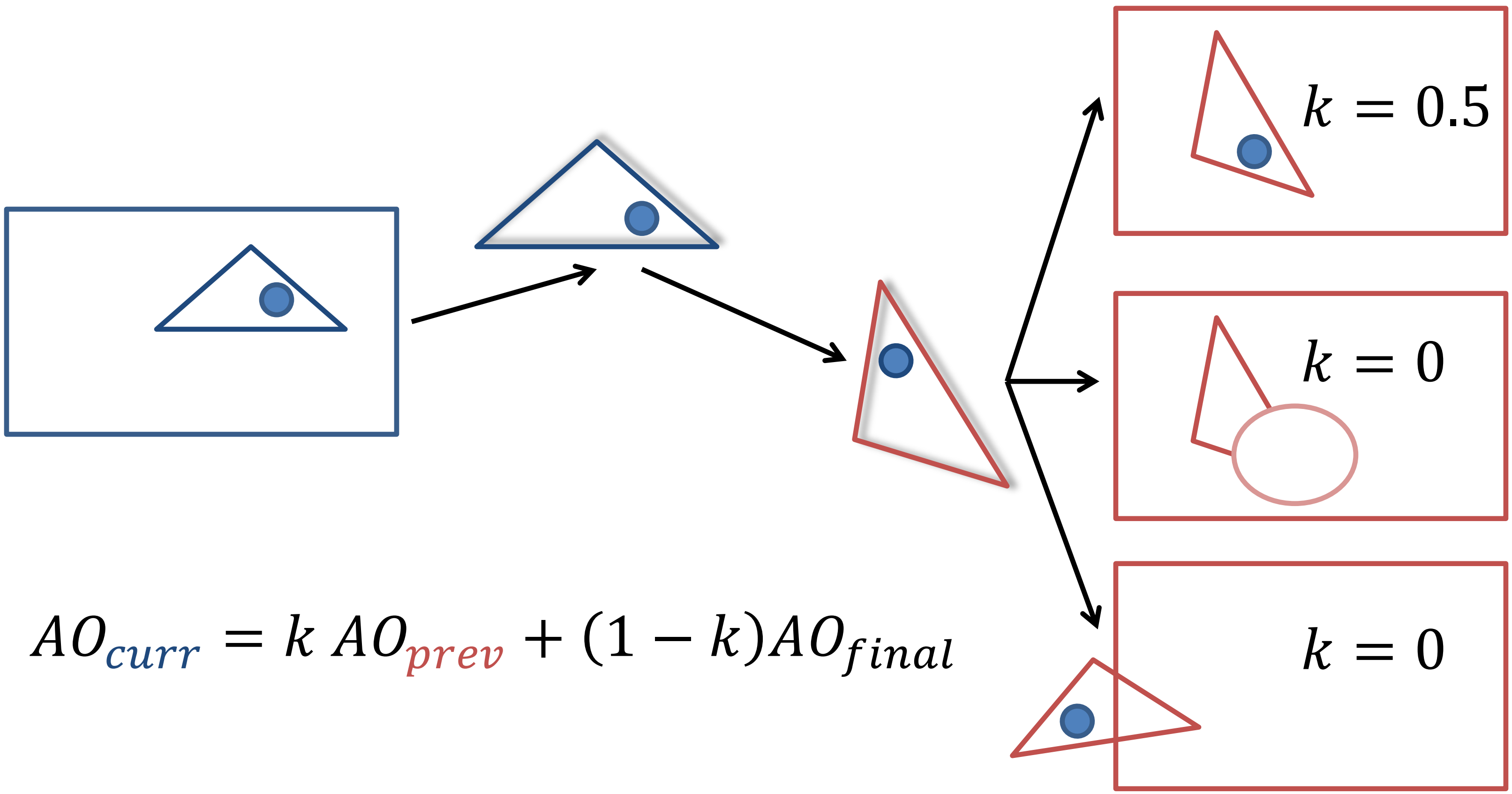
$$AO(p) = \sum_{i=1}^{4} w_b(p_i) w_z(p_i) w_n(p_i) AO(p_i)$$

MSSAO
Combining AO Values

$$AO_{final} = 1 - (1 - \max(AO_i))(1 - \text{avg}(AO_i))$$

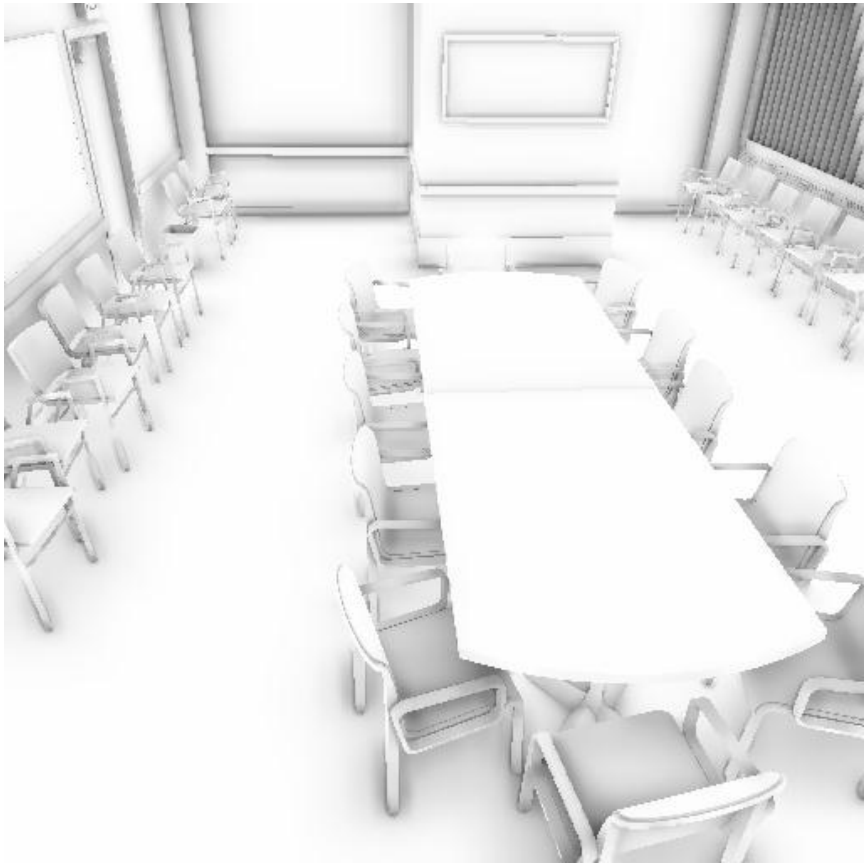
- $\max(AO_i)$ and $\text{avg}(AO_i)$ are computed by "propagating" appropriate values across resolutions
- Avoid underestimating AO by ensuring
$$AO_{final} \geq \max(AO_i)$$
- And a plausible heuristic
$$AO_{final} \propto \text{avg}(AO_i)$$

MSSAO
Temporal Filtering



$$AO_{curr} = k\, AO_{prev} + (1 - k) AO_{final}$$

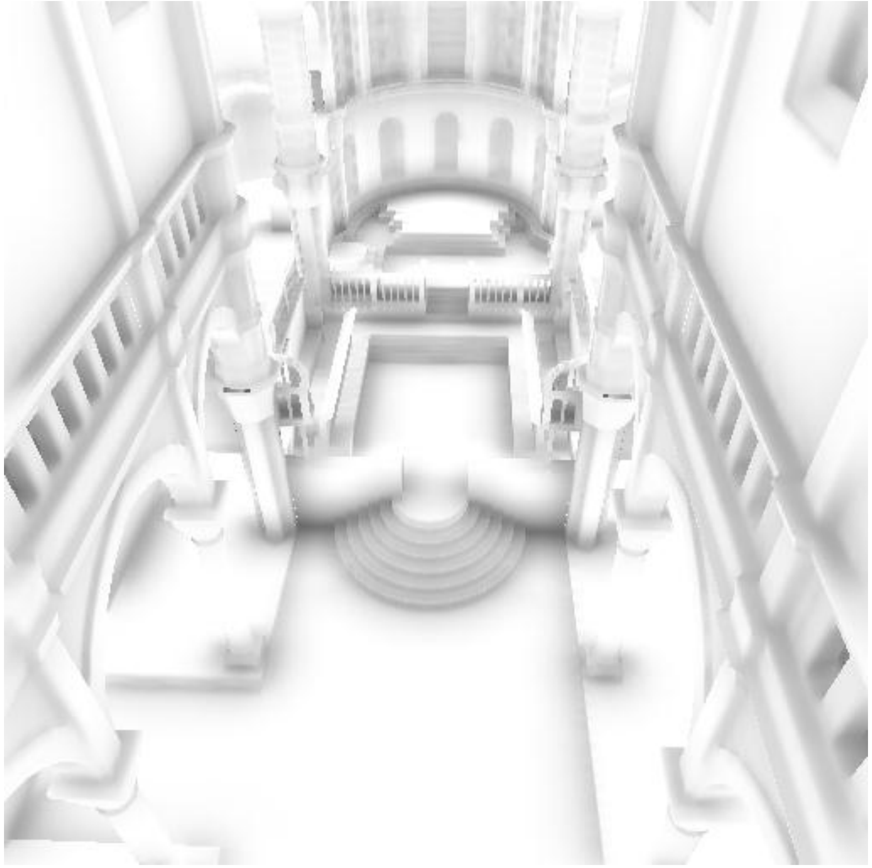
Results
Quality



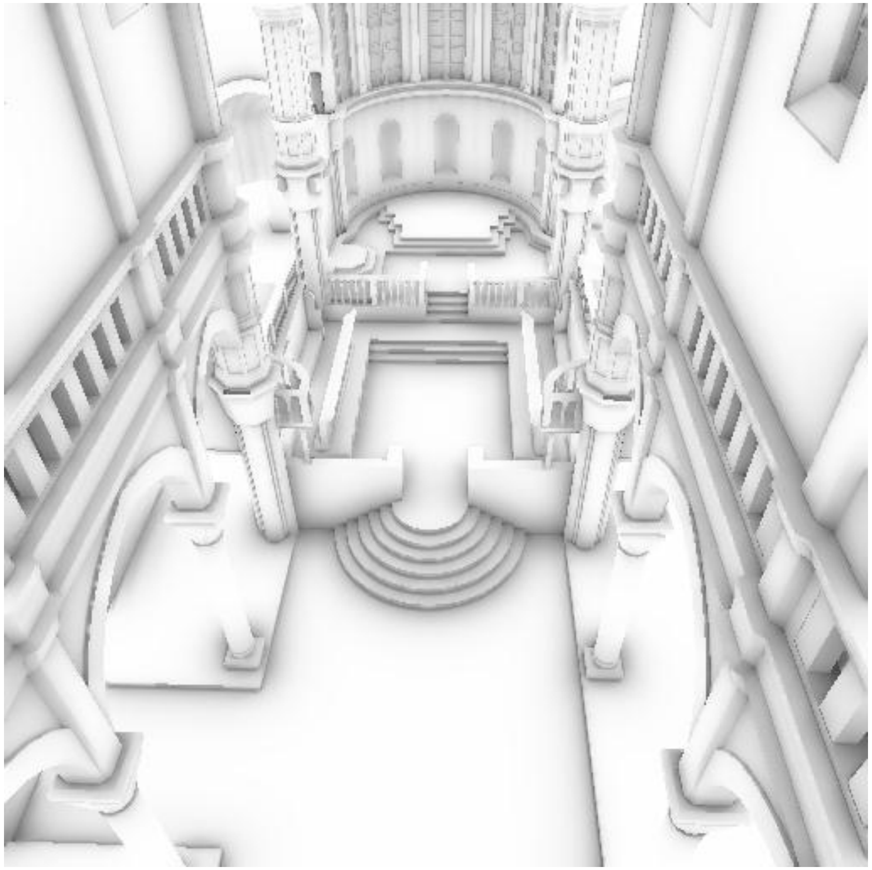
Blizzard [FM08]

MSSAO

Results
Quality

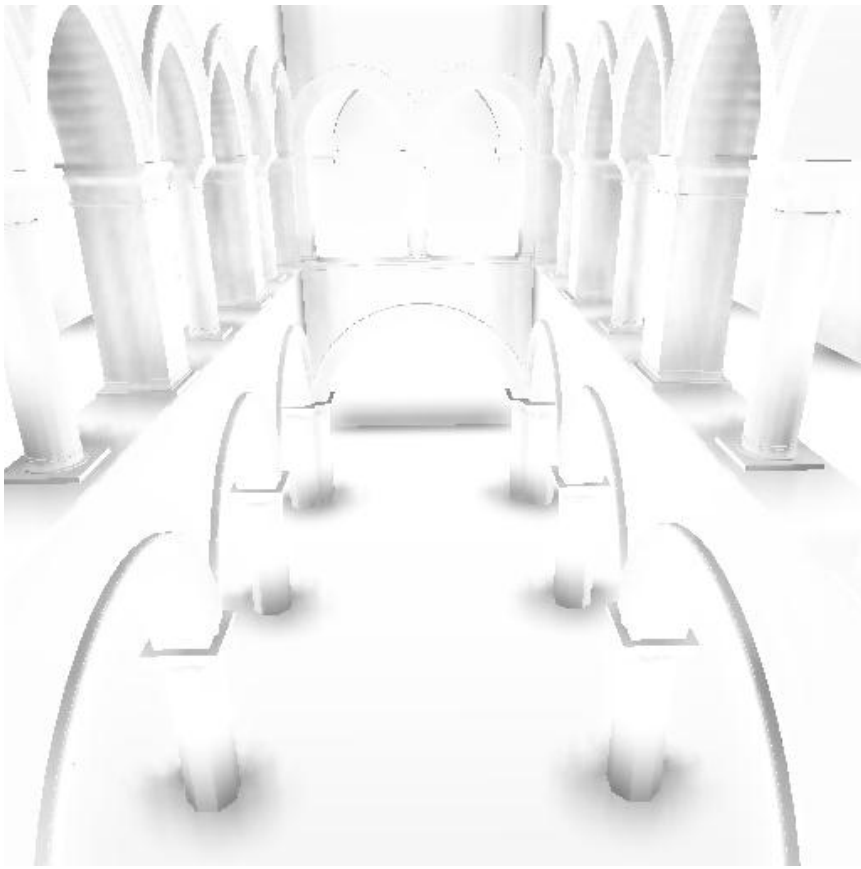


HBAO [BSD08]

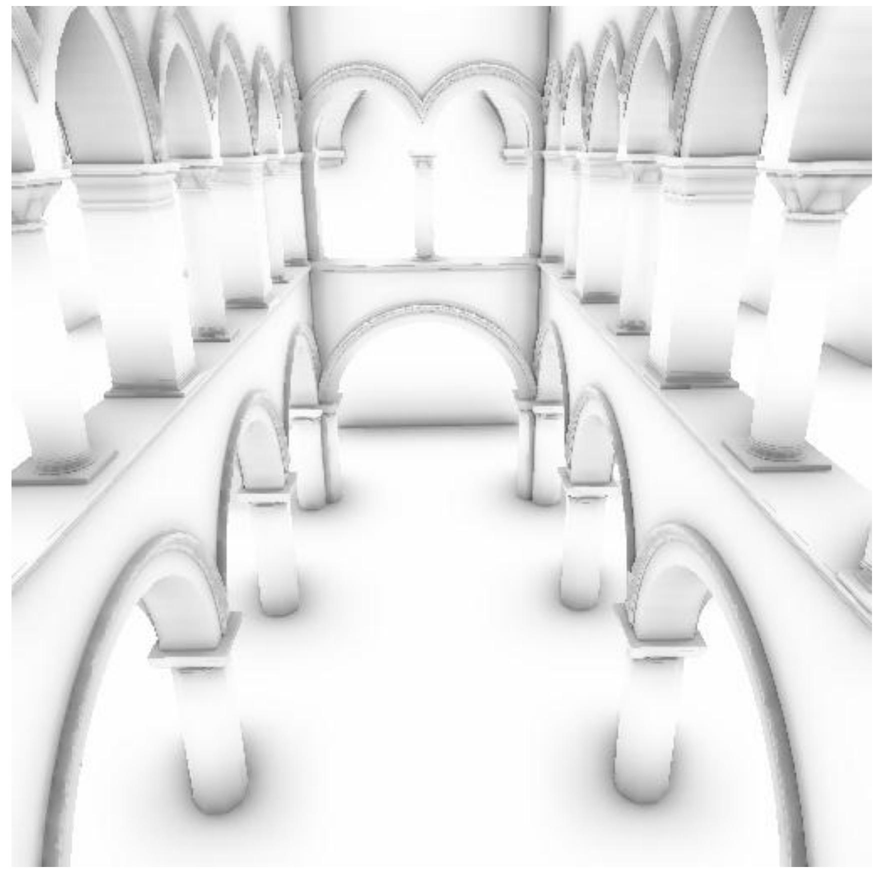


MSSAO

Results
Quality

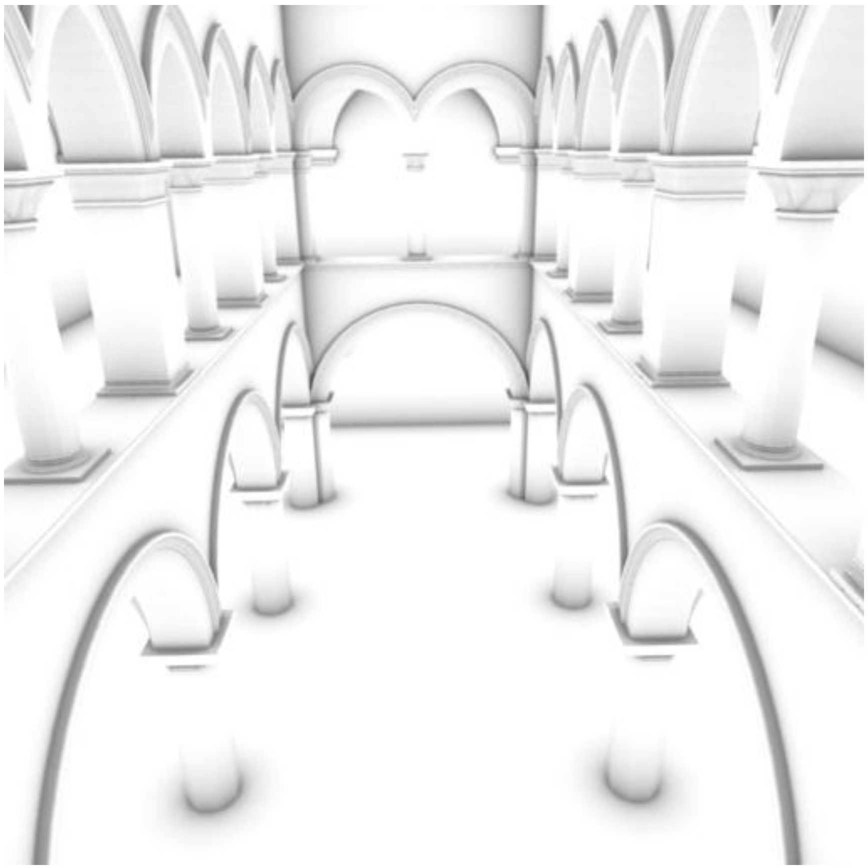


VAO [SKUT10]

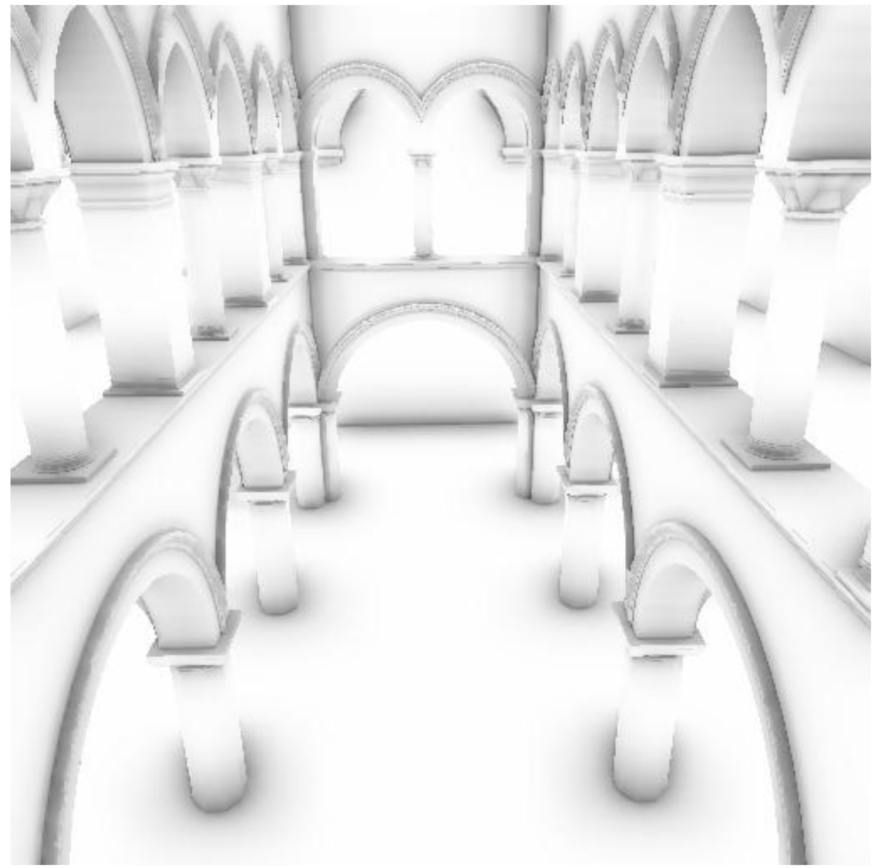


MSSAO

Results
Ground-truth Comparison

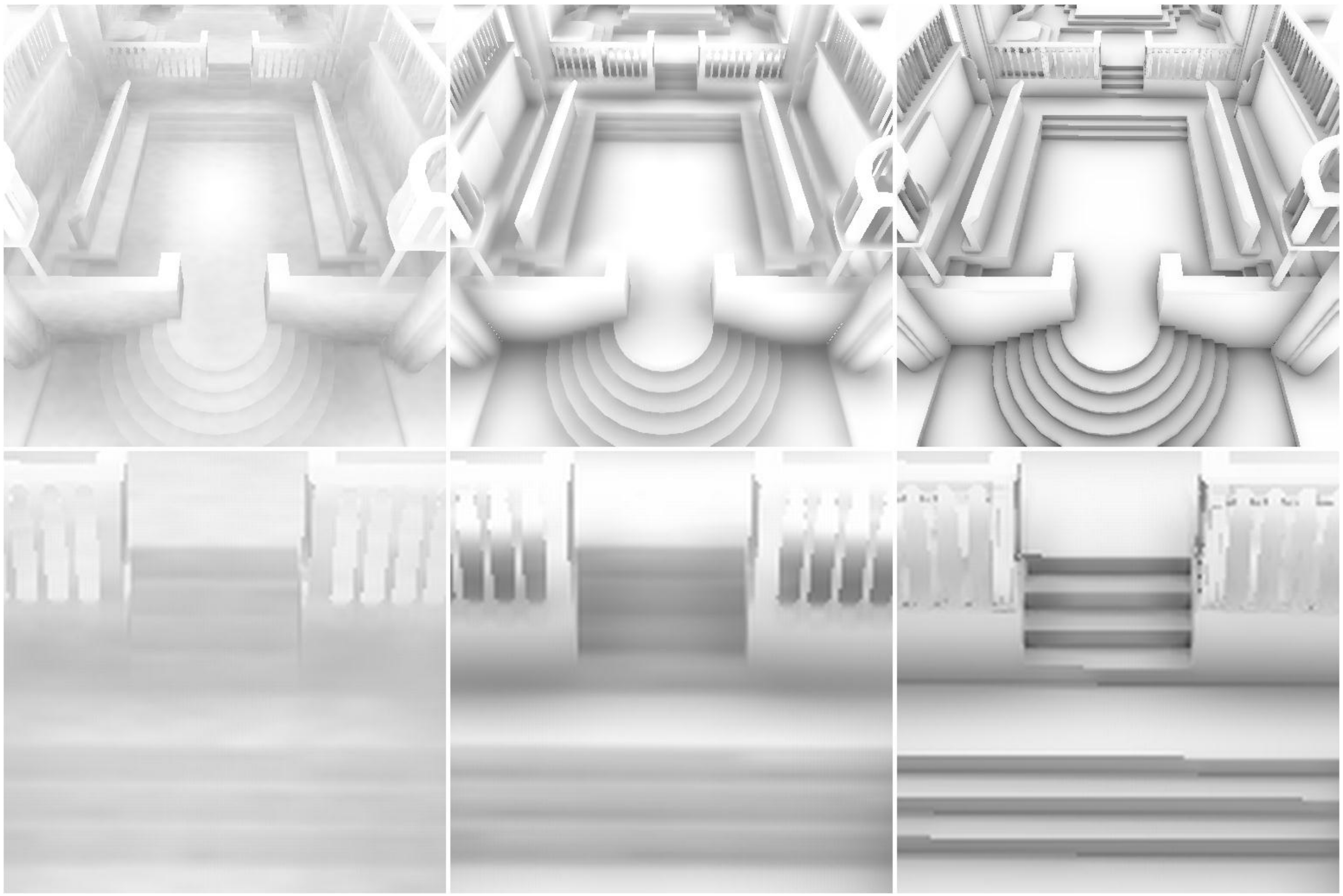


Blender



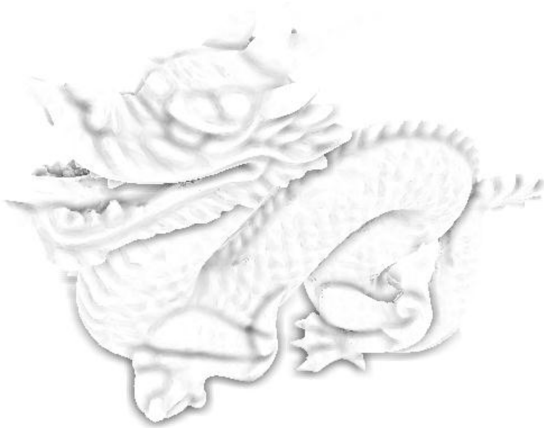
MSSAO

Results
Noise/Blur



Blizzard [FM08] HBAO [BSD08] MSSAO

Results
Multiple AO Scales



Small AO radius

Large AO radius

MSSAO

Results
Performance

- Scenes rendered at 1024x1024 on GeForce GTX 460M
- Exclusive of geometry pass
- The same parameters used to produce the shown images

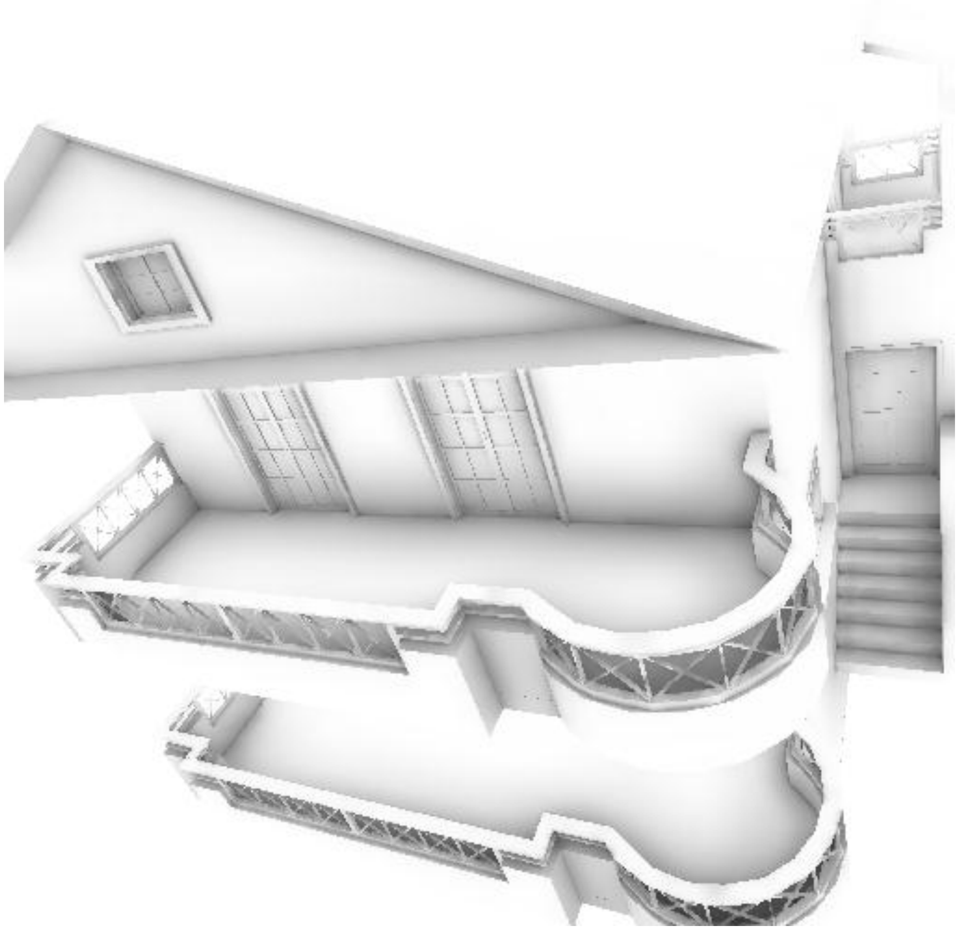
	MSSAO	**VAO**	**Blizzard**	**HBAO**
Sibenik Cathedral	21.9 ms	22.9	25.7	50.1
Conference Room	24.0 ms	24.8	24.9	49.5
Sponza Atrium	22.2 ms	24.0	28.9	54.3

MSSAO Conclusions

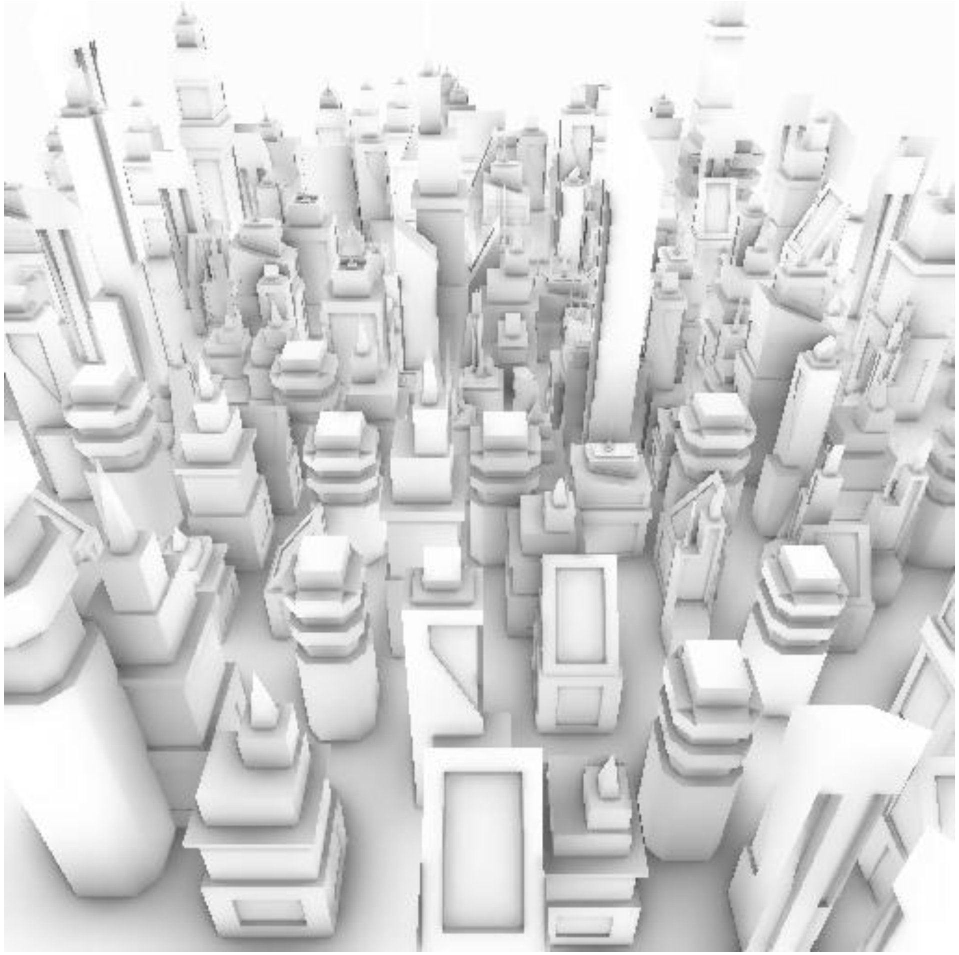
- ✖ Inaccurate
  - ~~✖ Local AO~~
  - ✖ Over/underestimated AO
- ~~✖ Low quality~~
  - ~~✖ Noise~~
  - ~~✖ Blur~~
- ✖ Use more memory
- ✖ Poor temporal coherence on very thin geometry
  - ✓ Not too noticeable
- ✖ Errors due to the use of coarse resolutions
  - ✓ Not too noticeable unless compared with ground-truths

- ✓ Simple
- ✓ Fast
- ✓ General
- ✓ Easy to integrate
- ✓ Capture multiple shadow frequencies

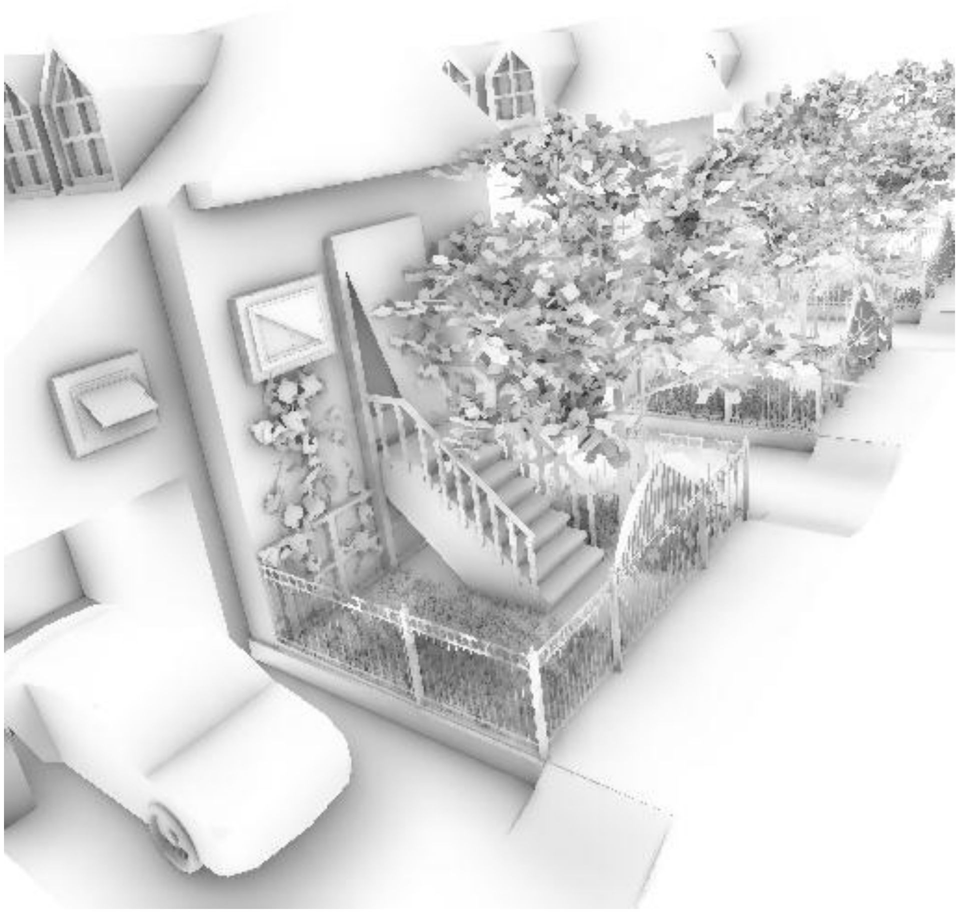
Results
Additional Results



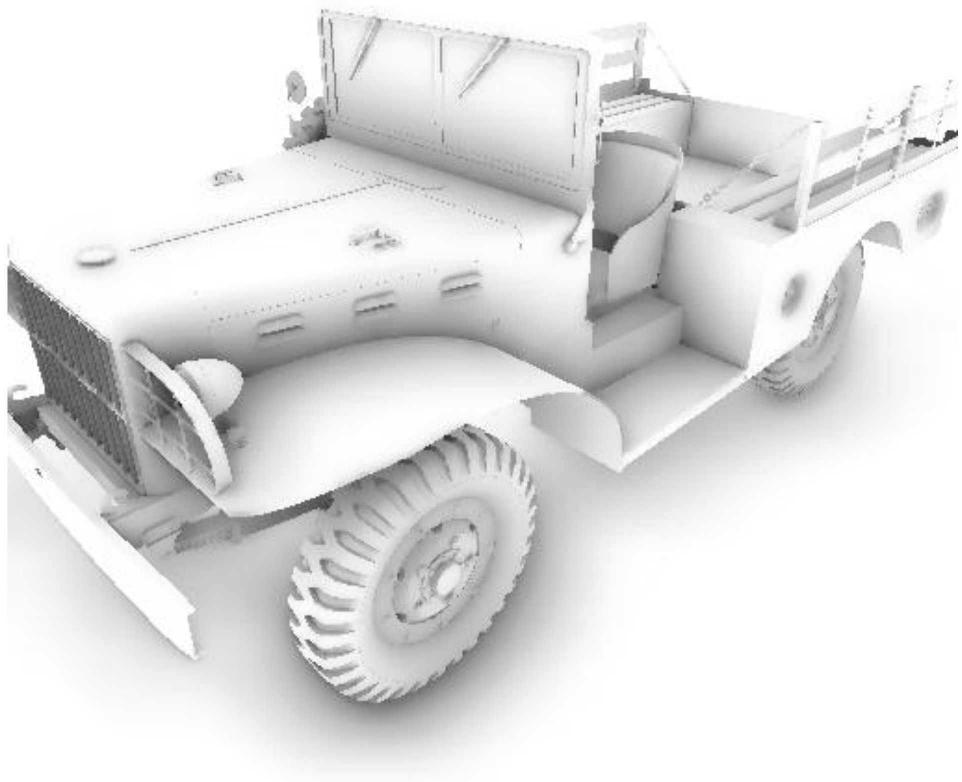
Results
Additional Results



Results
Additional Results



Results
Additional Results



Thank You