

# Reduced Aggregate Scattering Operators for Path Tracing

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Jan Novák

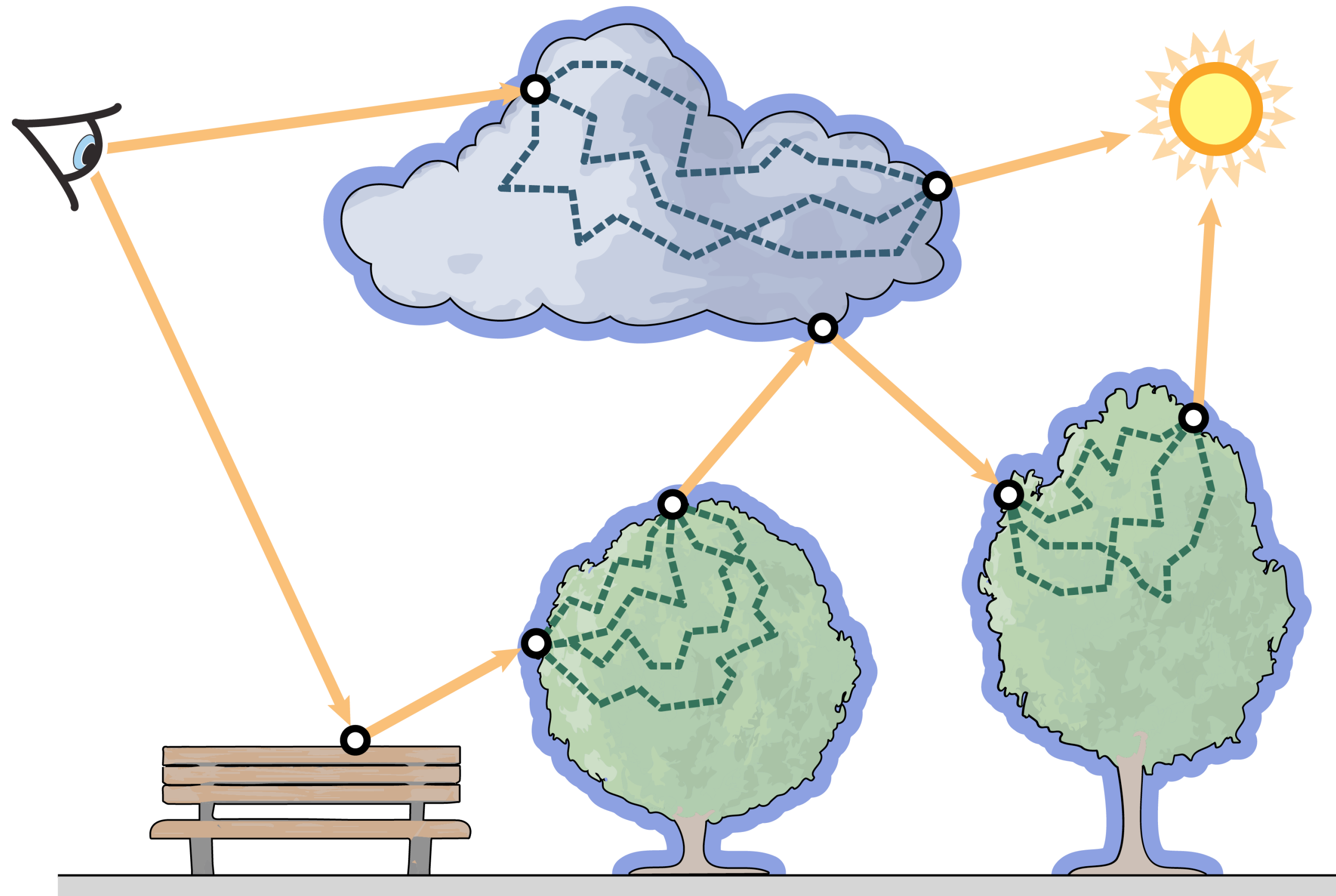
Ralf Habel

Derek Nowrouzezahrai

Wojciech Jarosz



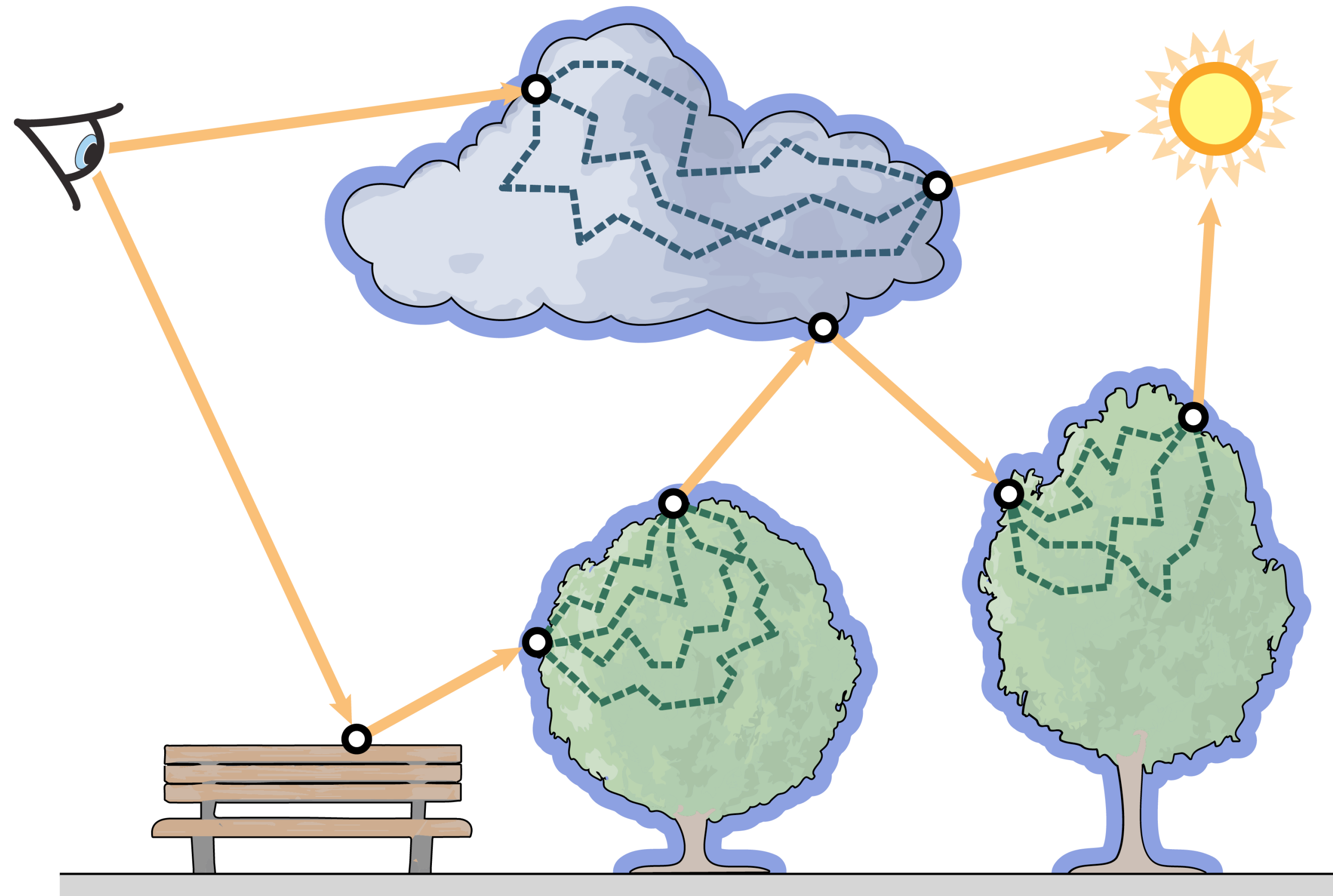
# Overview



Reduced  
Aggregate  
Scattering Operators  
for Path Tracing



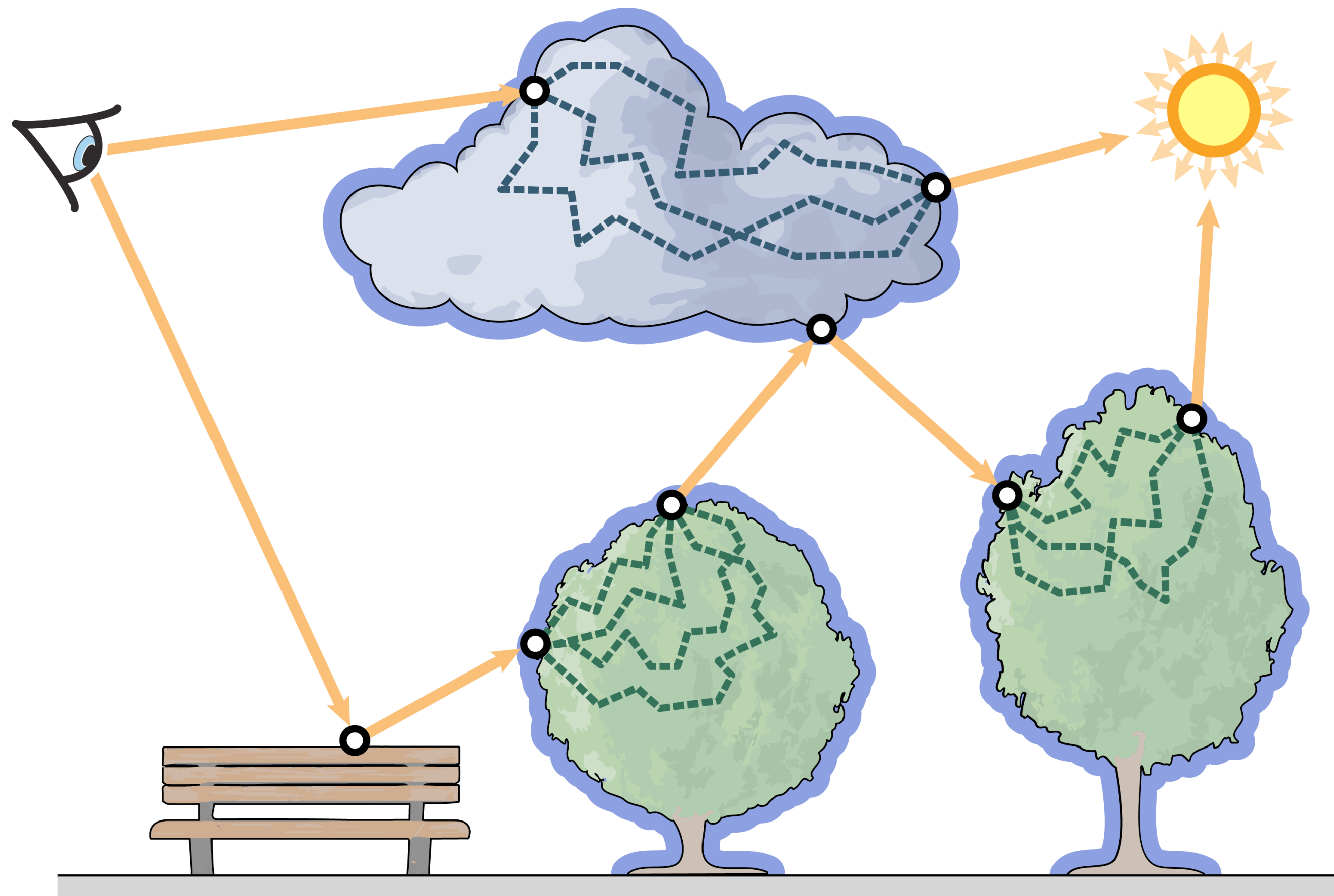
# Overview



Reduced  
Aggregate  
**Scattering Operators**  
for Path Tracing



# Overview



Reduced

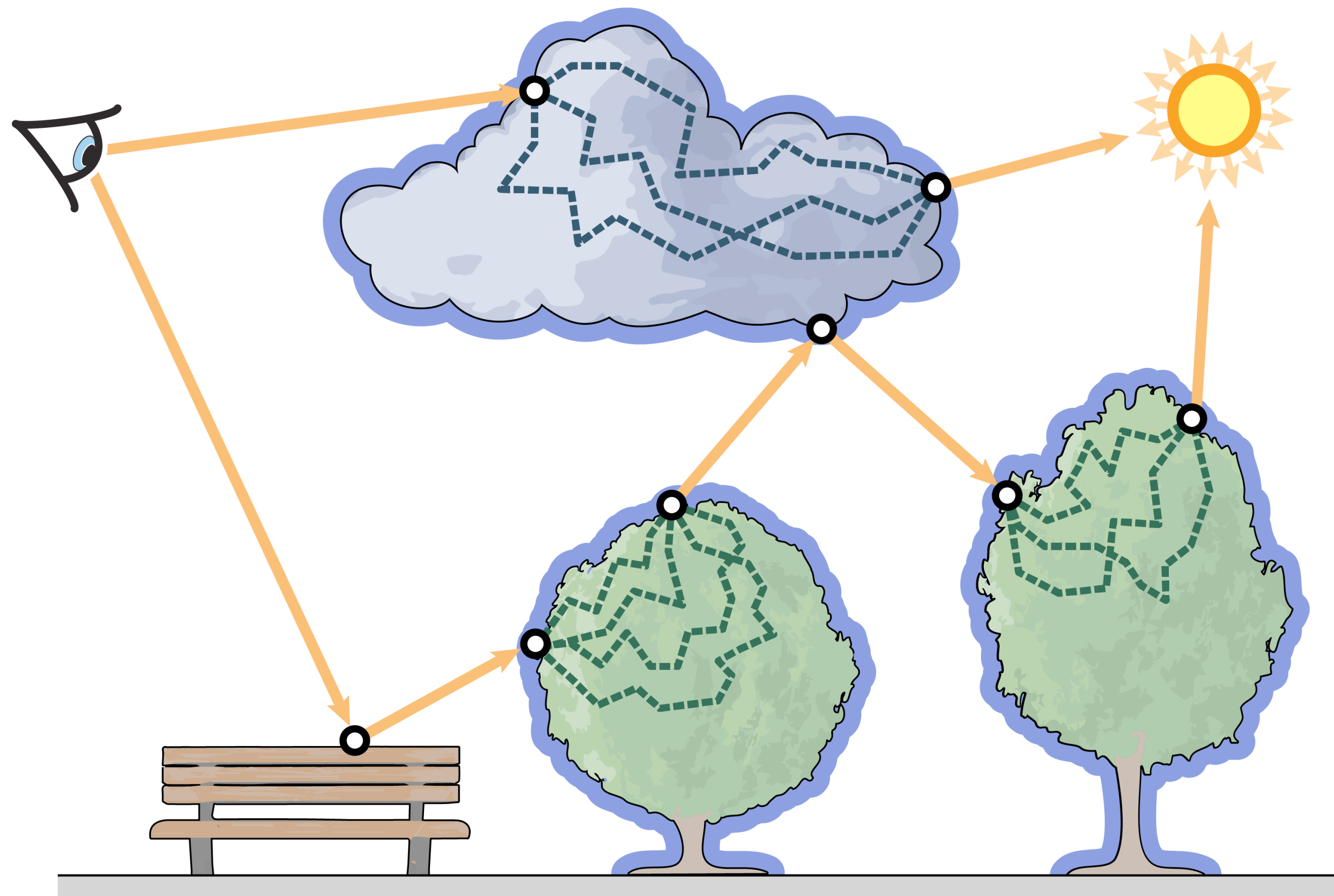
**Aggregate**

Scattering Operators

for Path Tracing



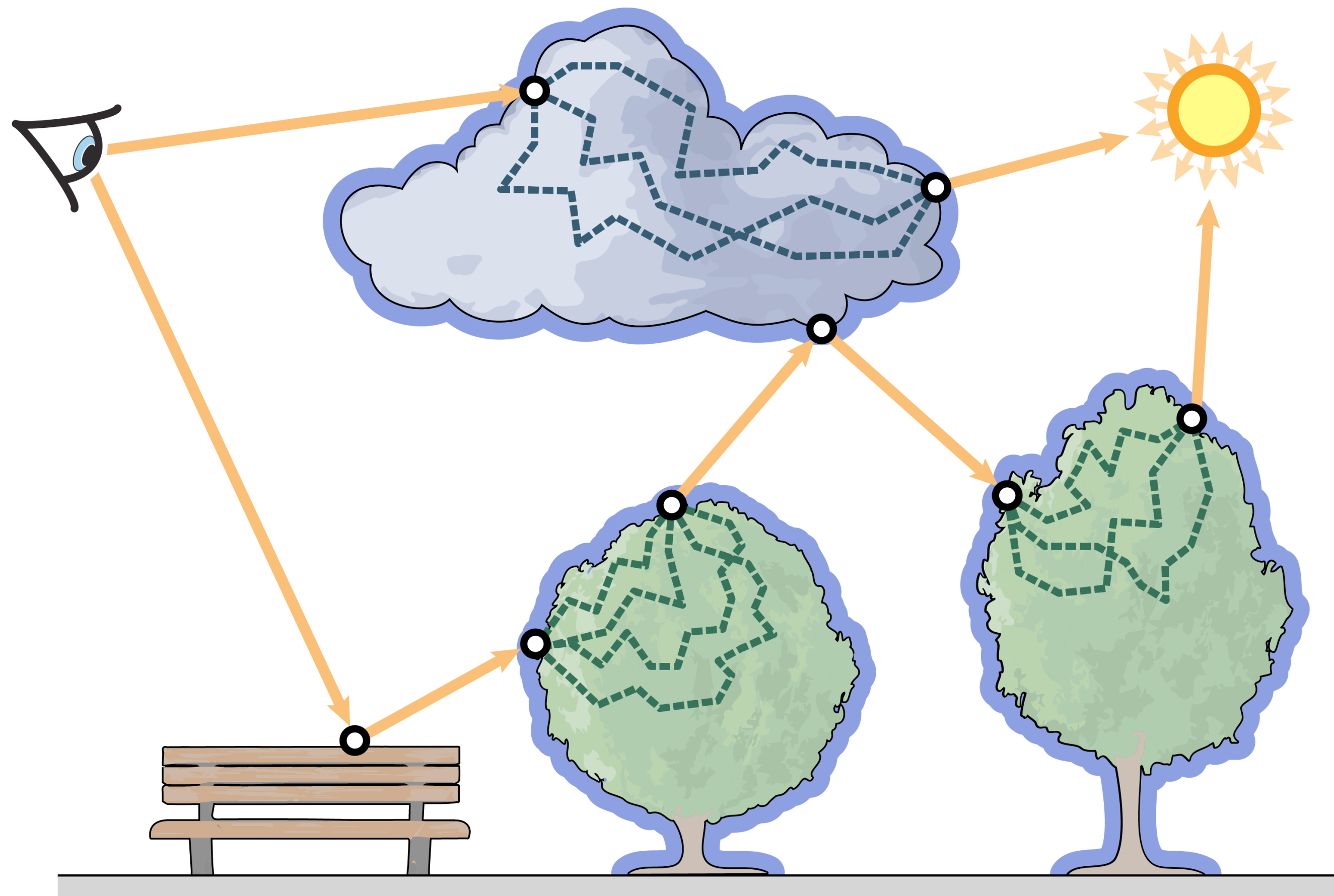
# Overview



Reduced  
Aggregate  
Scattering Operators  
for Path Tracing



# Overview



Reduced

Aggregate

Scattering Operators

for Path Tracing



# Motivation



image sources:

clouds: <https://www.flickr.com/photos/rocor/608762581>

tree: [http://www.wallpaperonview.com/wallpapers/landscape\\_astonishing\\_nature\\_quality\\_trees\\_background\\_picture-2560x1600-12555.html](http://www.wallpaperonview.com/wallpapers/landscape_astonishing_nature_quality_trees_background_picture-2560x1600-12555.html)

snowmen: <http://funmozar.com/christmas-snow-wallpapers/>

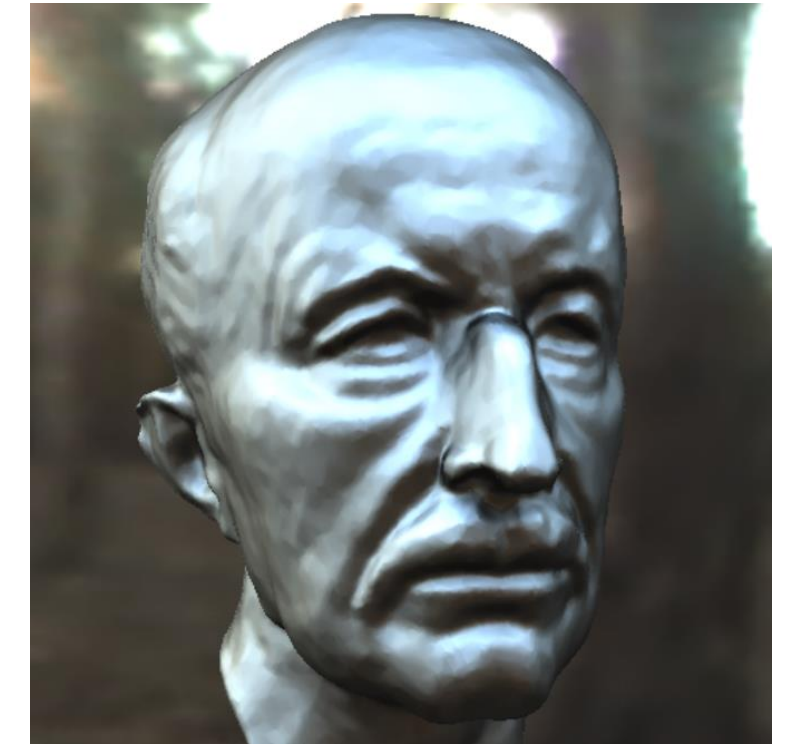
sheep: [https://travelblog.expedia.co.th/western\\_thailand/15043/](https://travelblog.expedia.co.th/western_thailand/15043/)



# Selected Related Work

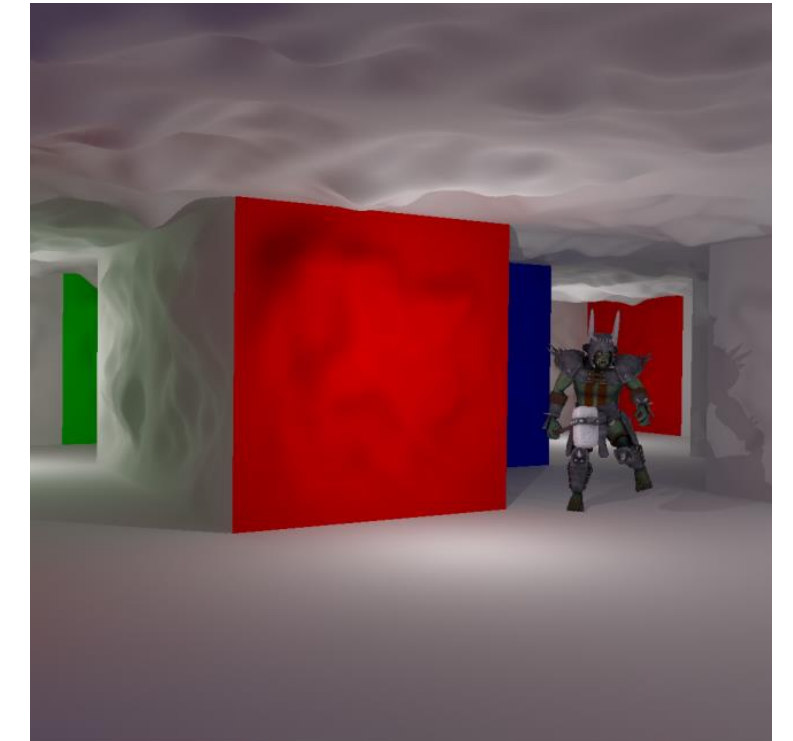
Clustered principal components for precomputed radiance transfer

*Sloan et al., 2003*



Modular radiance transfer

*Loos et al., 2011*



A Practical Model for Subsurface Light Transport

*Henrik et al., 2001*



Much more: importance sampling, caching of light transport, vegetation rendering, subsurface scattering, ...





# Precomputation

## Path tracer integration



# Precomputation

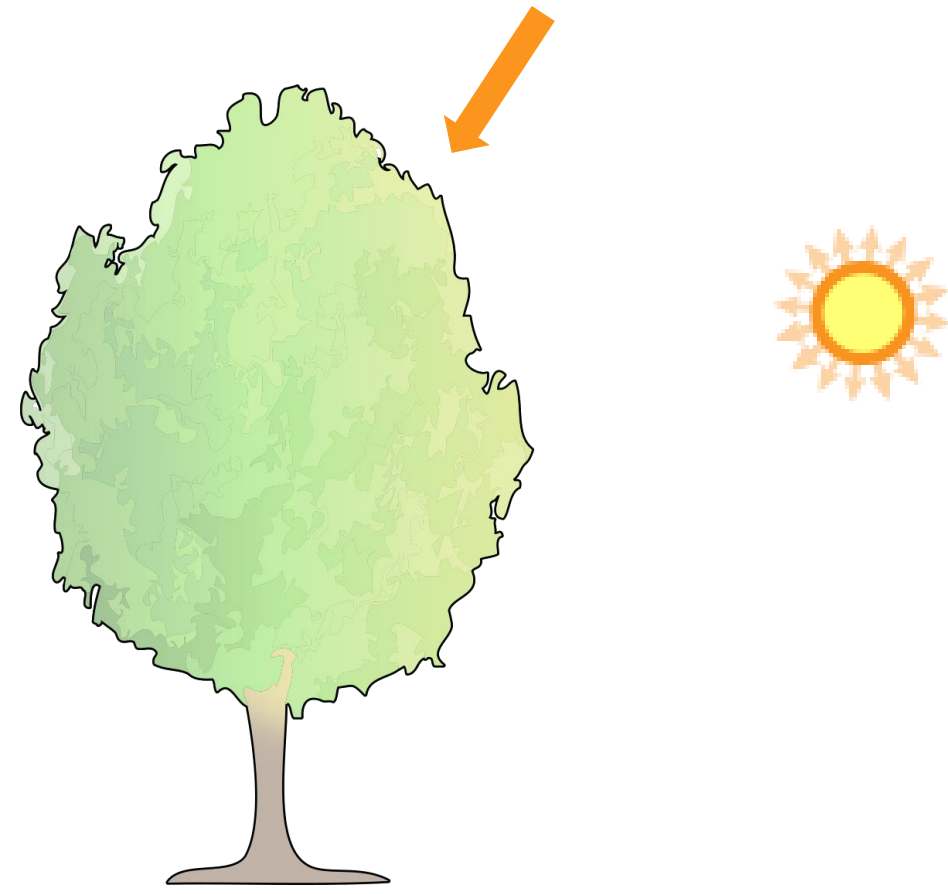
Path tracer integration



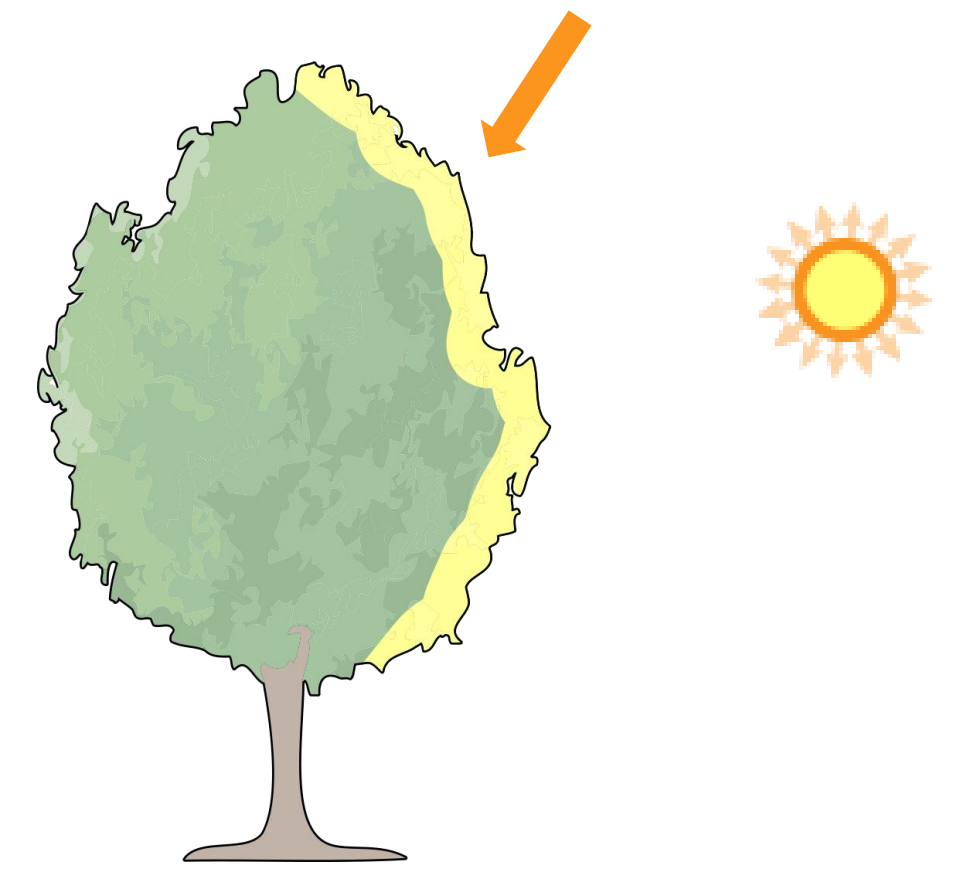
# Method

Light transport as a matrix operation

indirect illumination



direct illumination

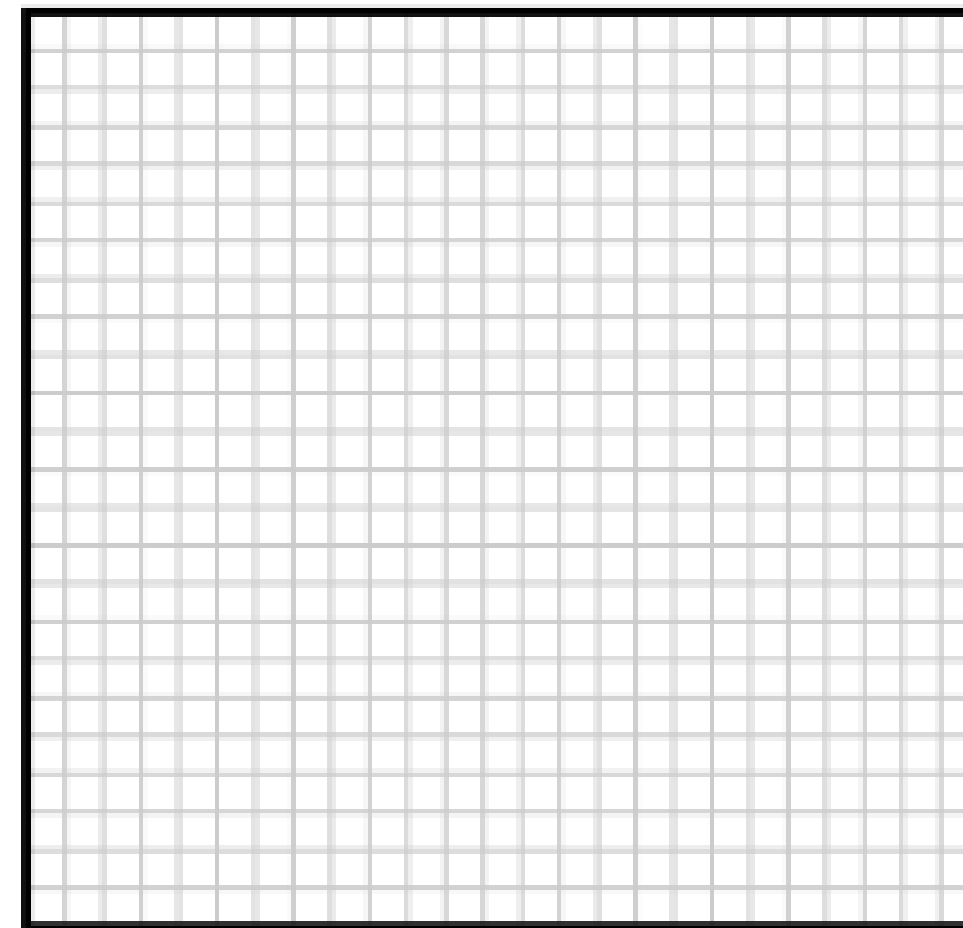


indirect



=

transport matrix



×

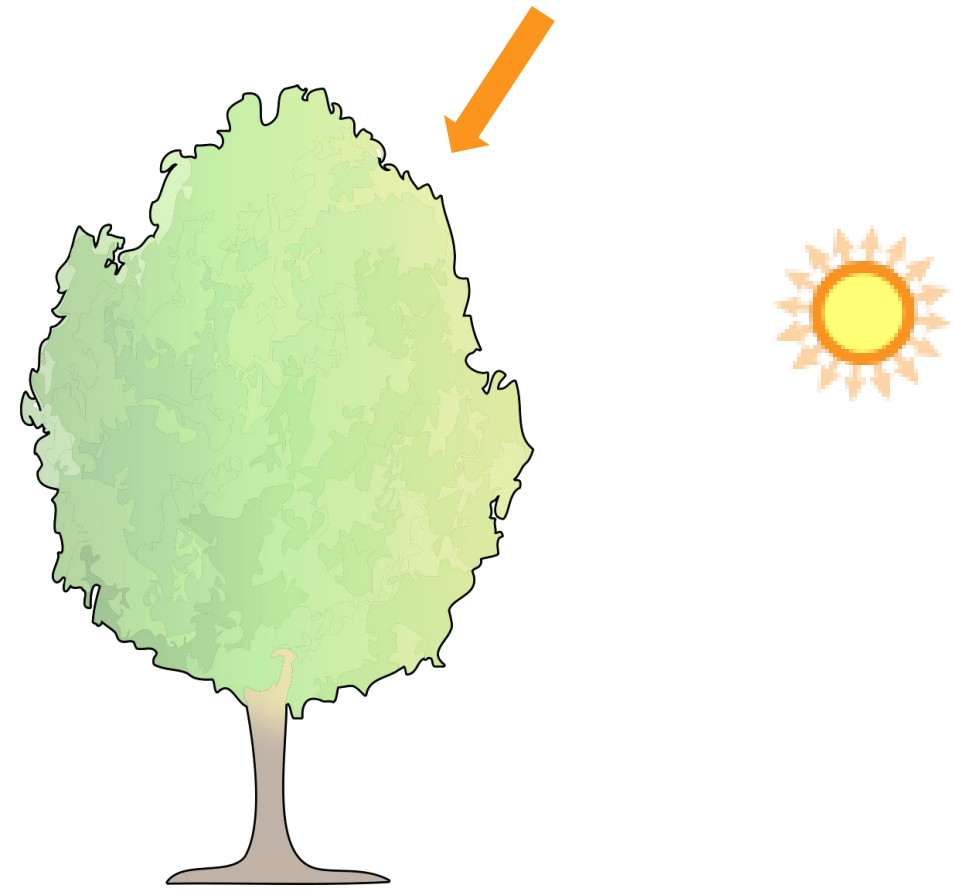
direct



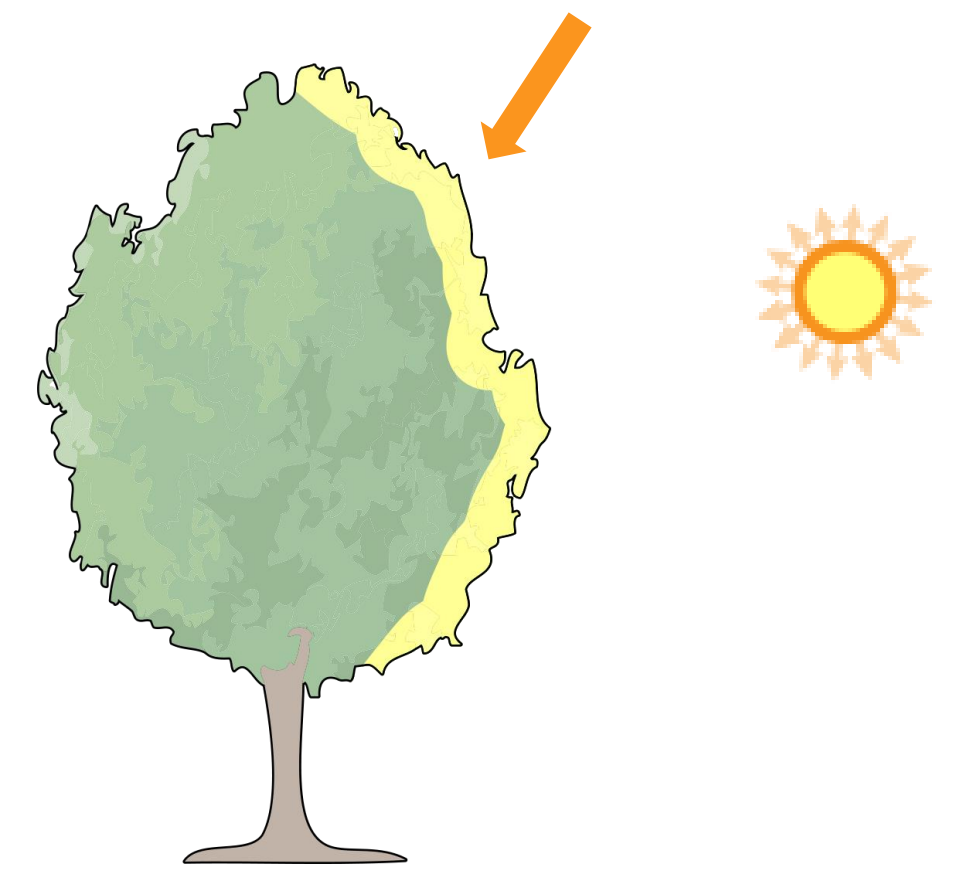
# Method

Light transport as a matrix operation

indirect illumination



direct illumination



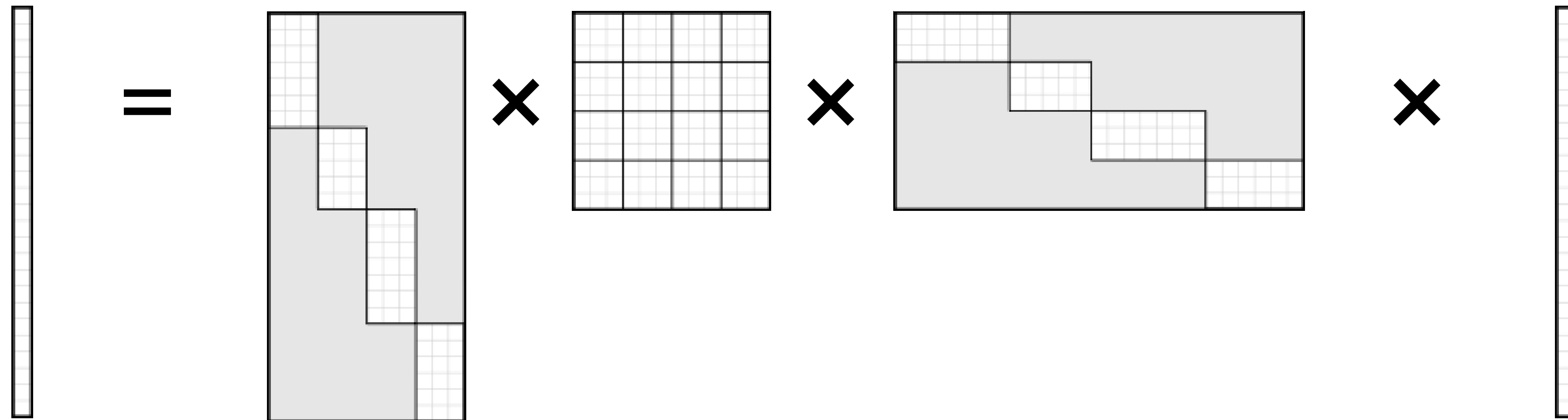
indirect

basis transform

transport

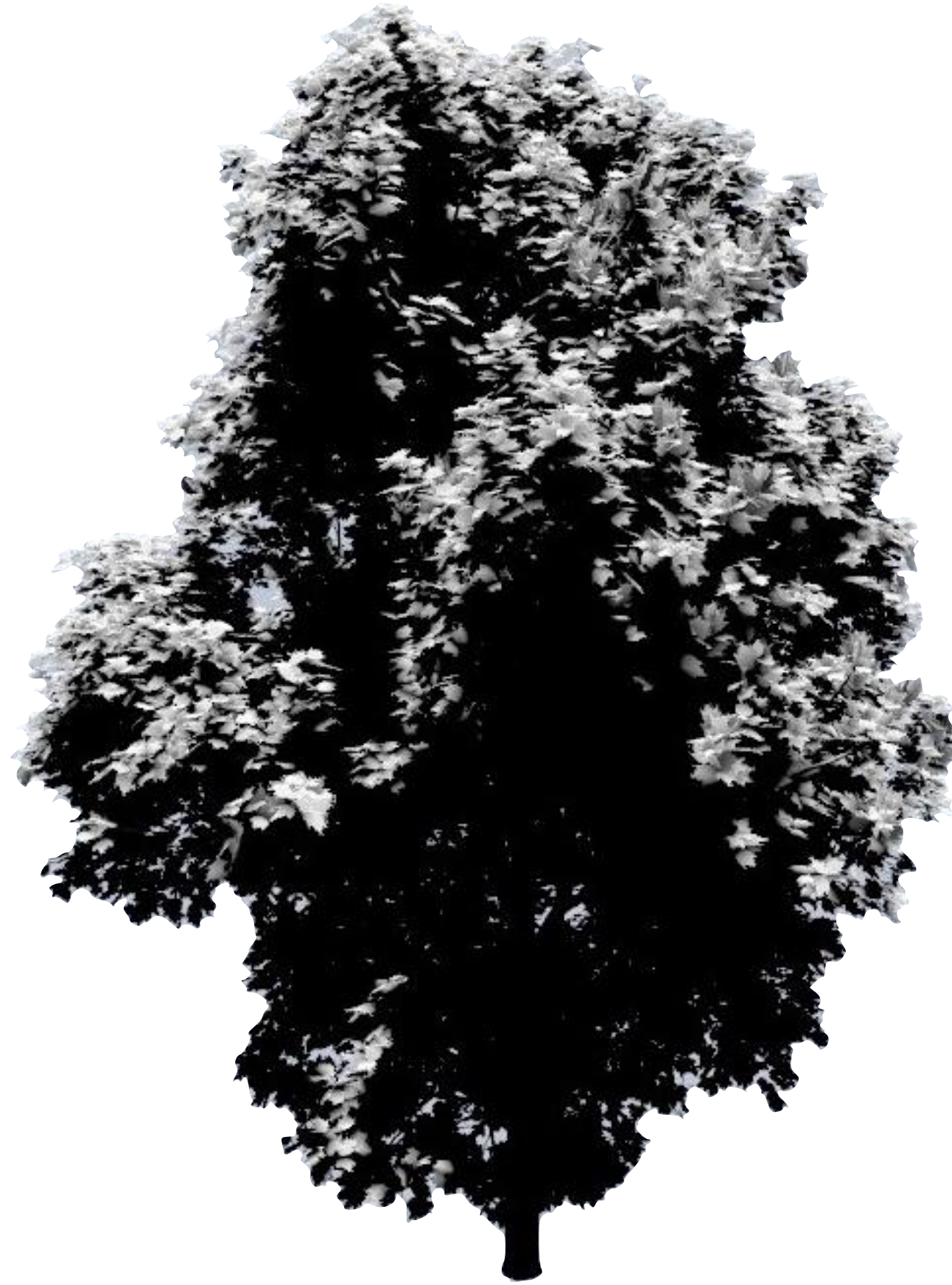
basis transform

direct



# Method

Learning reduced bases



# of vertices

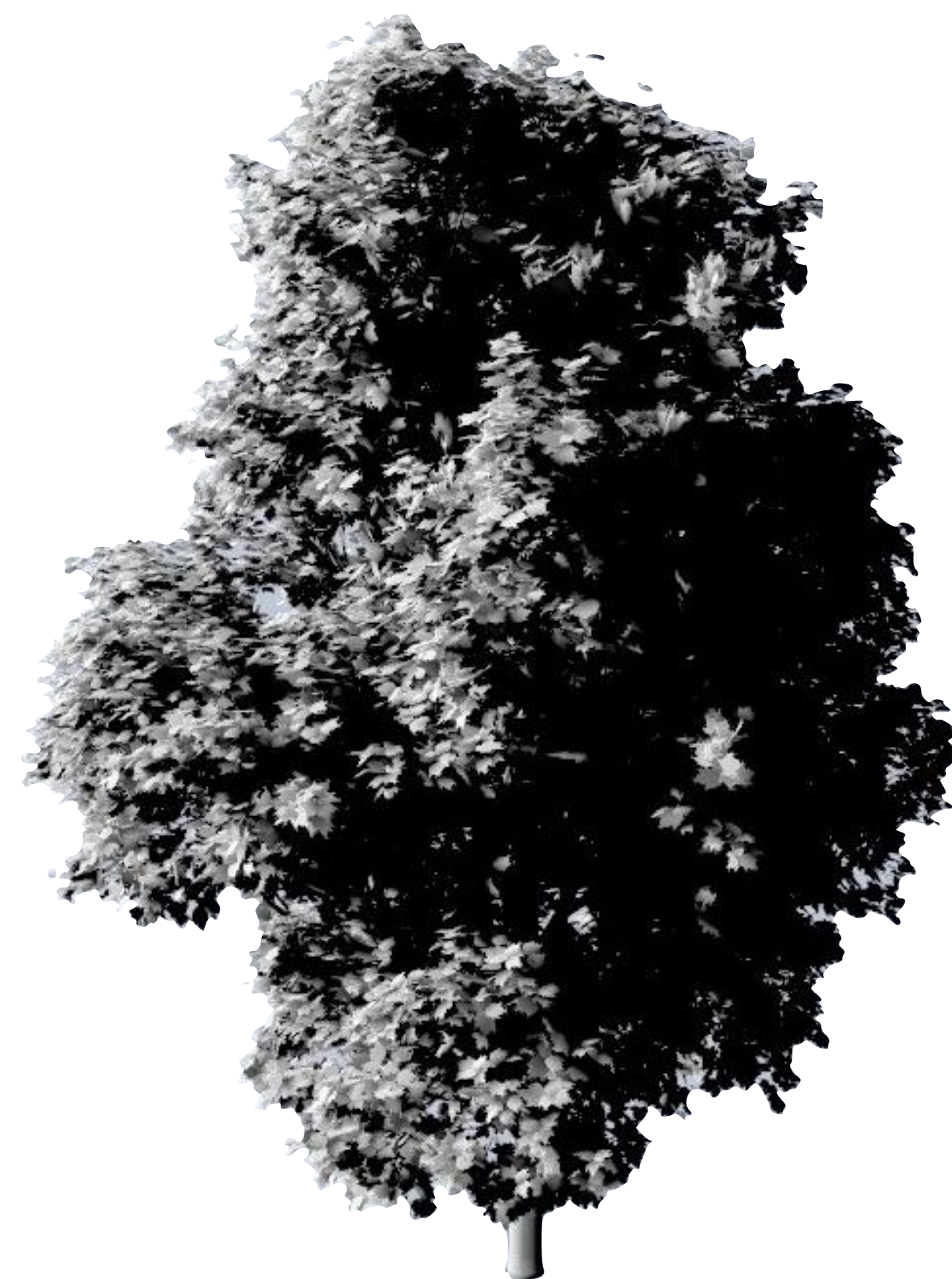
configuration 1

*Modular radiance transfer*  
*Loos et al., 2011*

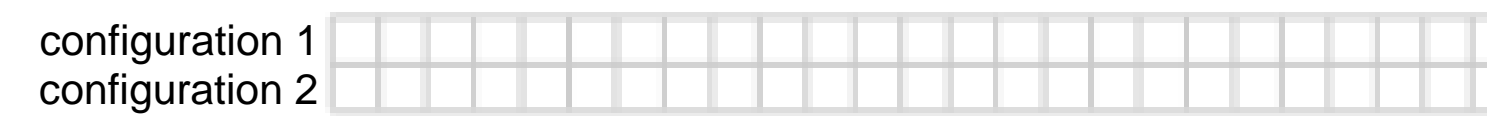


# Method

Learning reduced bases



# of vertices



*Modular radiance transfer*  
Loos et al., 2011





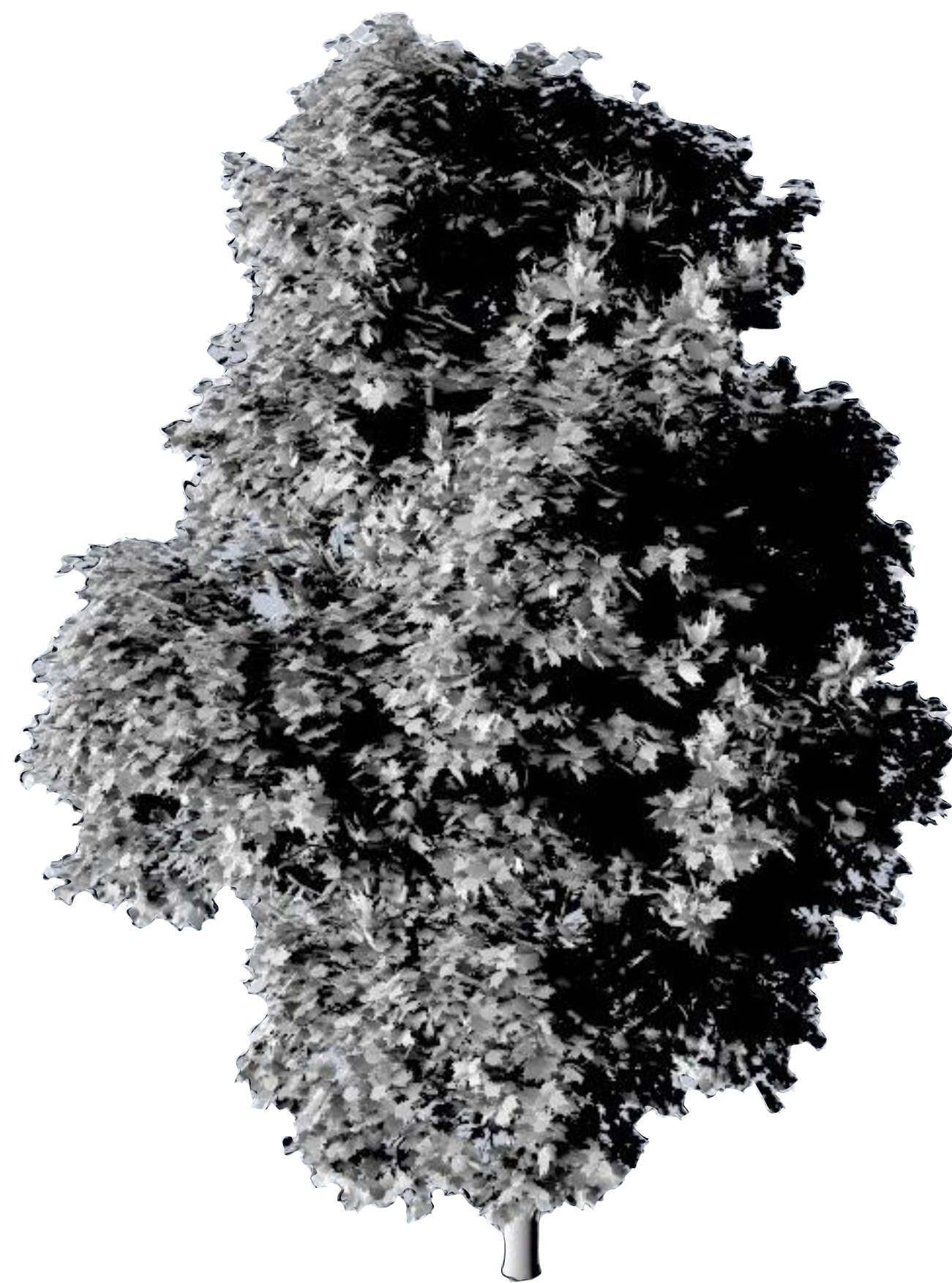




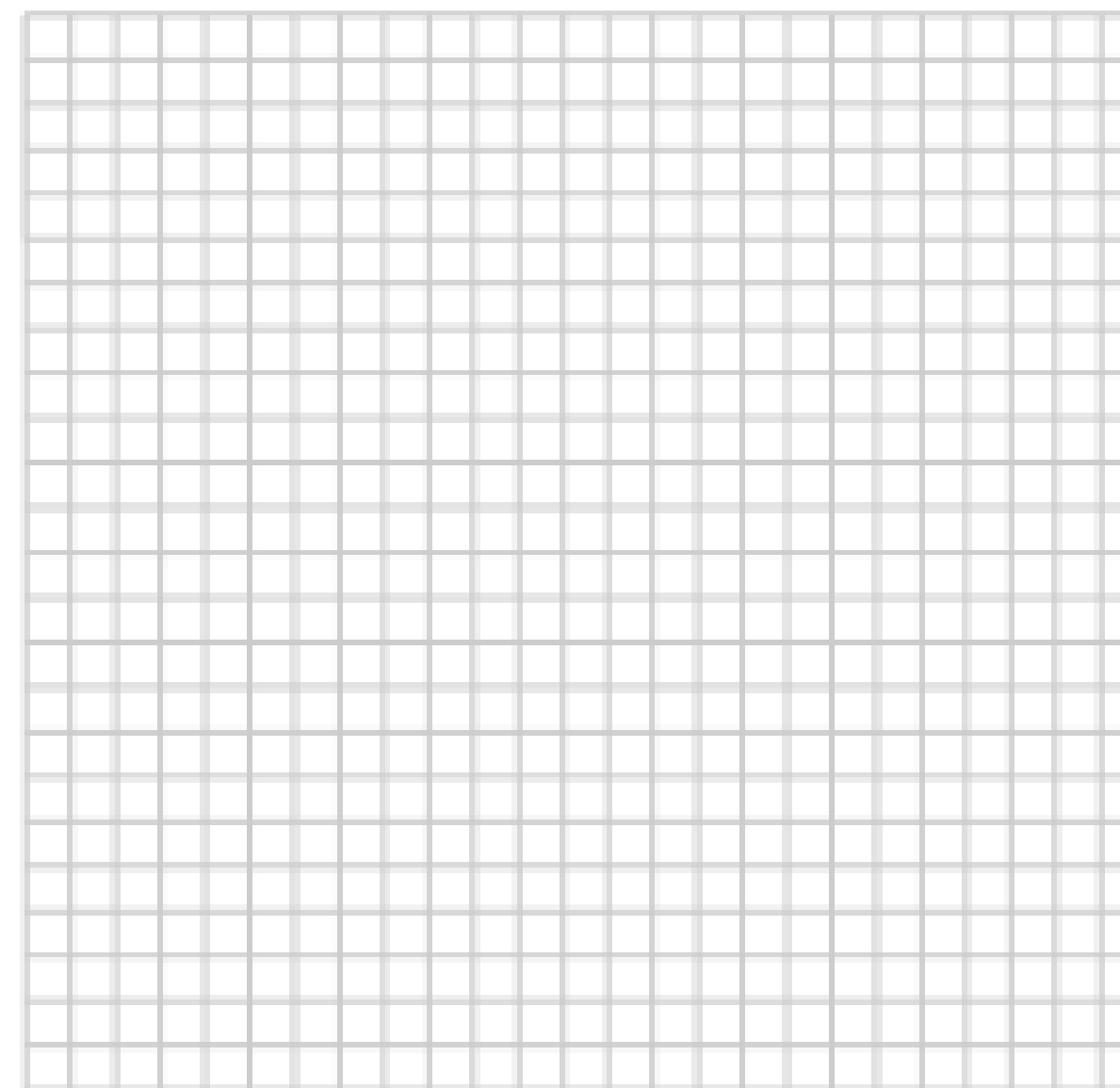


# Method

Learning reduced bases



# of vertices



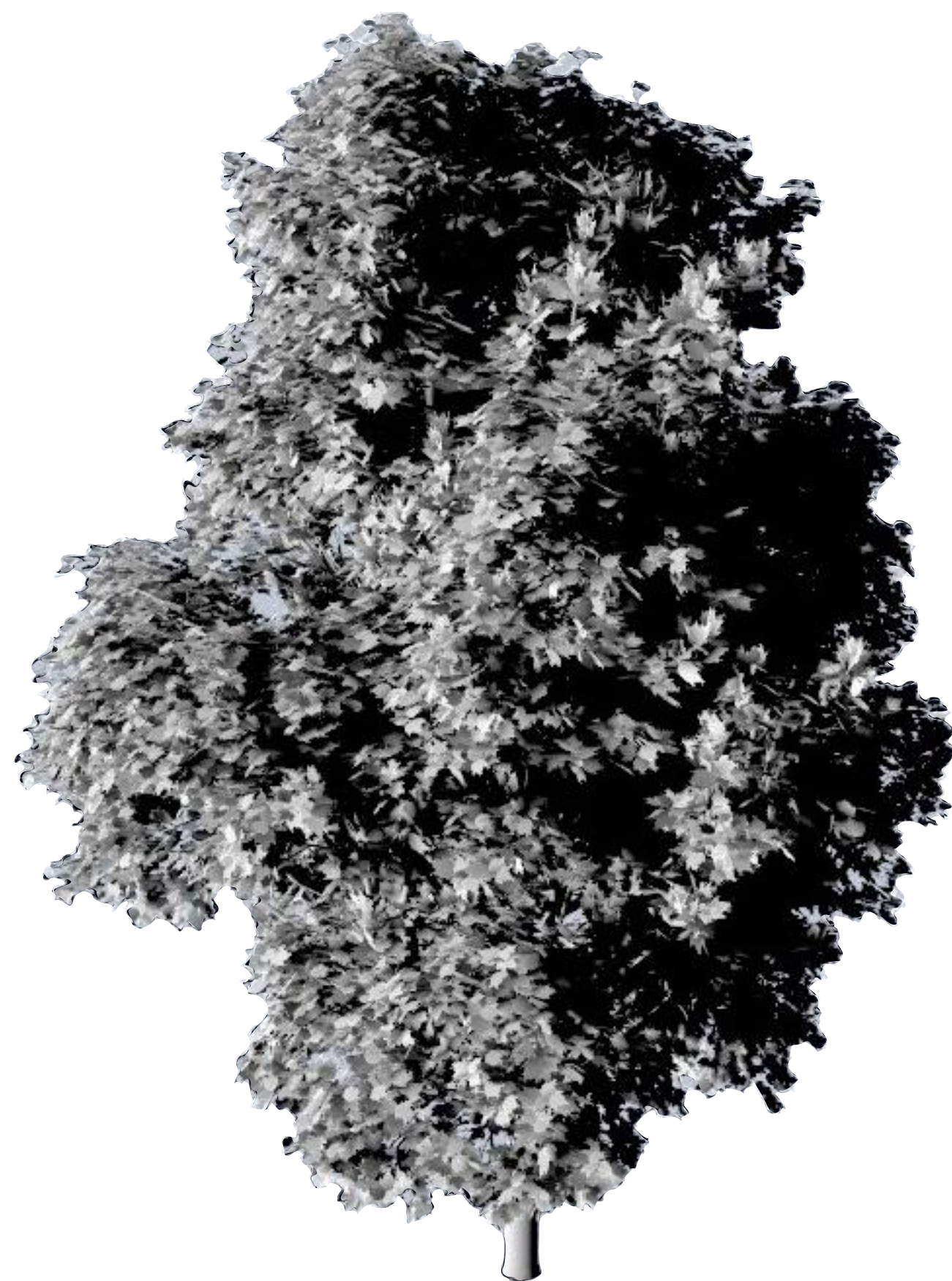
# of configurations

*Modular radiance transfer*  
*Loos et al., 2011*

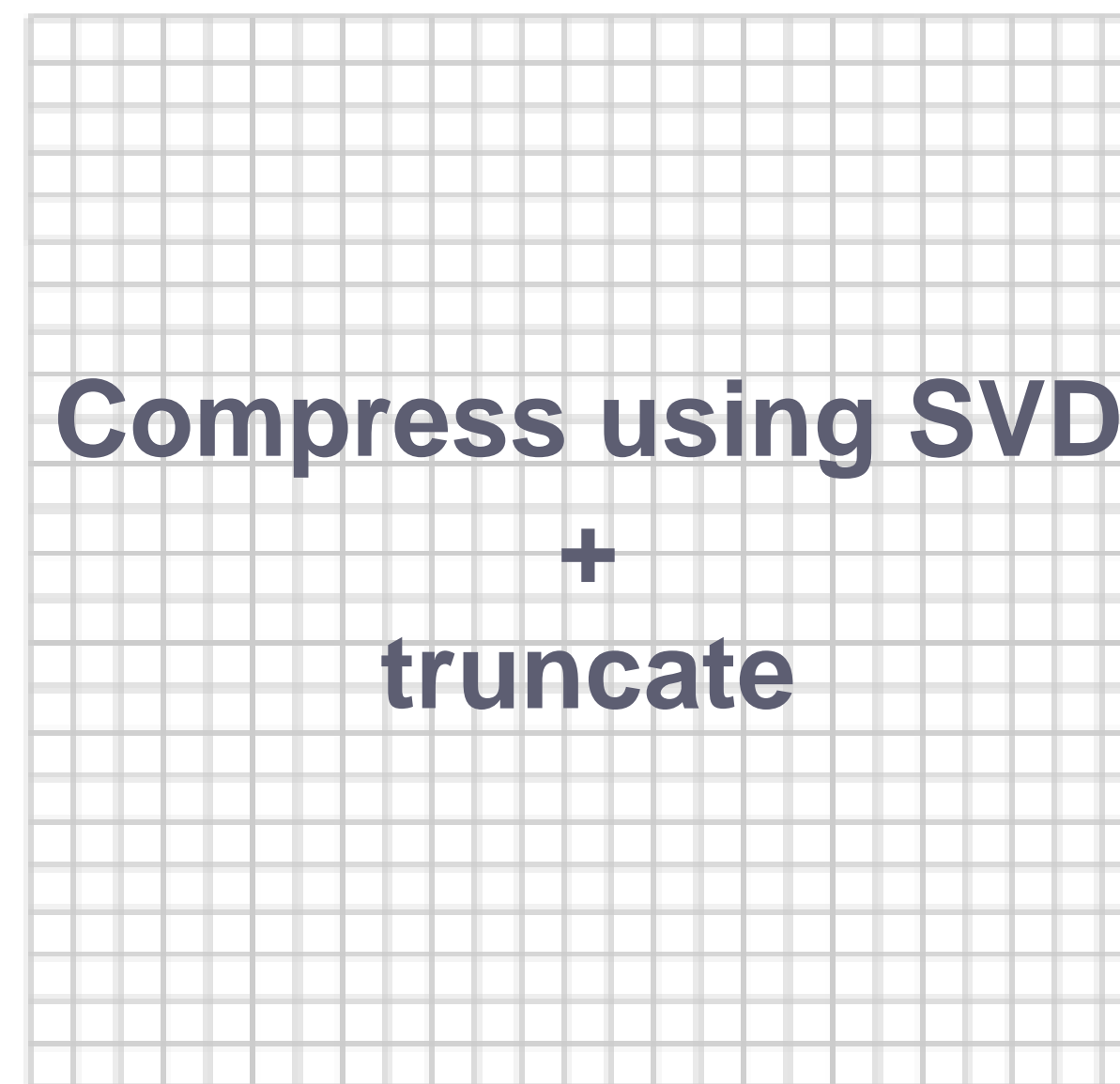


# Method

Learning reduced bases



# of vertices



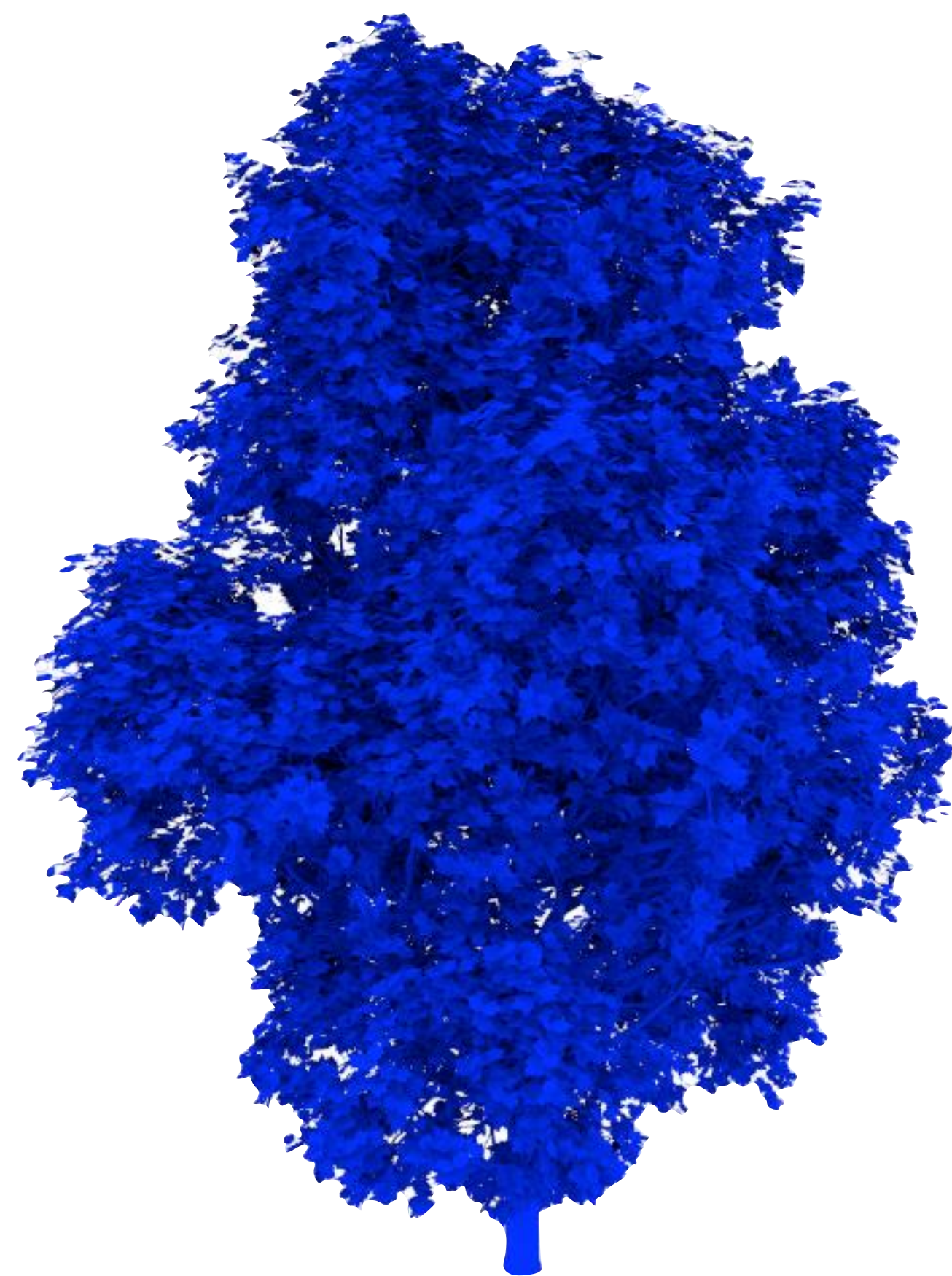
# of configurations

*Modular radiance transfer*  
*Loos et al., 2011*

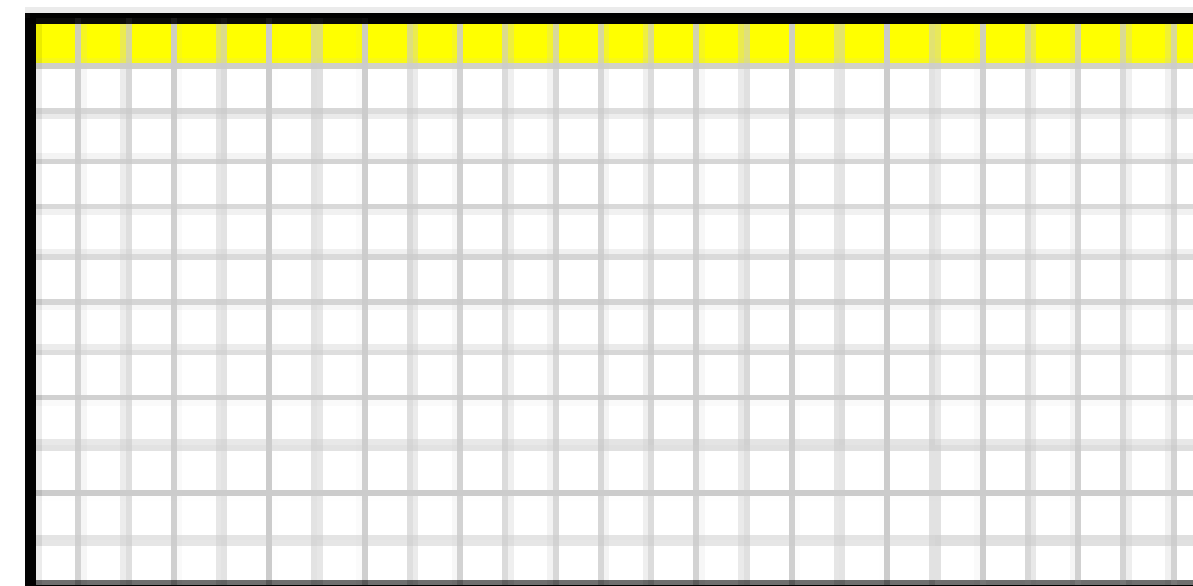


# Method

Learning reduced bases



# of vertices



# of basis functions

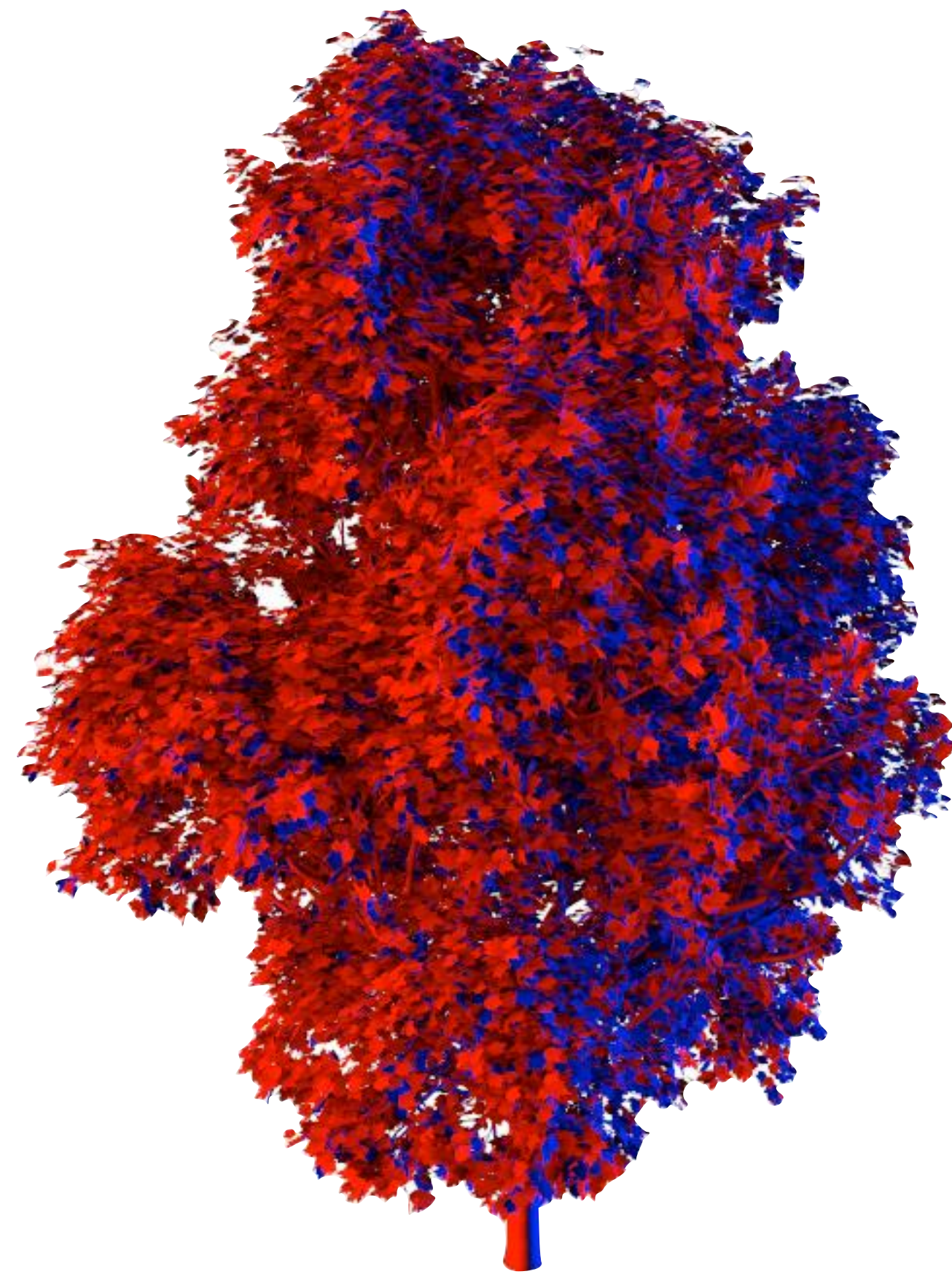
compact basis

*Modular radiance transfer*  
*Loos et al., 2011*

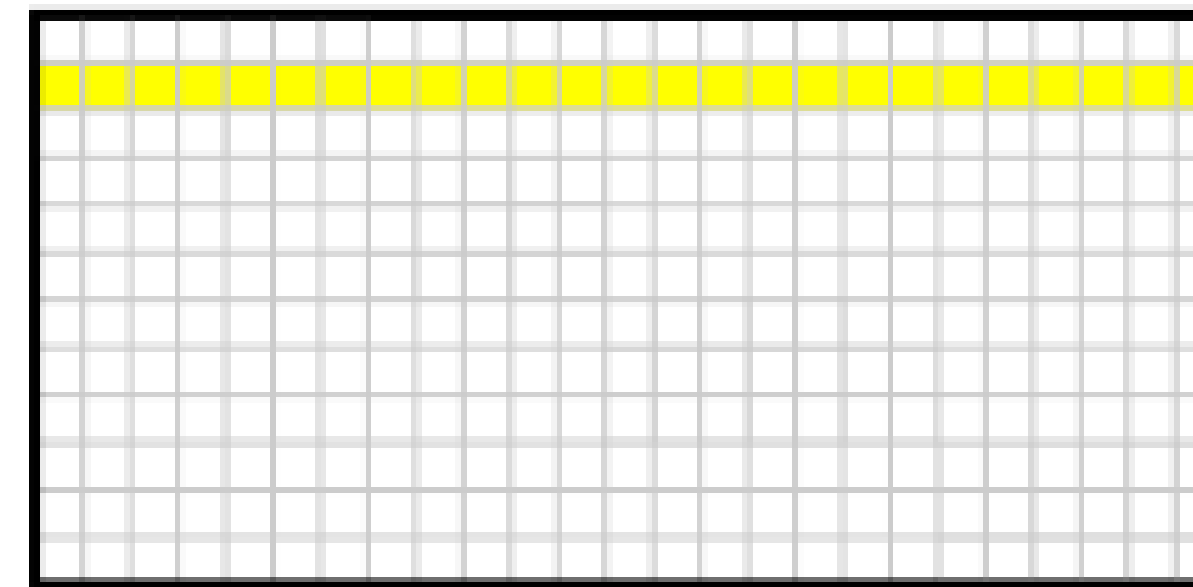


# Method

Learning reduced bases



# of vertices



# of basis functions

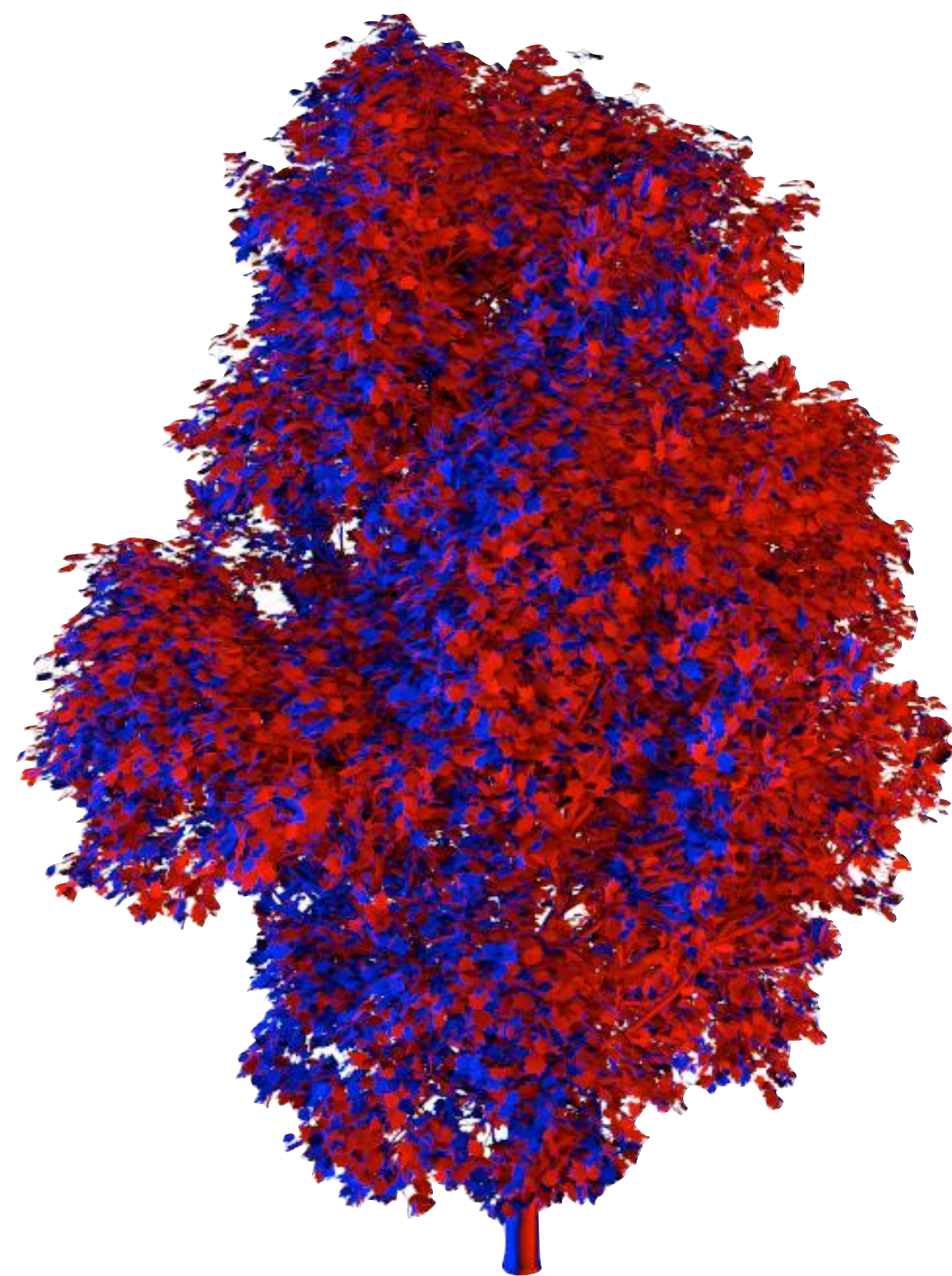
compact basis

*Modular radiance transfer*  
Loos et al., 2011

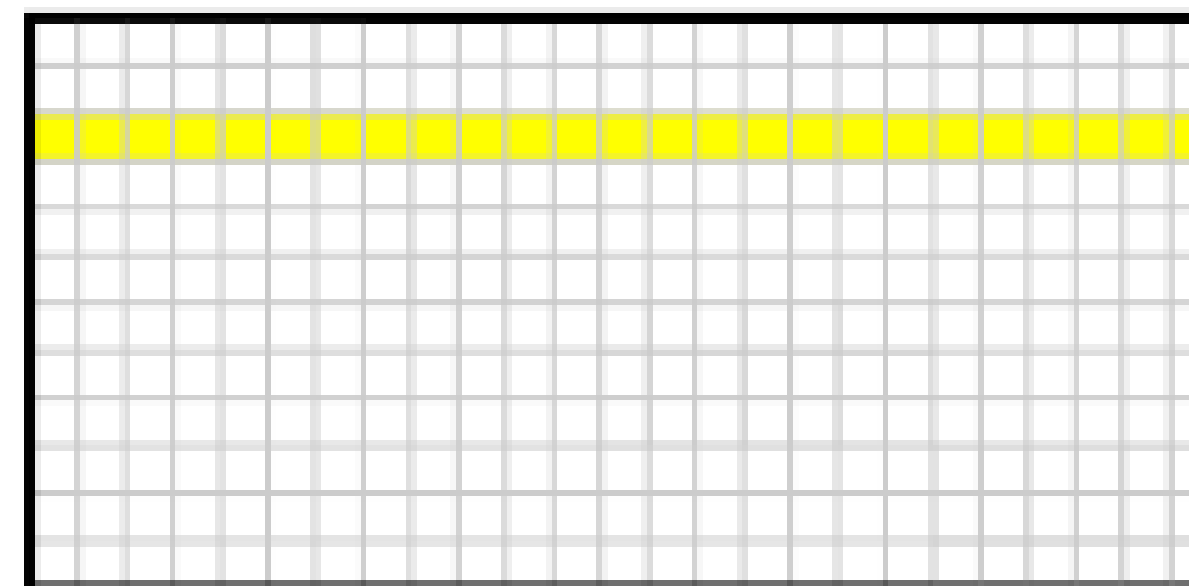


# Method

Learning reduced bases



# of vertices



# of basis functions

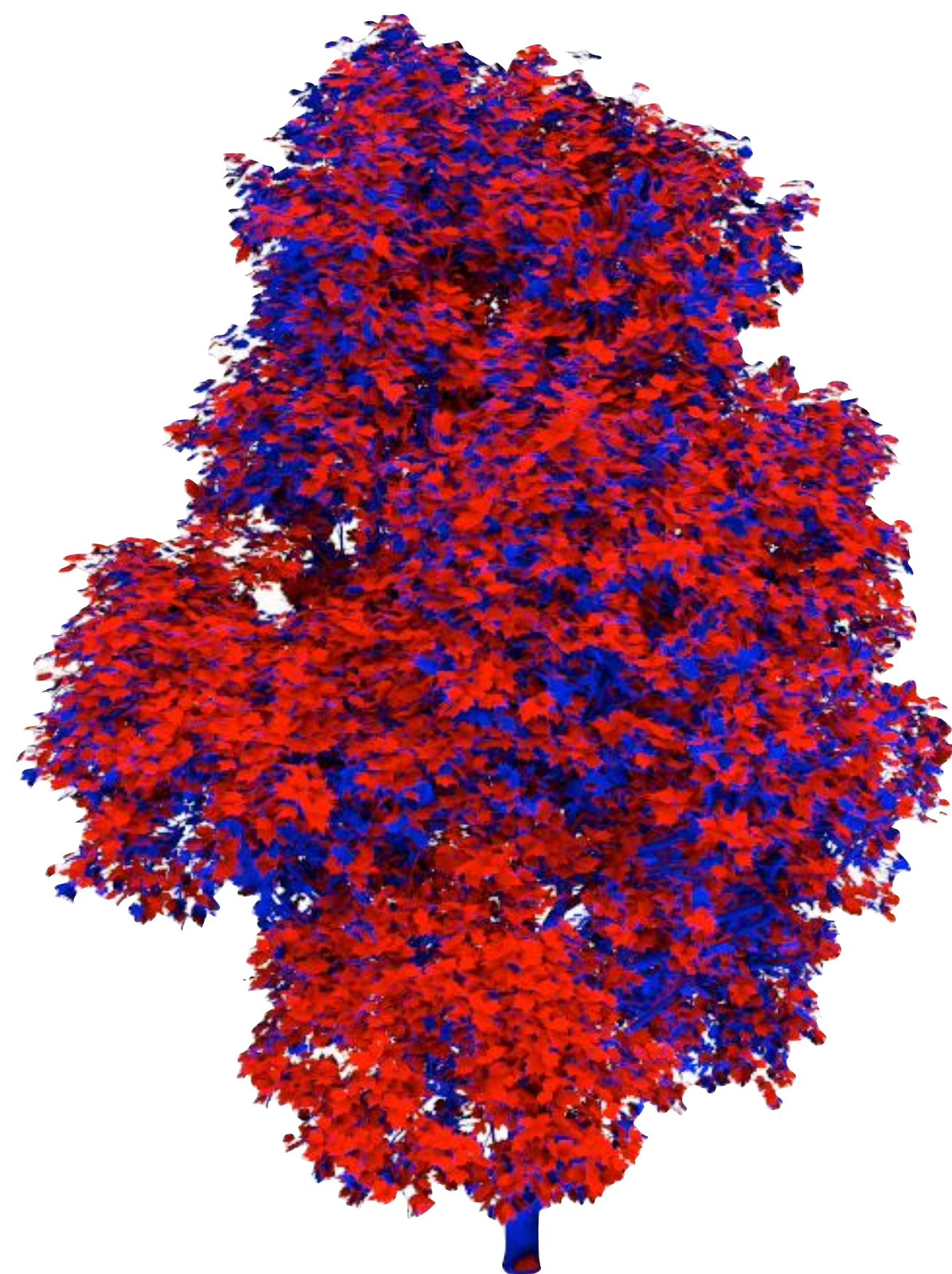
compact basis

*Modular radiance transfer*  
*Loos et al., 2011*

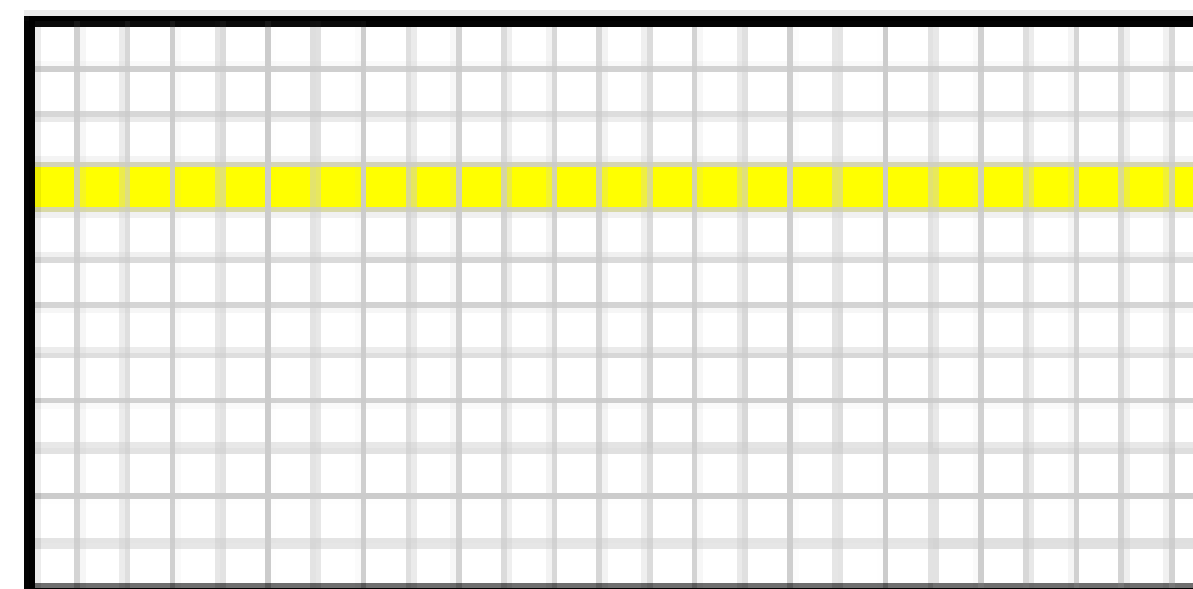


# Method

Learning reduced bases



# of vertices



# of basis functions

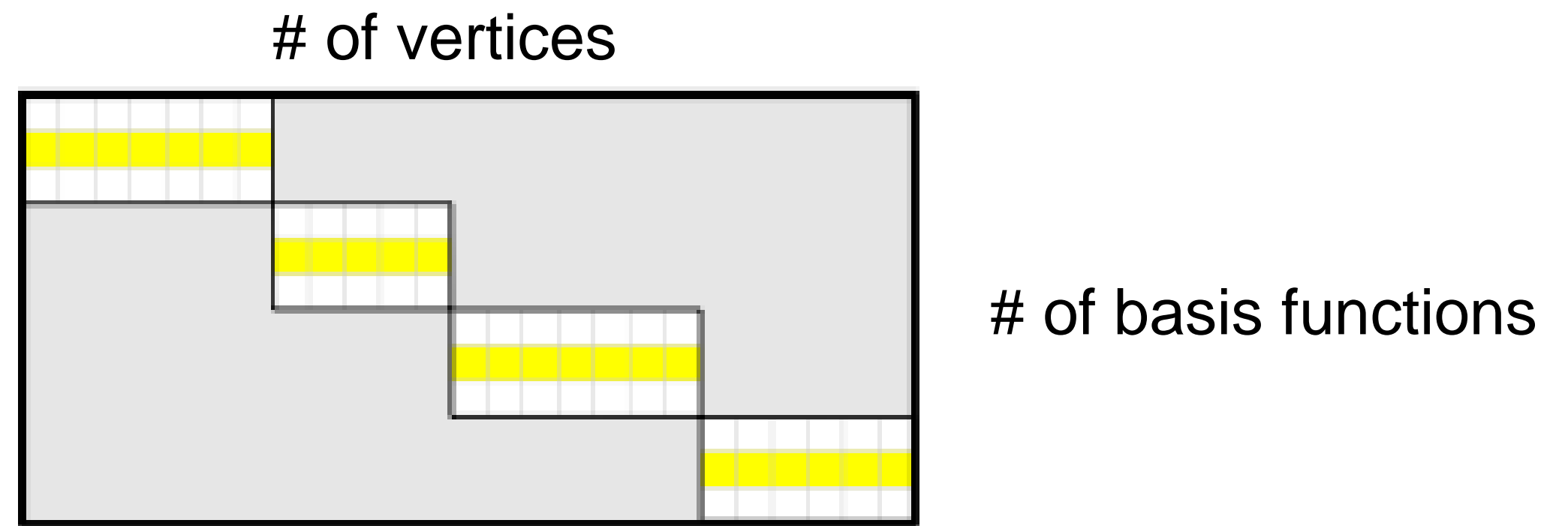
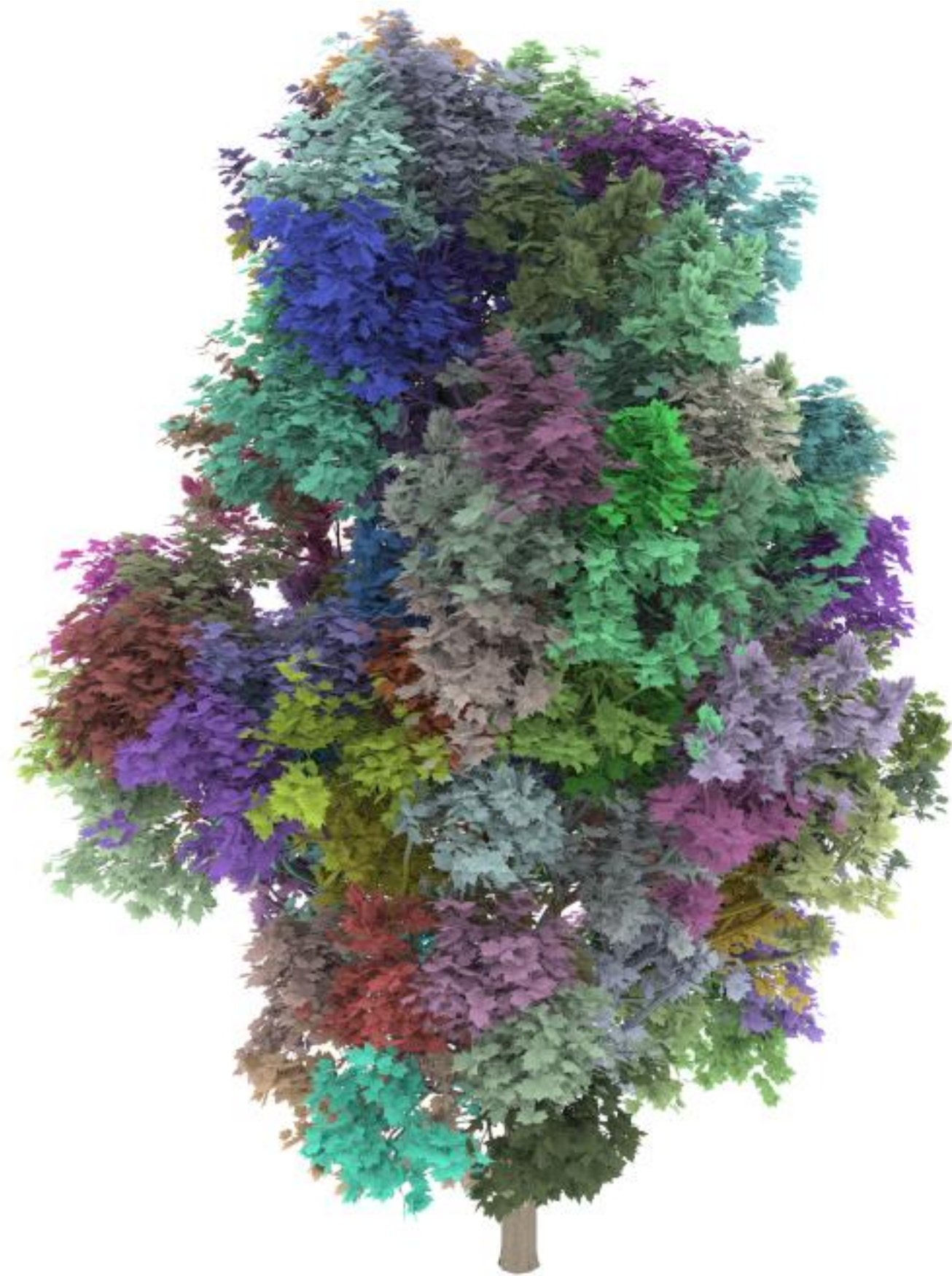
compact basis

*Modular radiance transfer*  
*Loos et al., 2011*



# Method

Learning reduced bases



clustered compact basis

*Clustered principal components for precomputed radiance transfer*  
Sloan et al. 2003

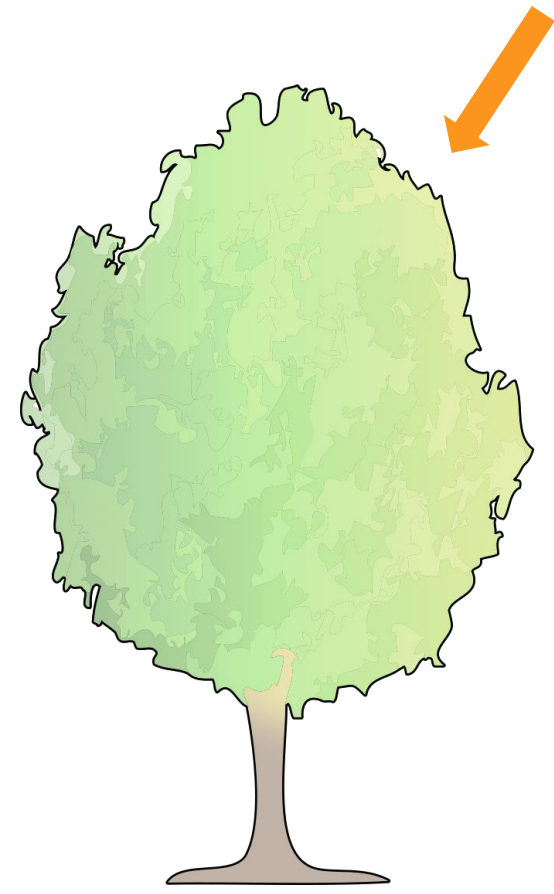




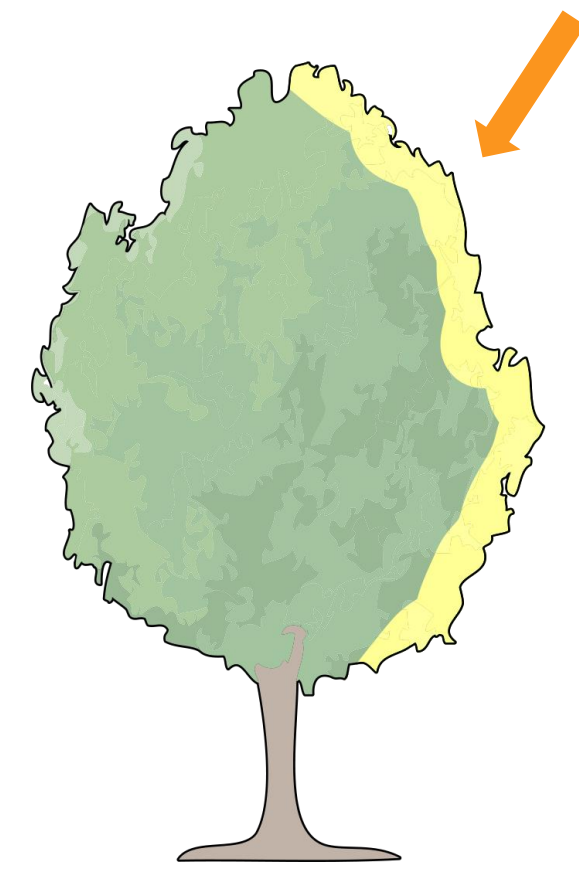
# Method

Learning reduced bases

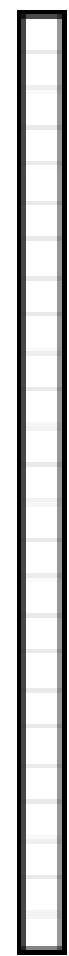
indirect illumination



direct illumination

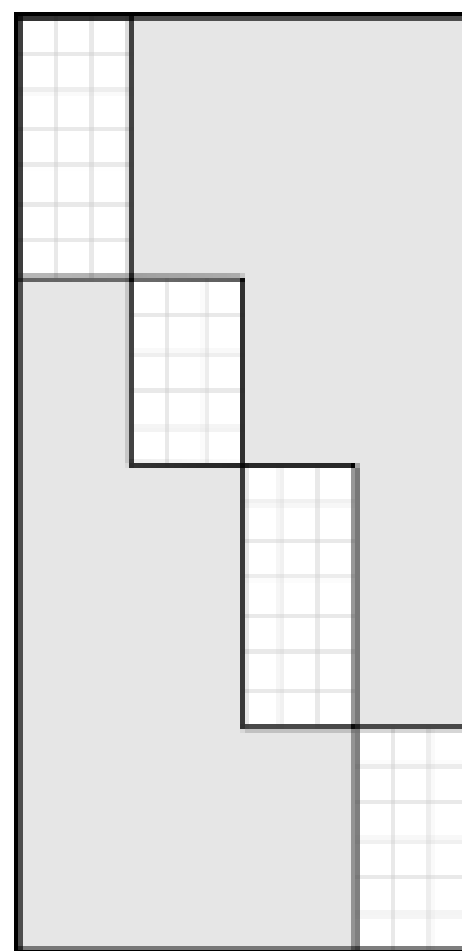


indirect



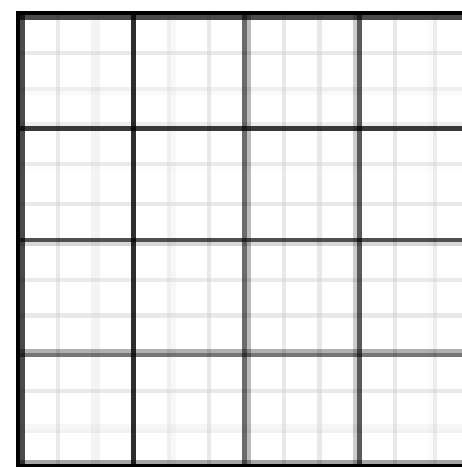
=

indirect basis transform



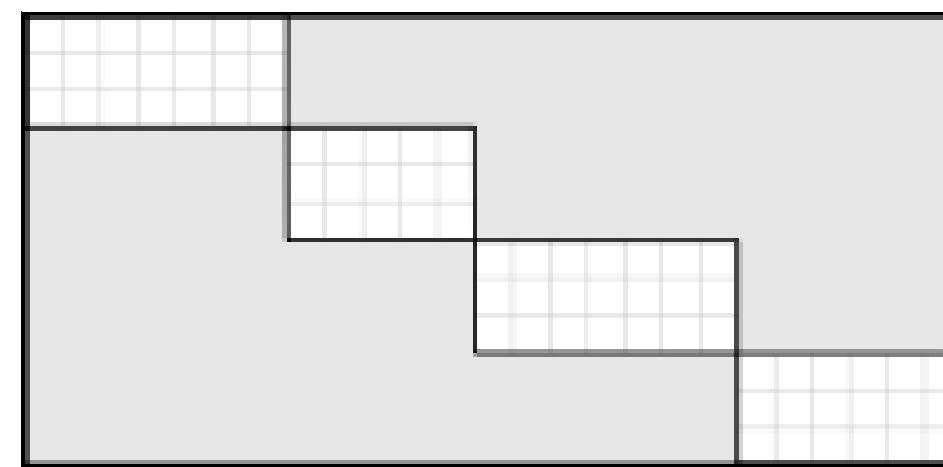
×

transport



×

direct basis transform



×

direct



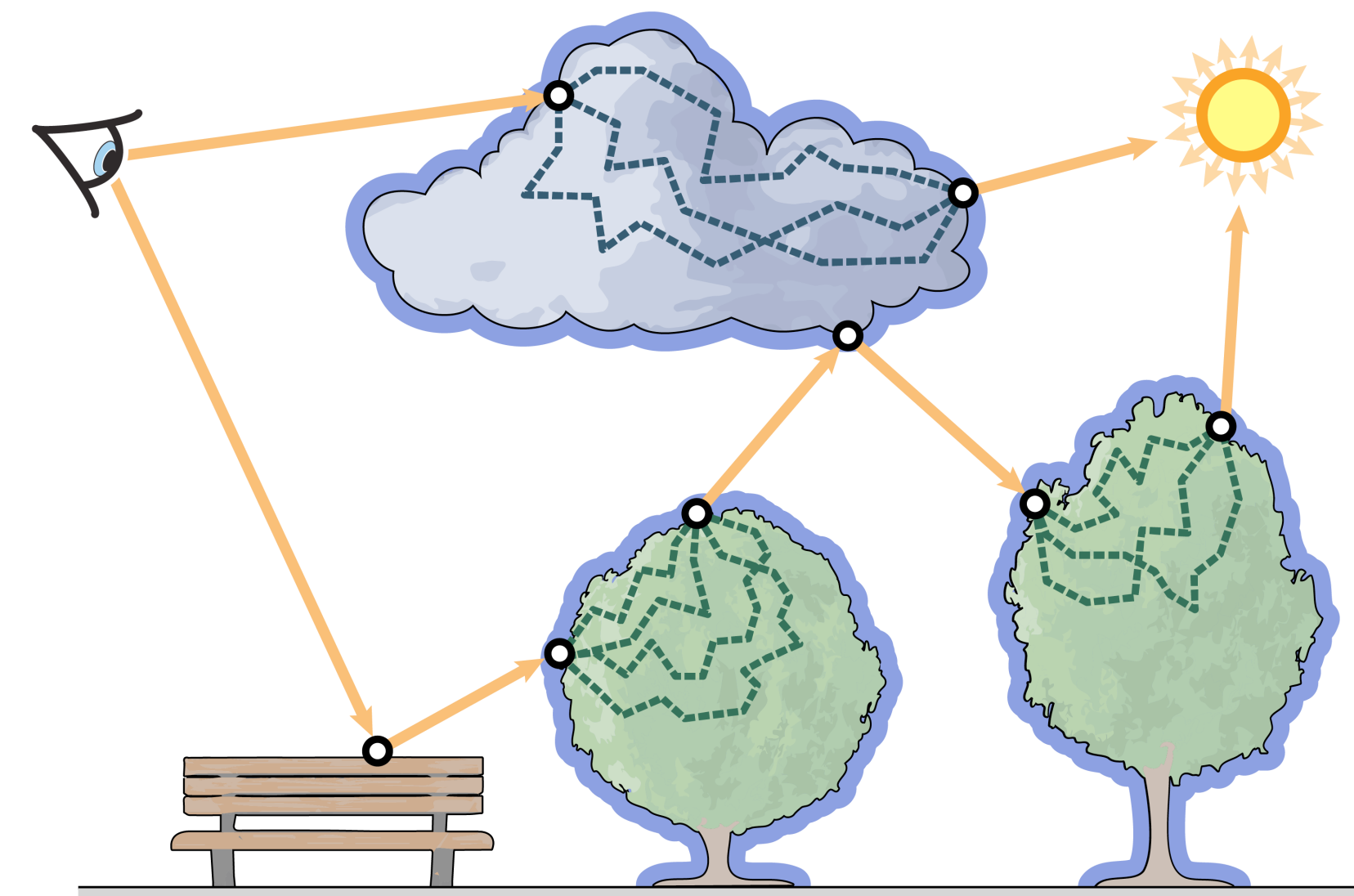
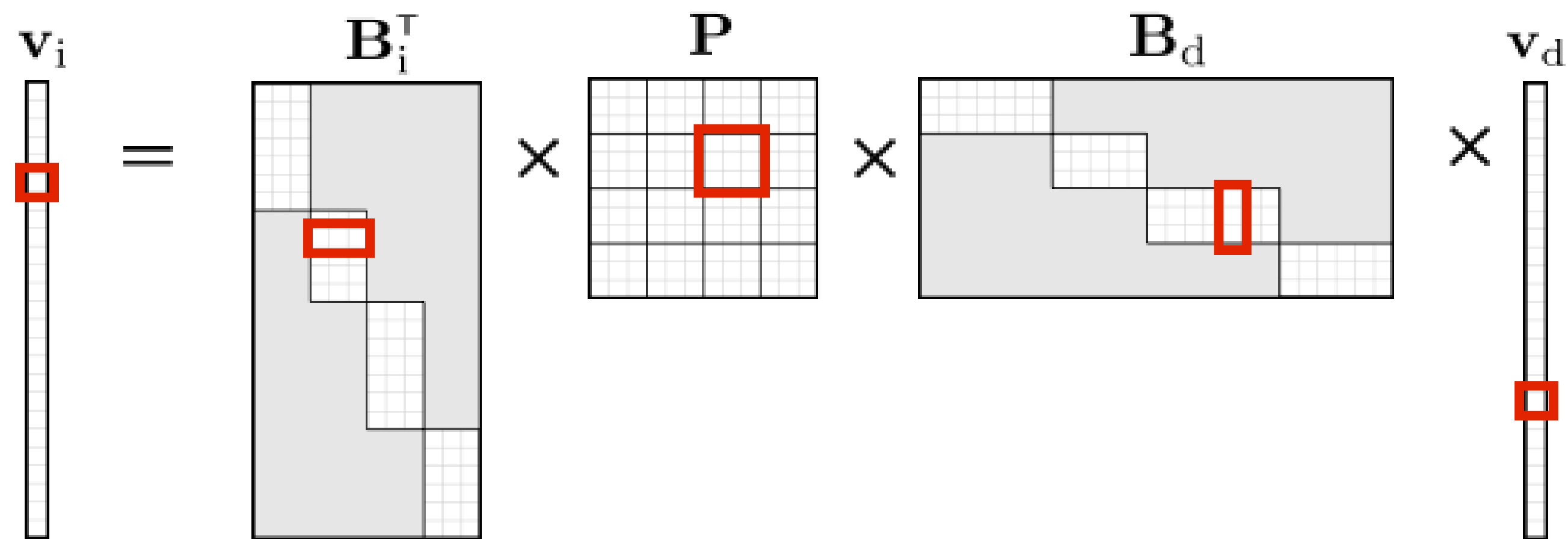
# Precomputation

## Path tracer integration



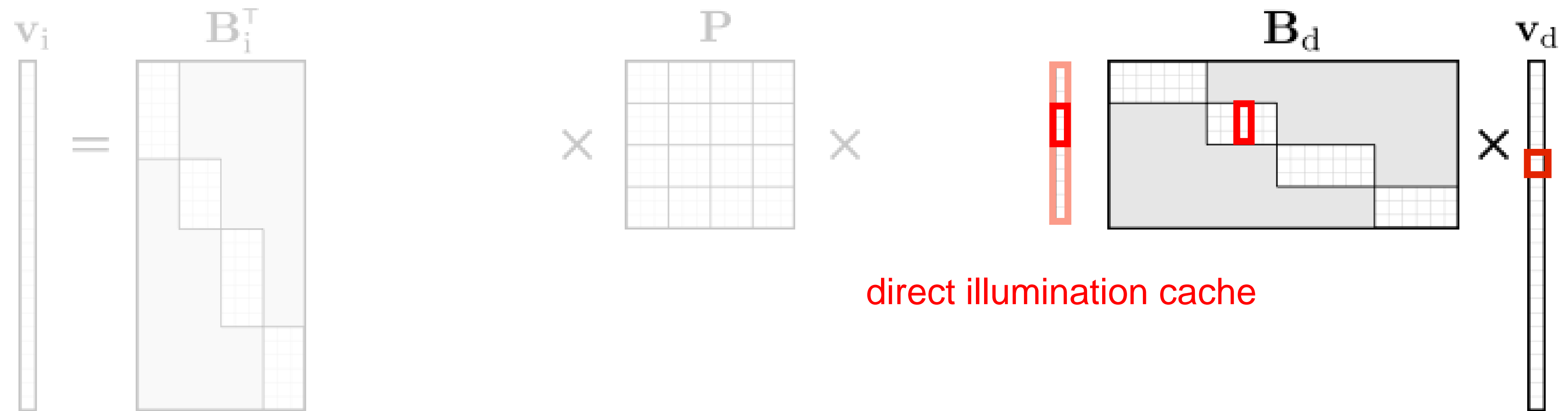
# Path tracer integration

## Monte Carlo evaluation



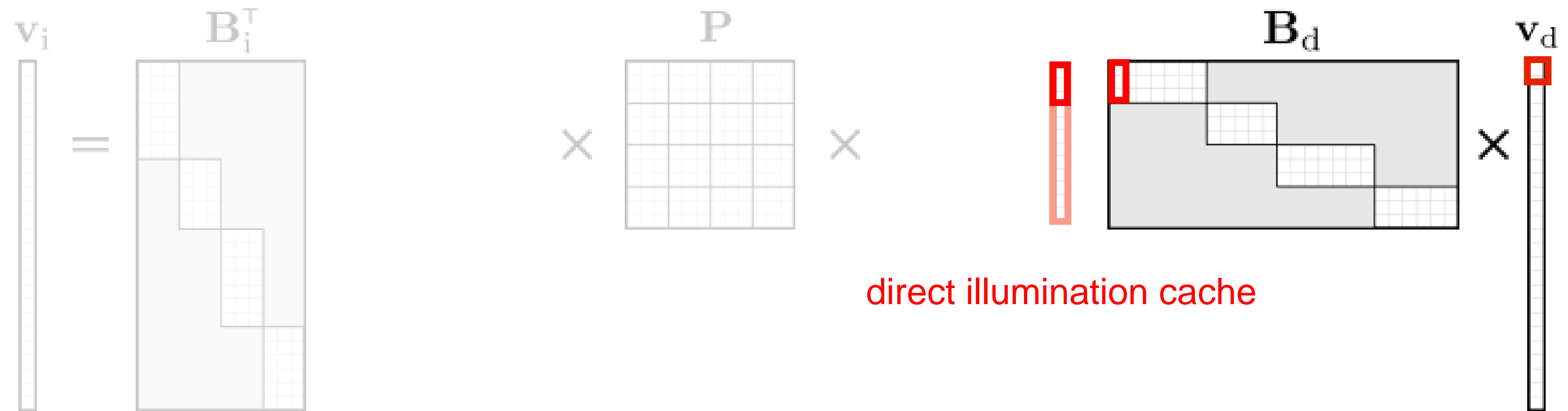
# Path tracer integration

batching and caching



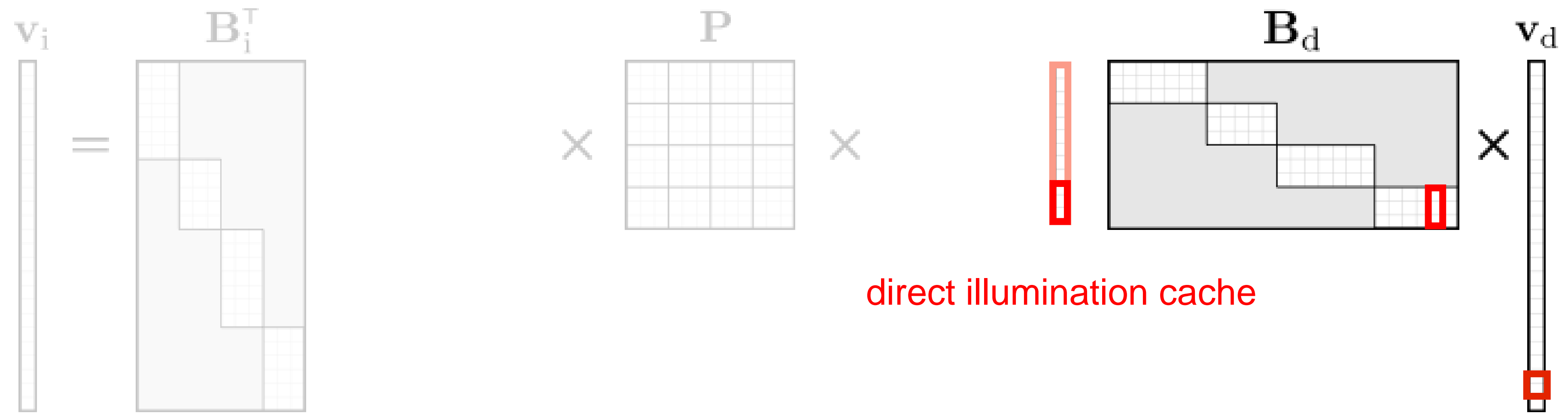
# Path tracer integration

batching and caching



# Path tracer integration

batching and caching

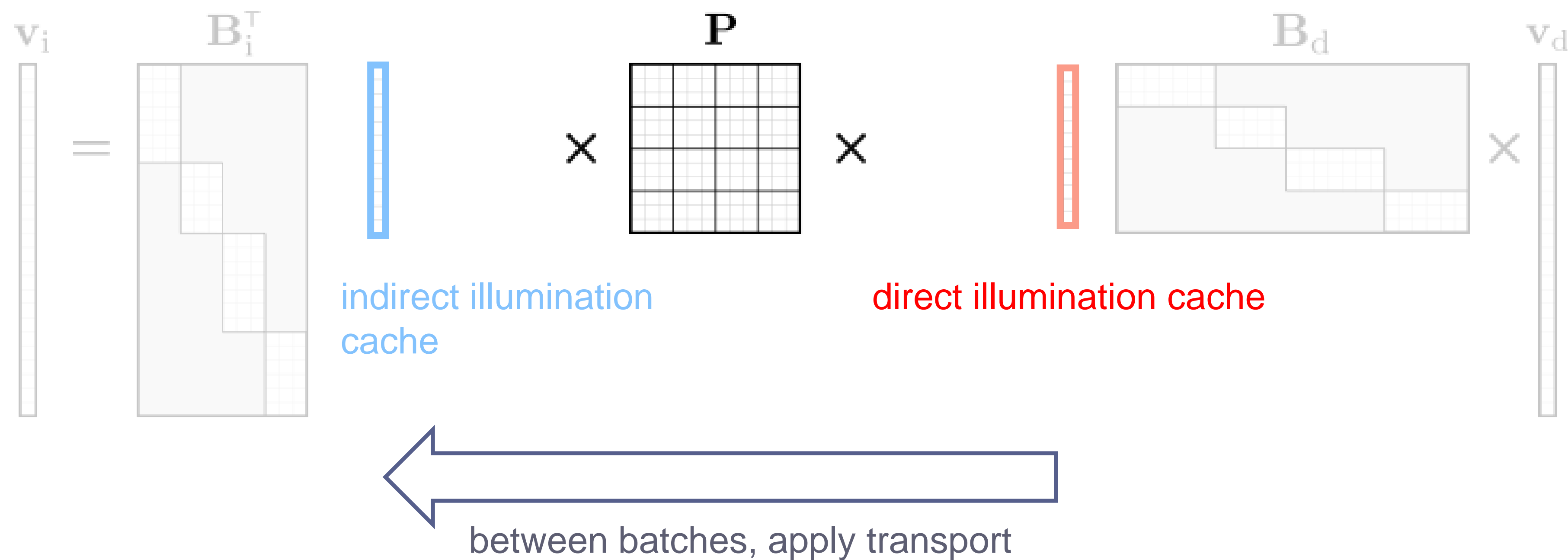


direct illumination cache



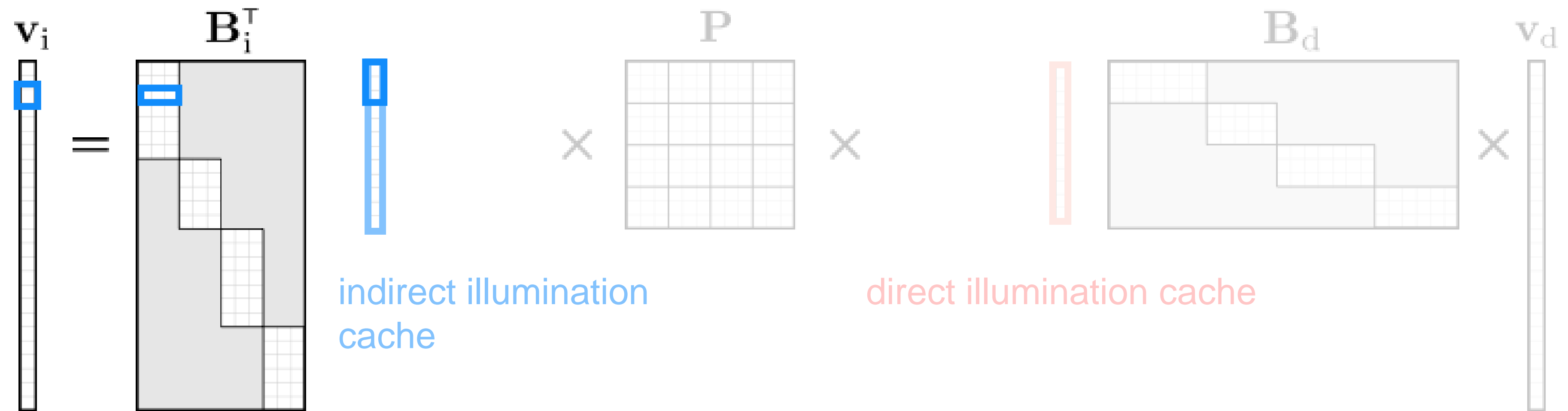
# Path tracer integration

batching and caching



# Path tracer integration

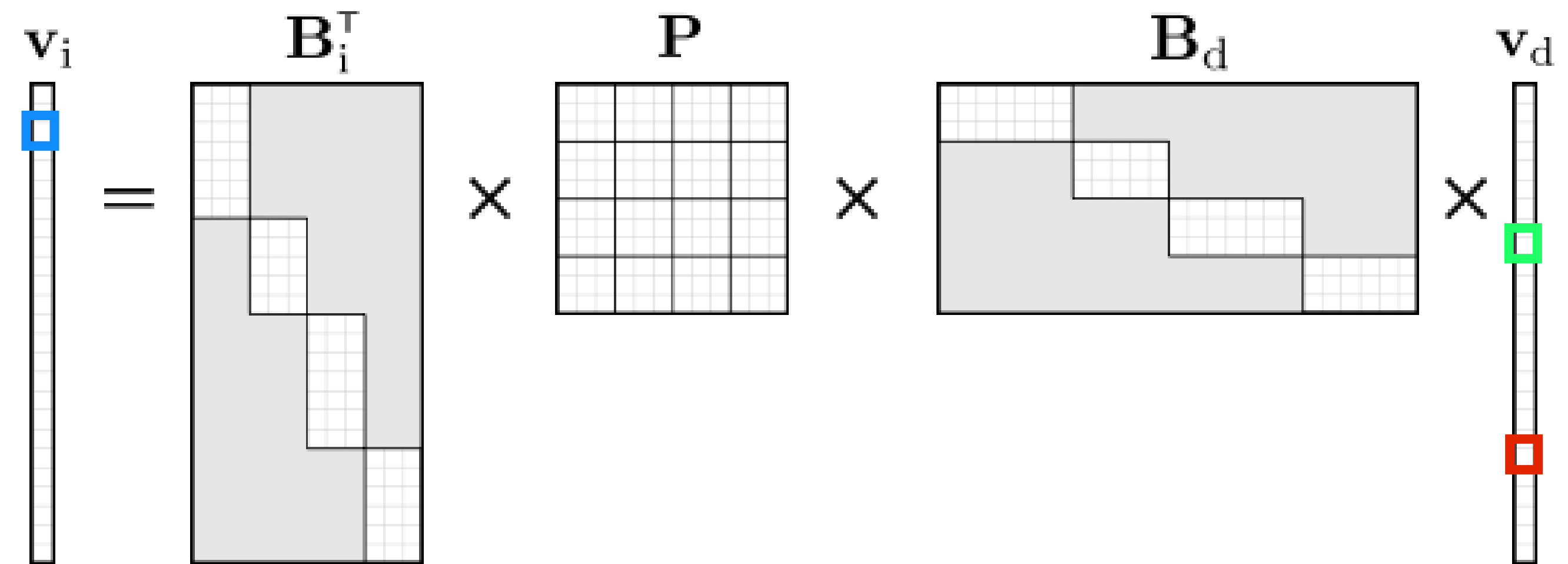
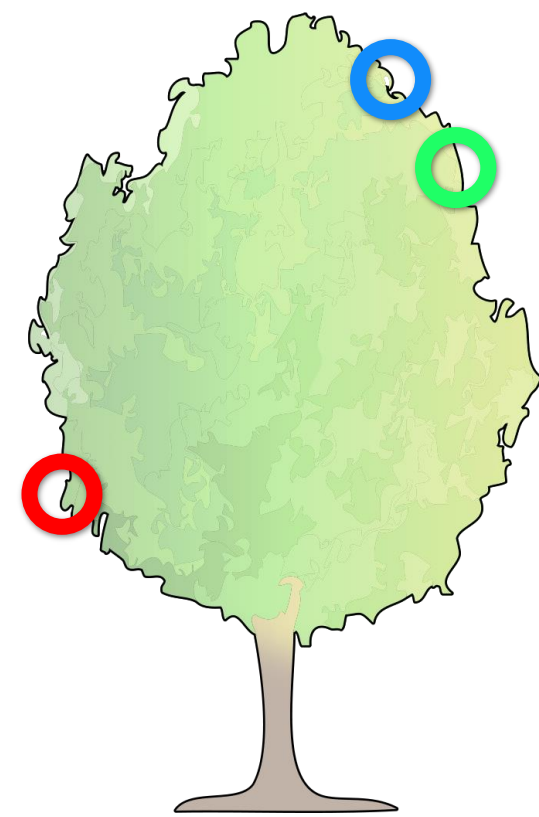
batching and caching





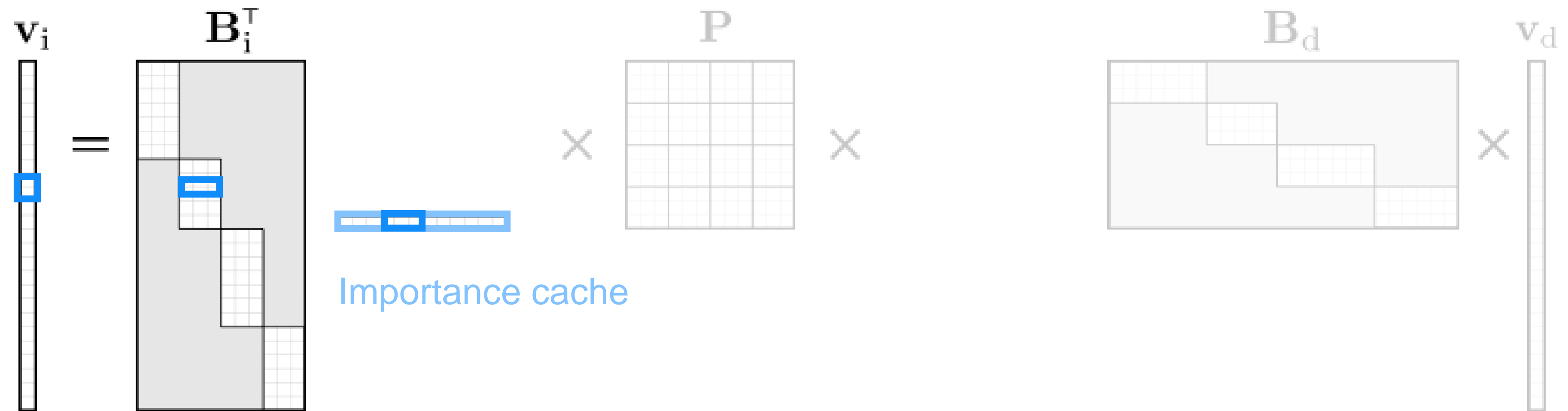
# Path tracer integration

Importance caching and sampling



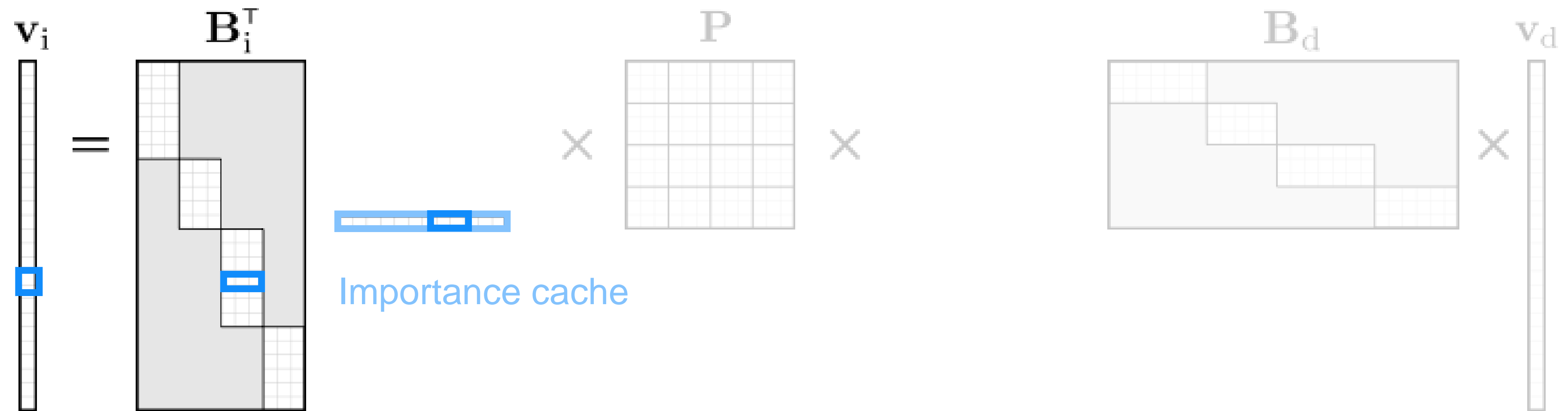
# Path tracer integration

Importance caching and sampling



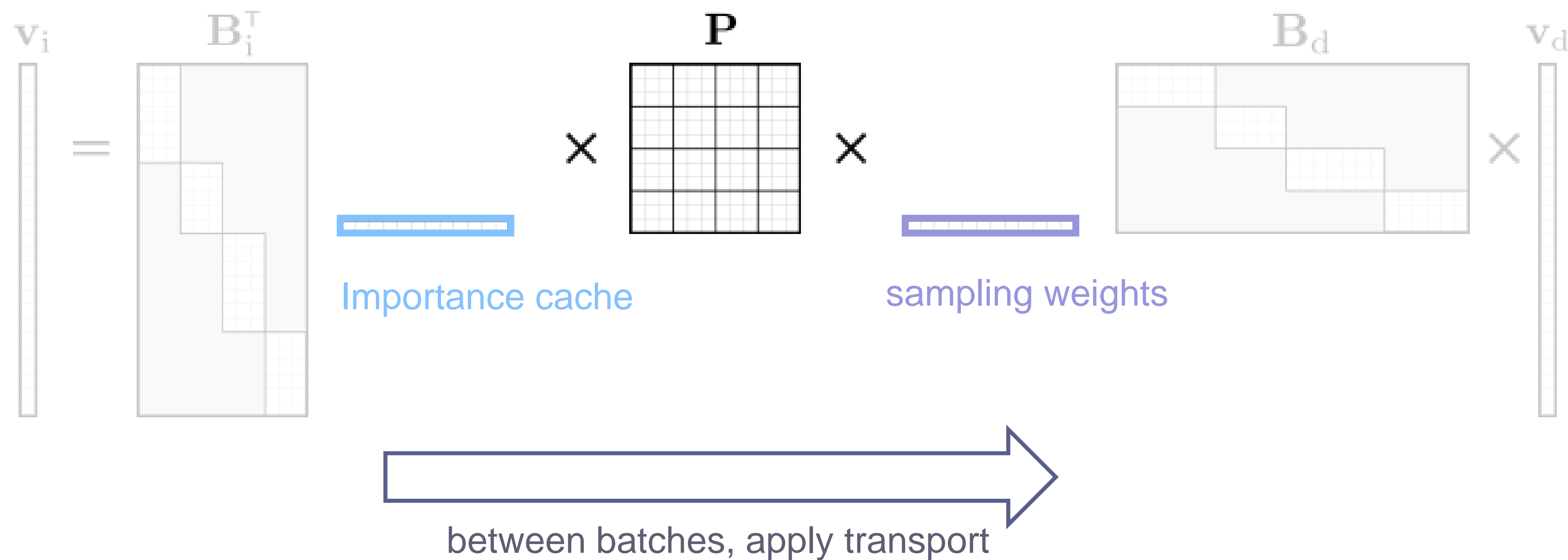
# Path tracer integration

Importance caching and sampling



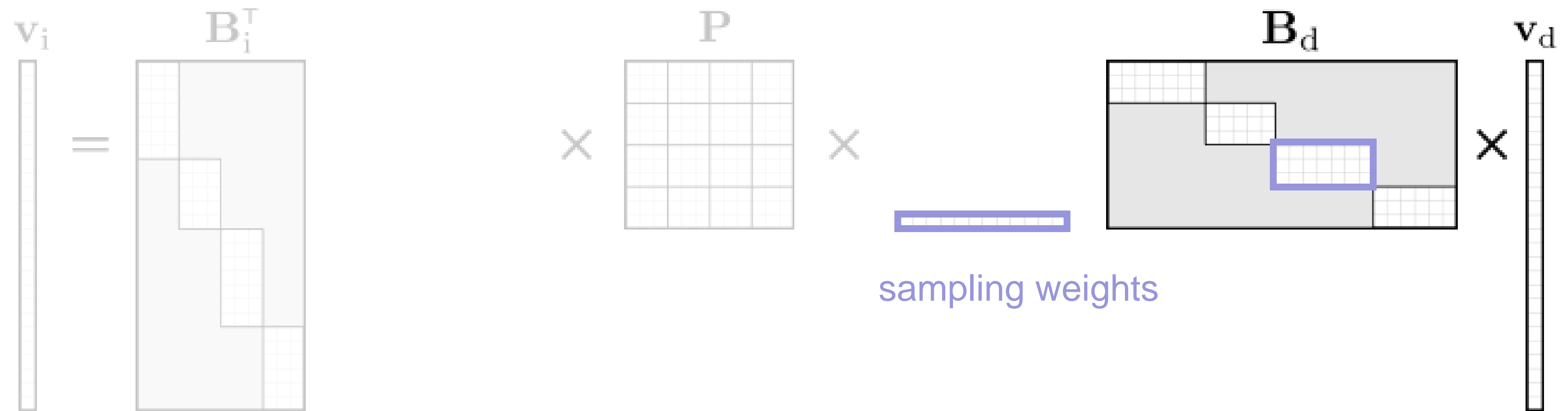
# Path tracer integration

Importance caching and sampling



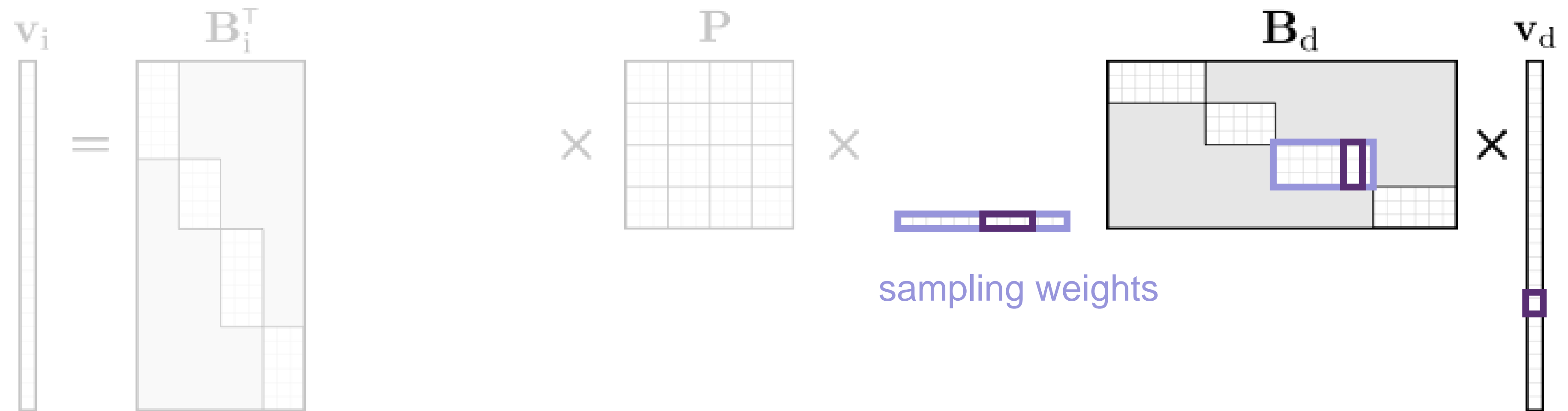
# Path tracer integration

Importance caching and sampling



# Path tracer integration

Importance caching and sampling



# Results



# Quality

Path tracing



Path tracing with RASO



Side lighting  
(in the training set)

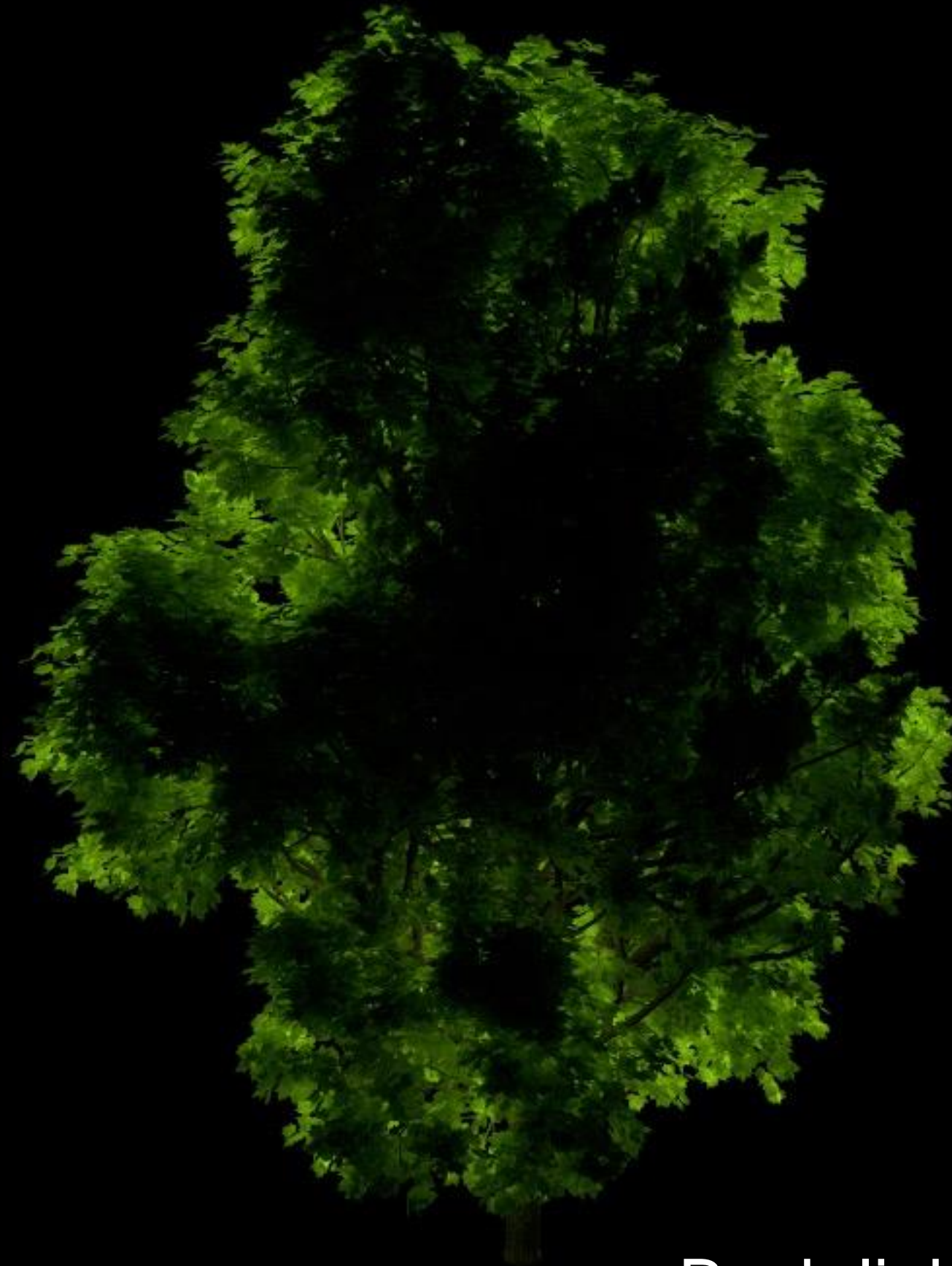
\*indirect illumination only





# Quality

Path tracing



Path tracing with RASO



Back-lighting  
(not in the training set)

\*indirect illumination only



# Quality

Path tracing



Path tracing with RASO



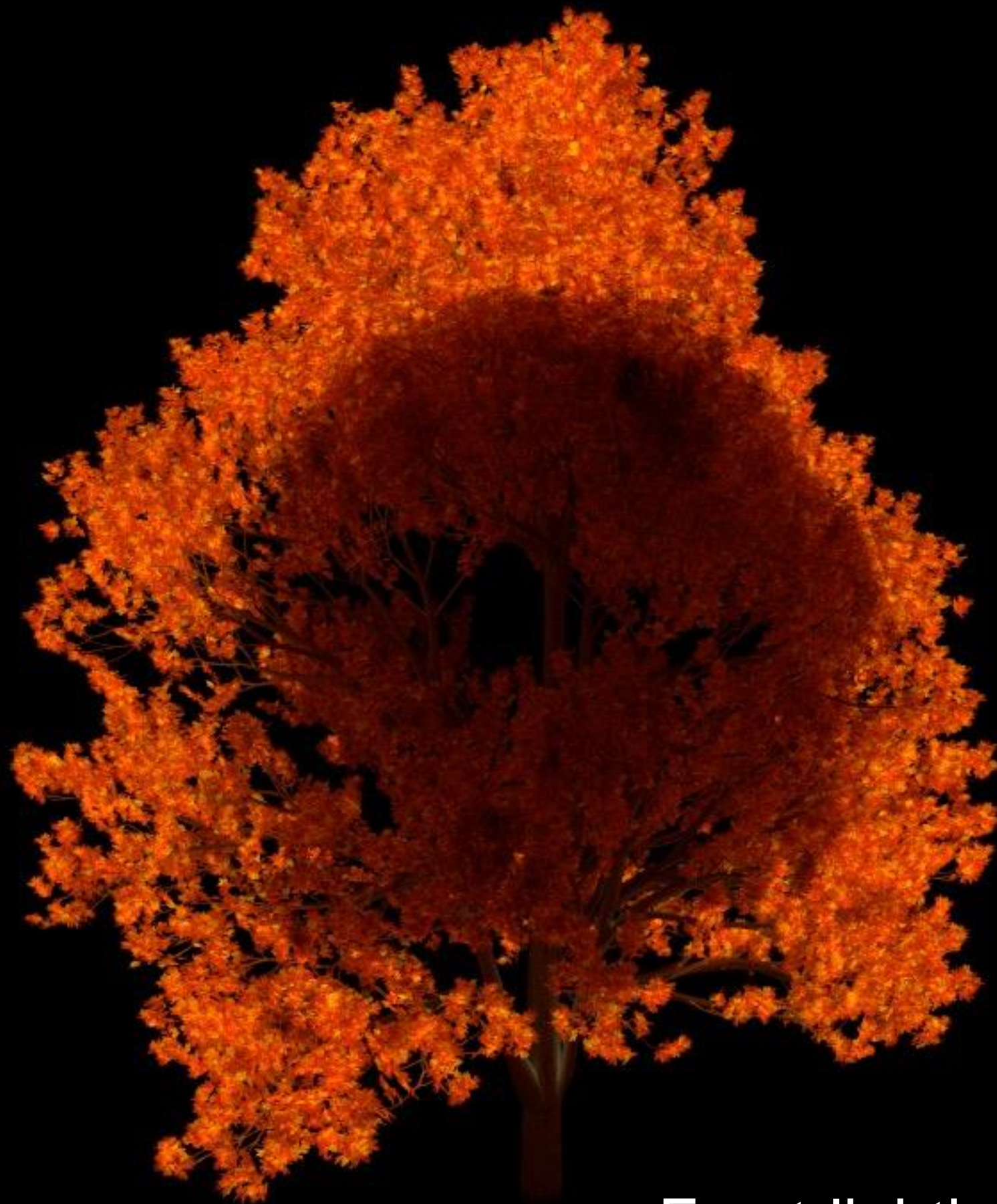
Ambient sky  
(not in the training set)

\*indirect illumination only



# Quality

Path tracing



Path tracing with RASO



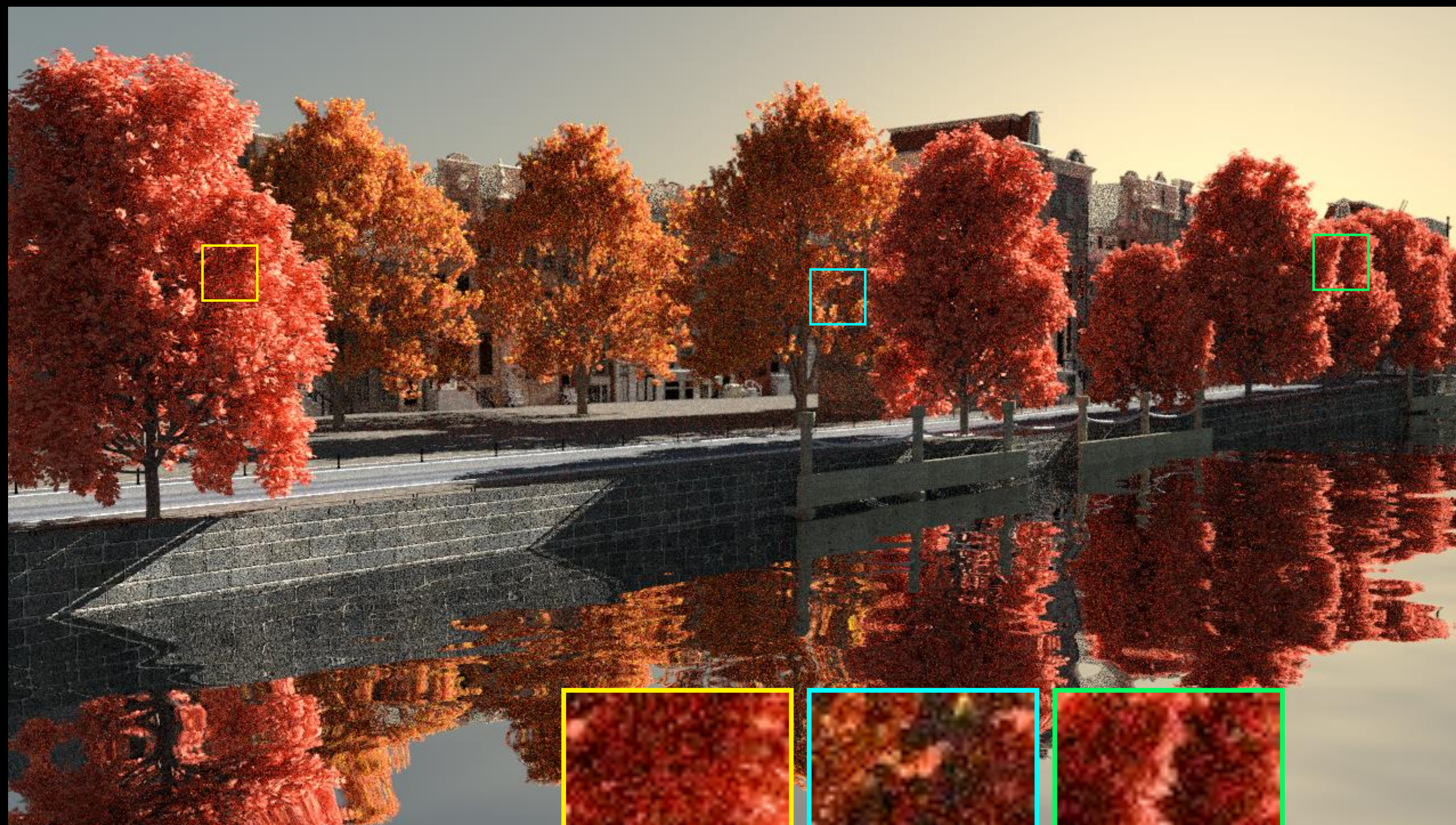
Front-lighting with occluder  
(**not** in the training set)

\*indirect illumination only



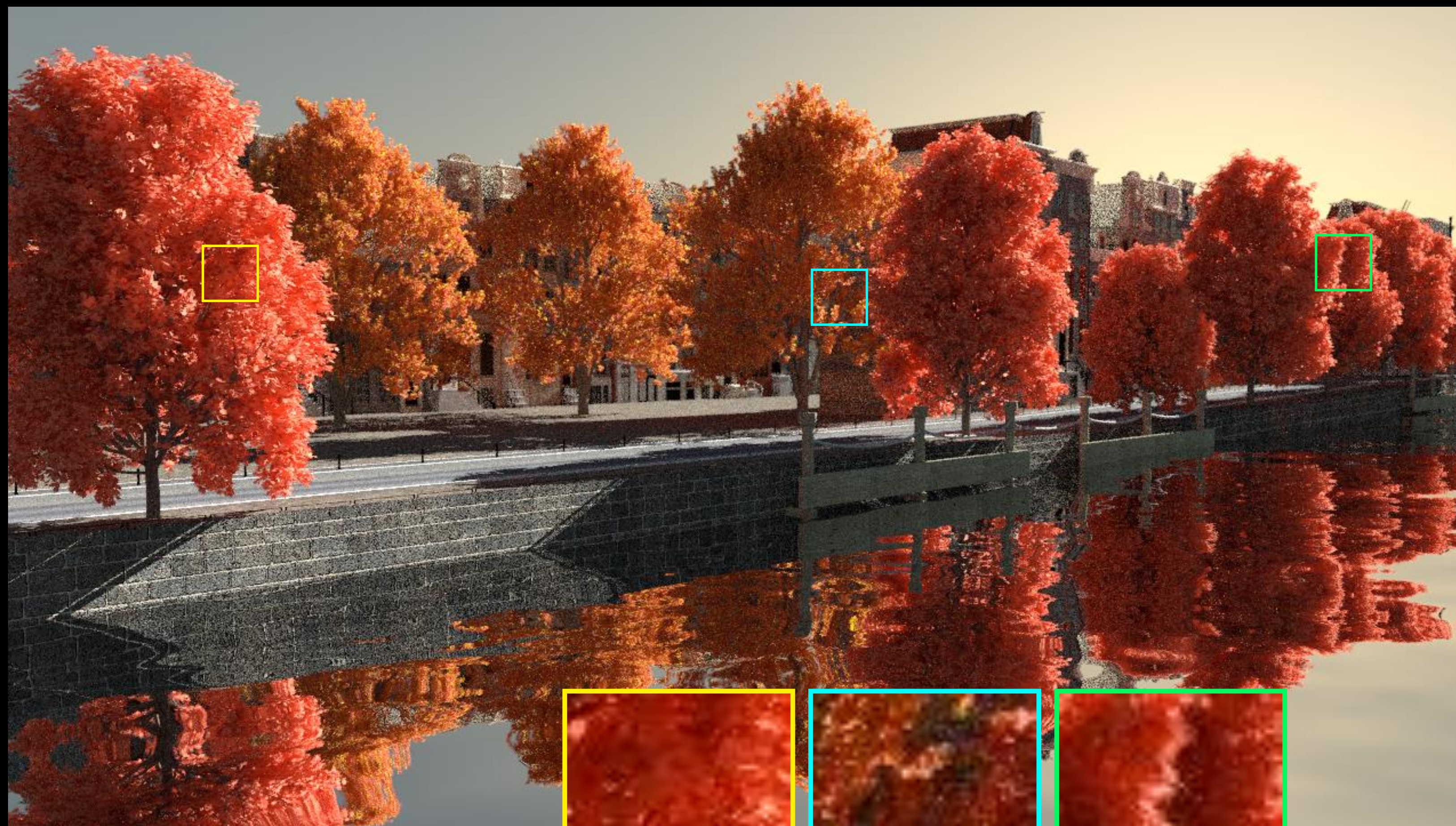
# Performance

Equal-time Path tracing

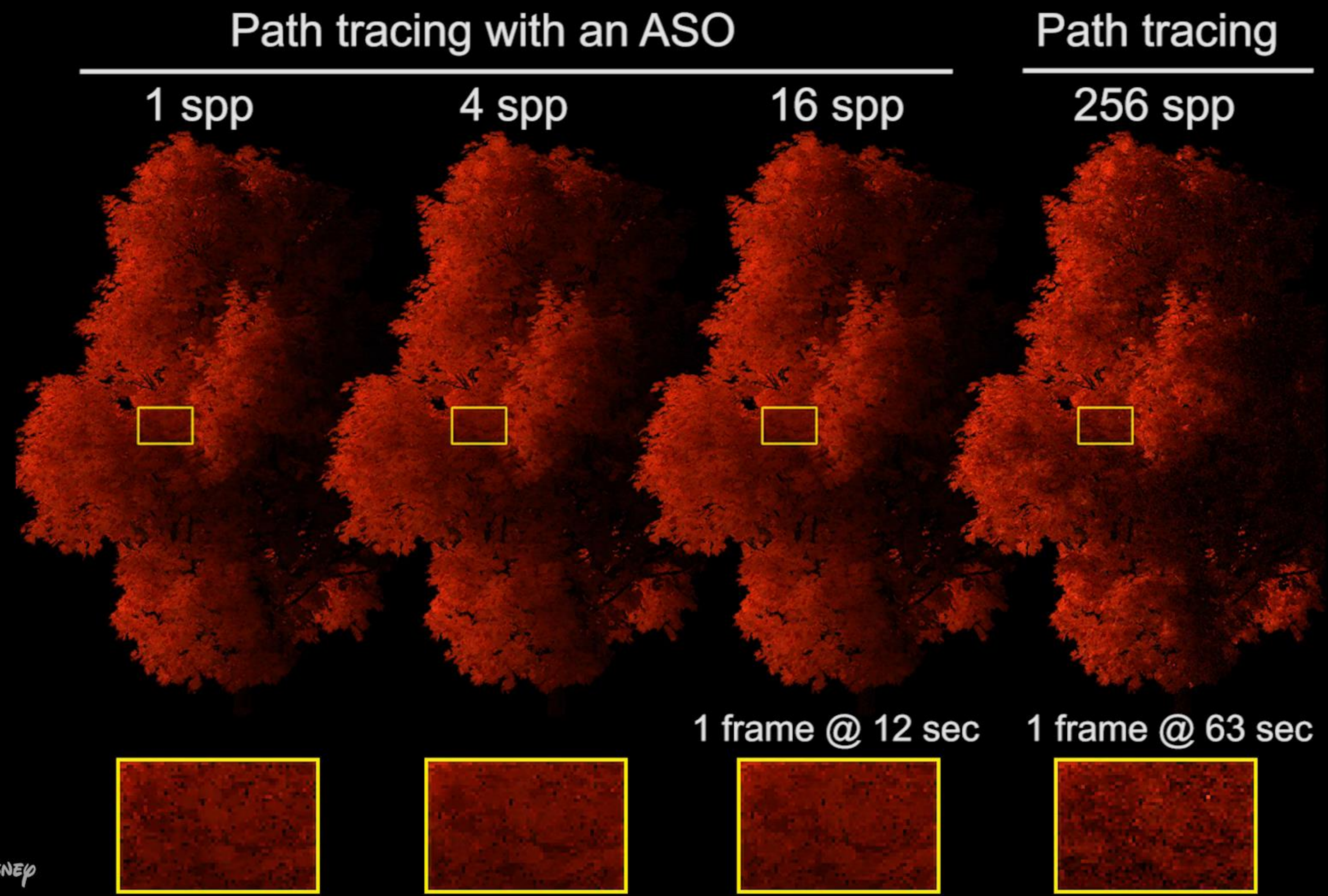


# Performance

Equal-time Path tracing with **RASOs** (ours)



# Temporal stability



© DISNEY



# Homogeneous volume

PT  
(17 min)

PT with RASO  
(3.1 min)

PT with RASO  
(6 s)

Diffusion dipole  
(6 s)



multiple-scattering only, discretization:  $128^3$  voxel grid,  
dipole parameters hand-tweaked for visually similar result



# Conclusion

## Advantages

- fast convergence
- perceptually unobtrusive error
- temporal stability

## Limitations

- precomputation & storage
- bias





# Future Work

- All-frequency Transport
- Application to Clouds
- Non-negative matrix factorization



Thanks for your time!

Questions?

