SIGGRAPH ASIA 2023 SYDNEY

Efficient Graphics Representation with Differentiable Indirection

Sayantan Datta[1,2] Carl Marshall[2] Derek Nowrouzezahrai[1,3] Zhao Dong[2] Zhengqin Li[2]

[1]McGill University [2]Meta [3]MILA

Connecting STORIES

The 16th ACM SIGGRAPH Conference and Exhibition on Computer Graphics and Interactive Techniques in Asia

CONFERENCE 12 - 15 December 2023

EXHIBITION 13 - 15 December 2023

ICC, Sydney, Australia

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What is Differentiable Indirection?

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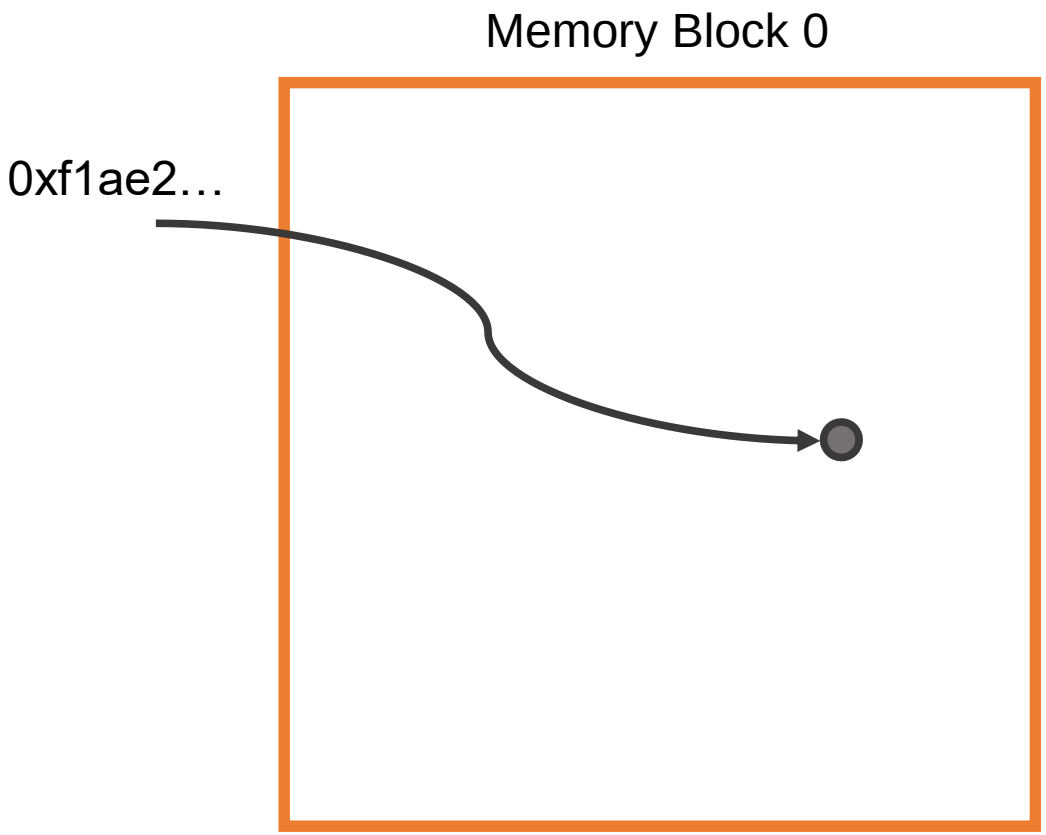

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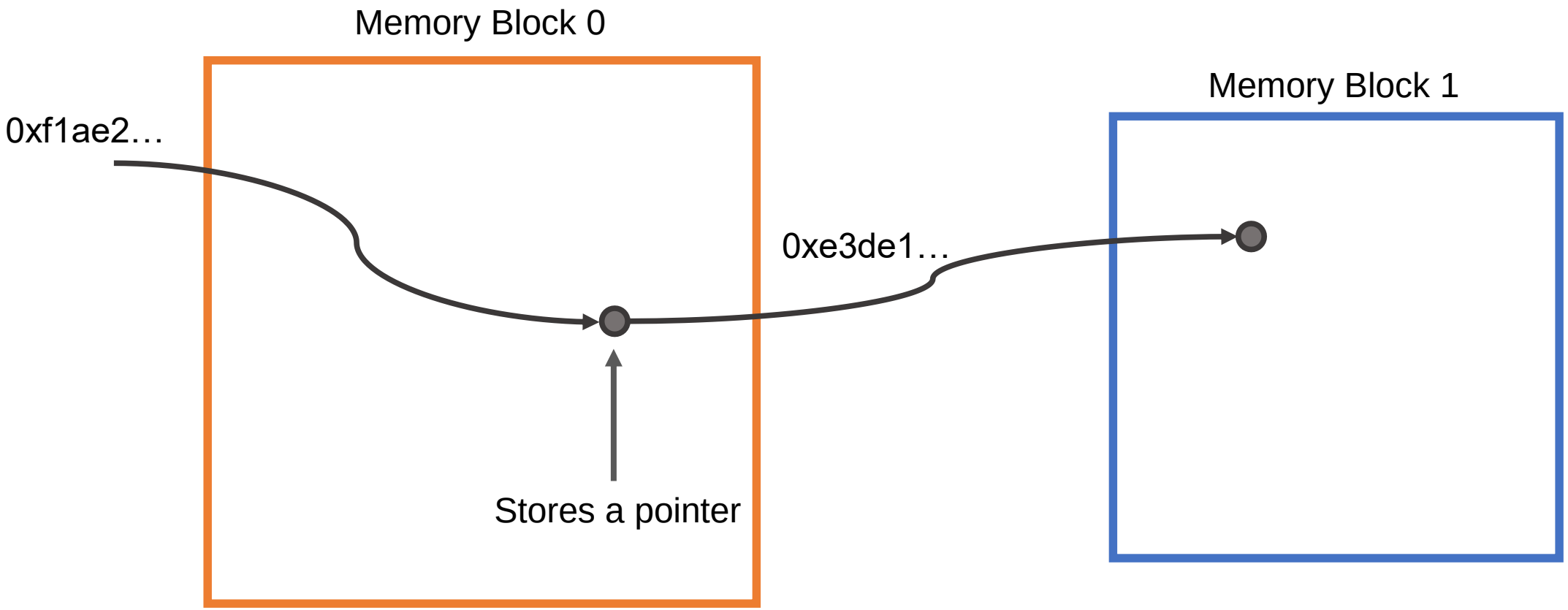

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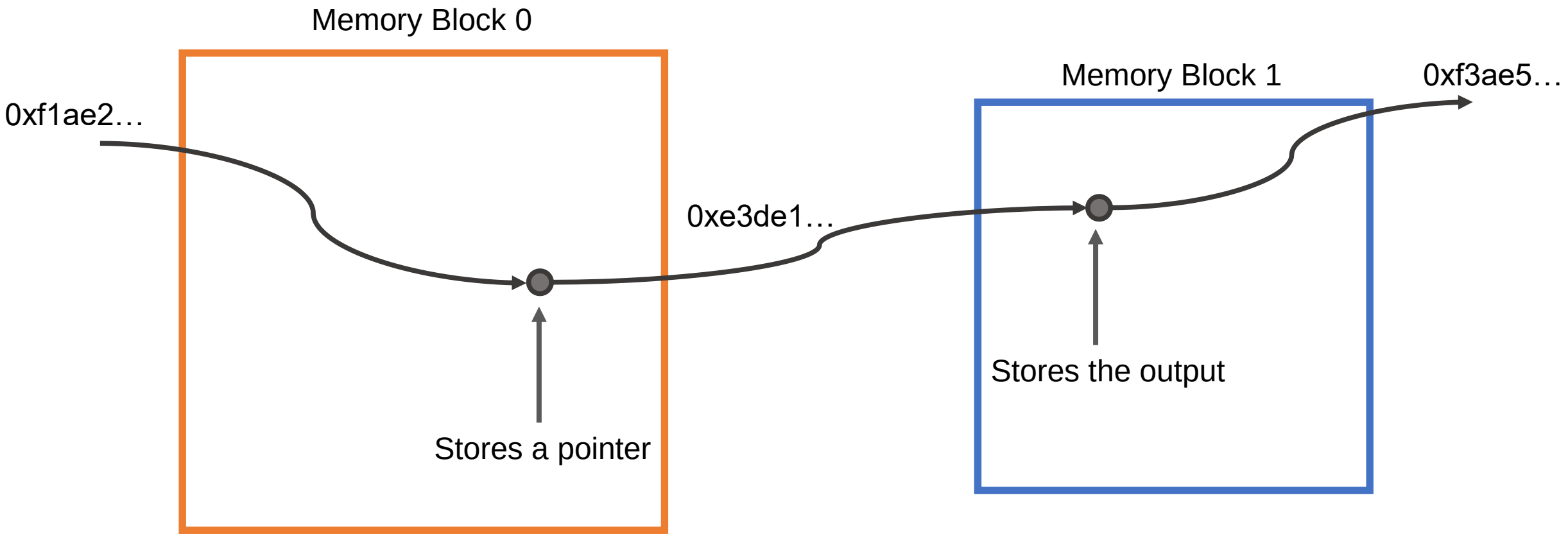

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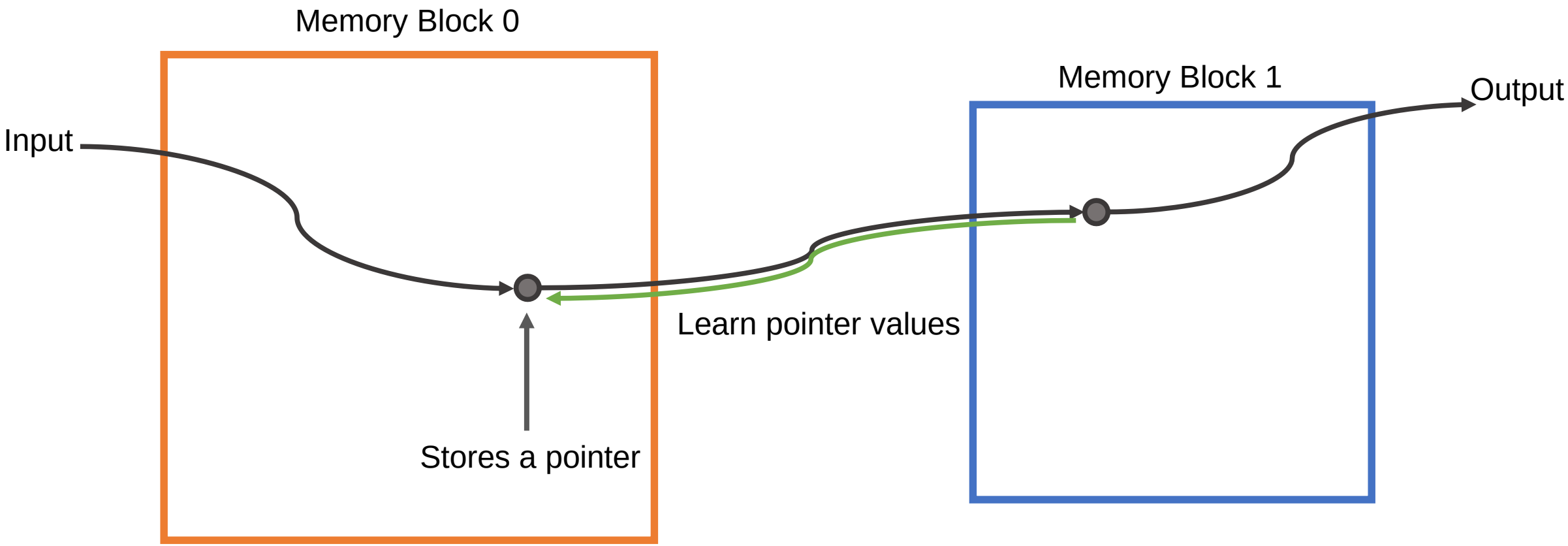

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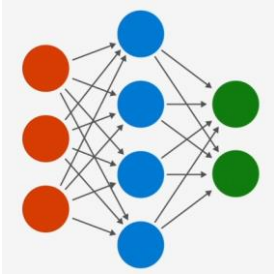
MLP



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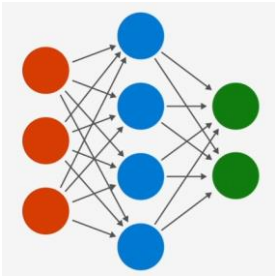
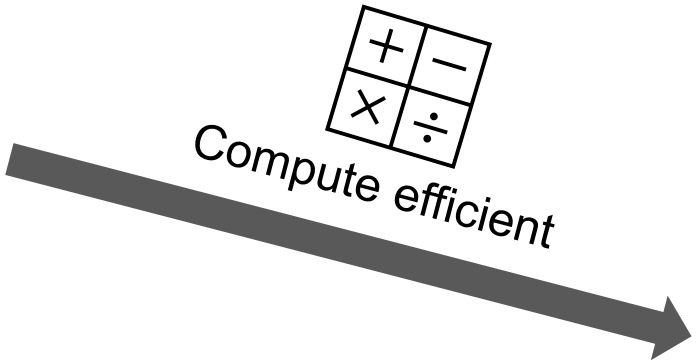
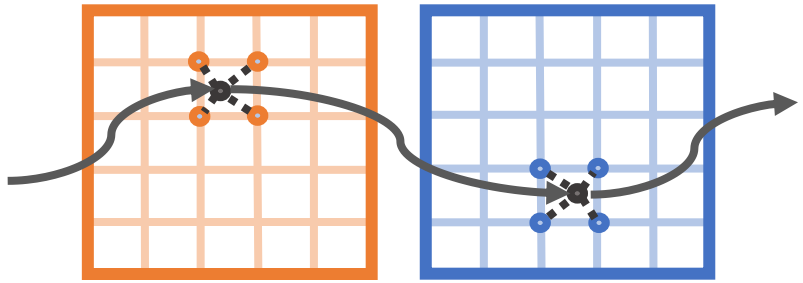




Differentiable indirection



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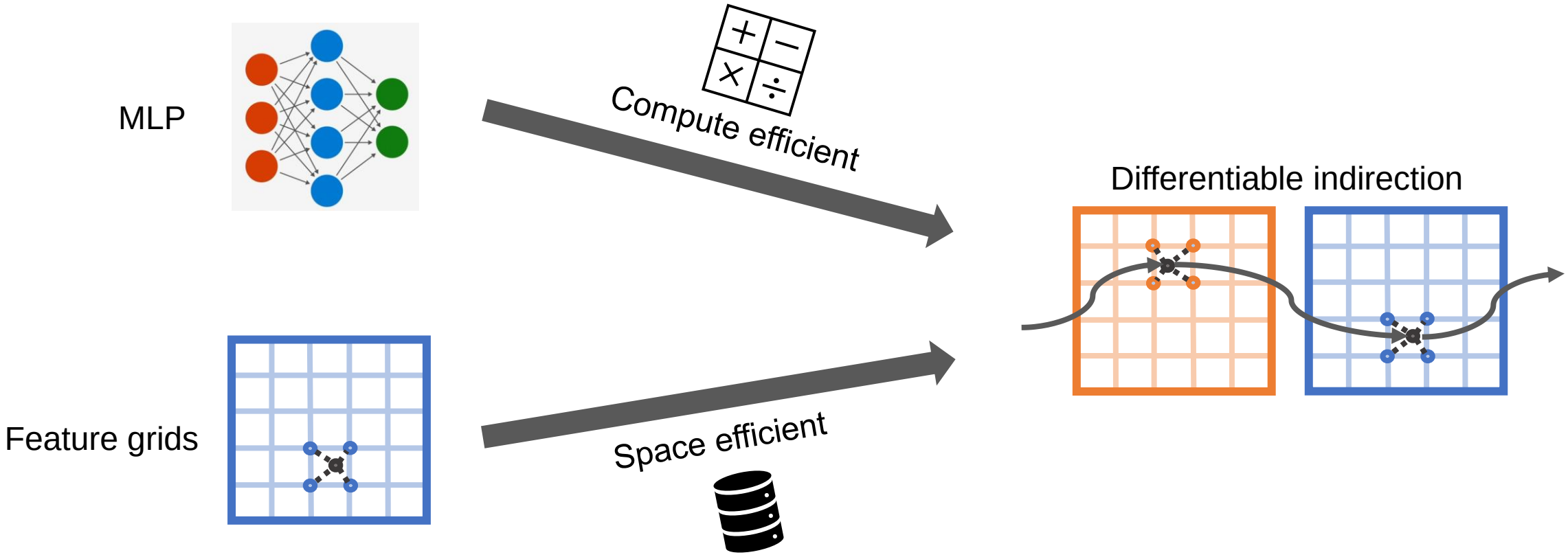

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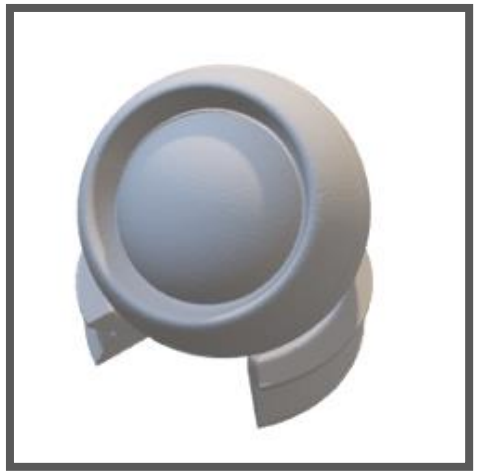

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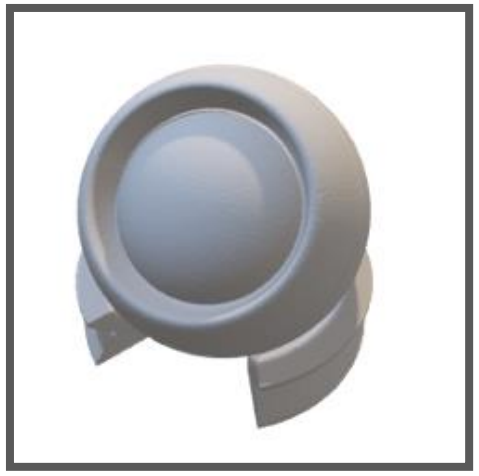

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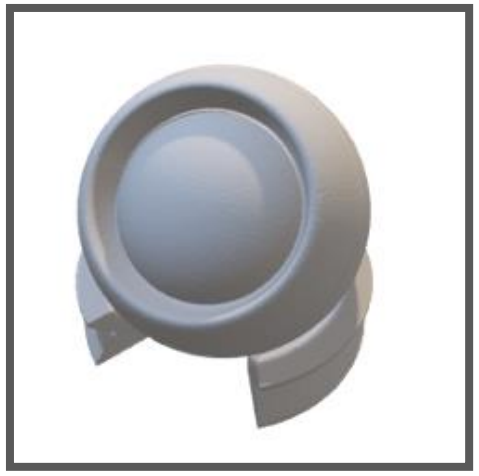
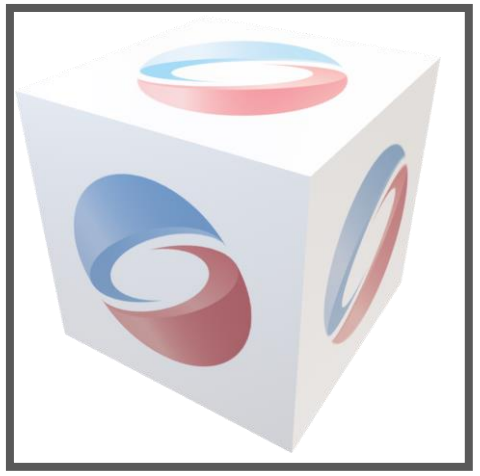


Texture Compression

Compression and Filtering



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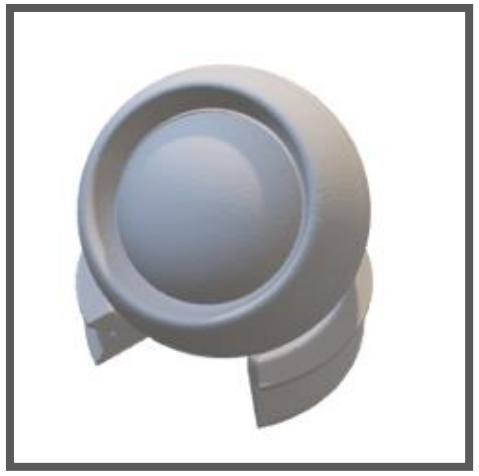

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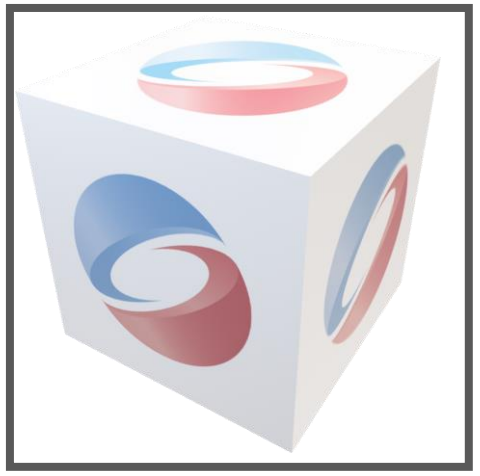

Disney Shading

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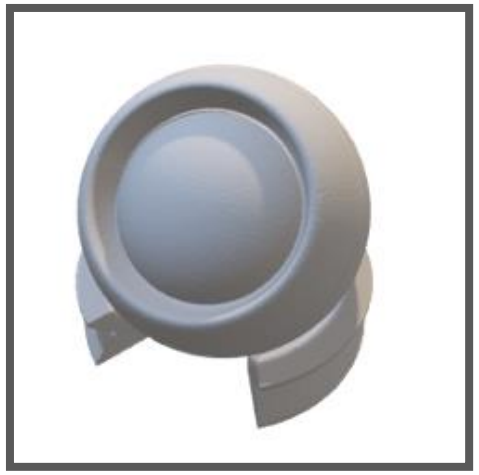

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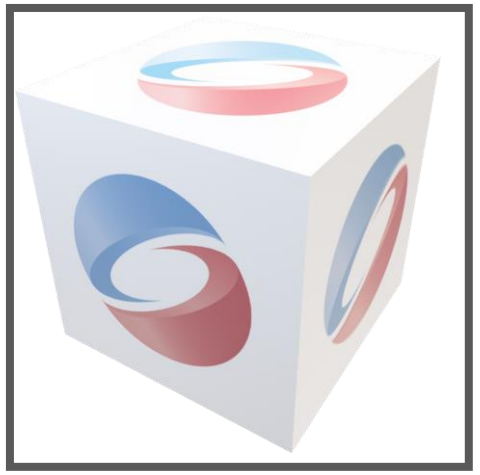

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Radiance Field Compression

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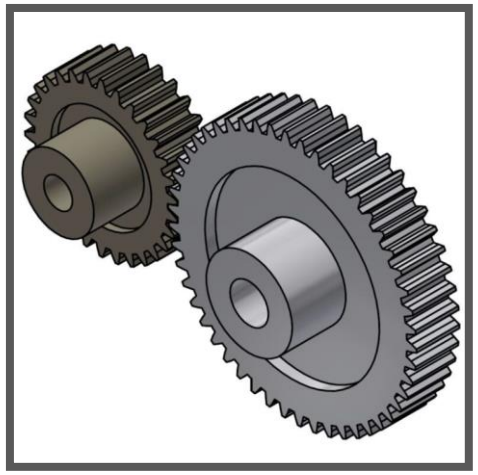
Graphics and beyond…



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- Adaptivity:

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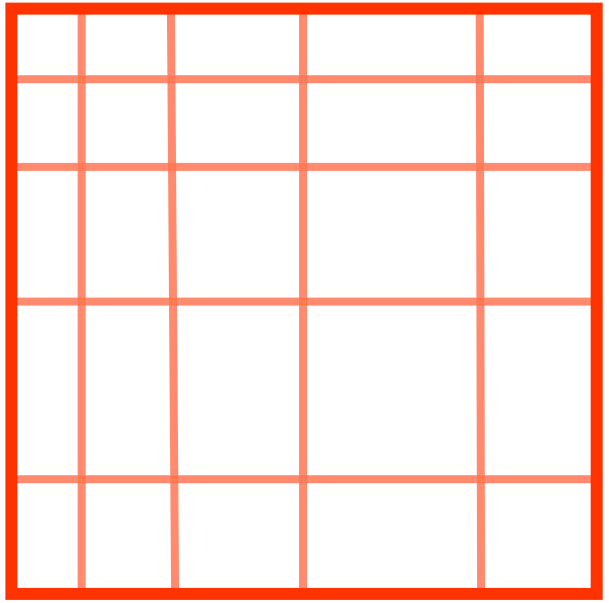
Adaptive resolution with differentiable indirection.



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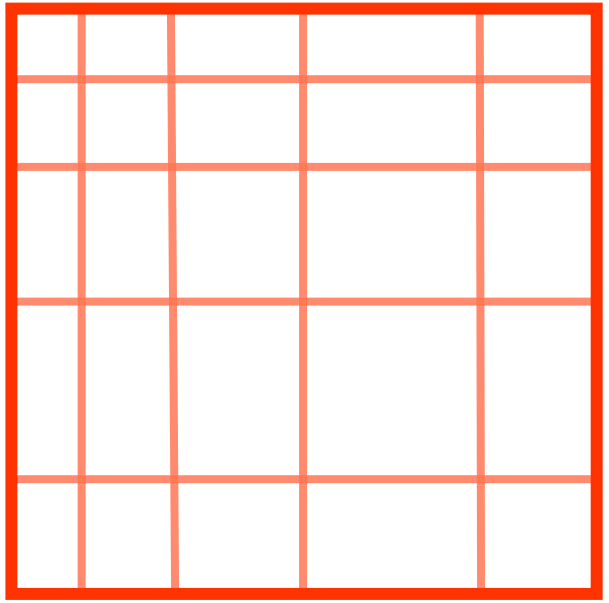

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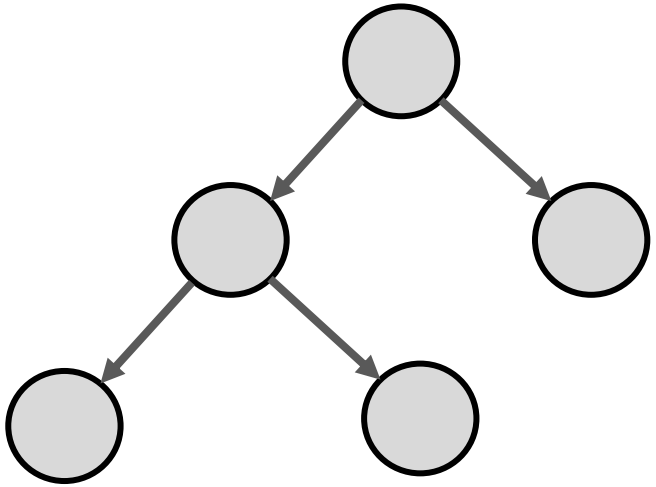
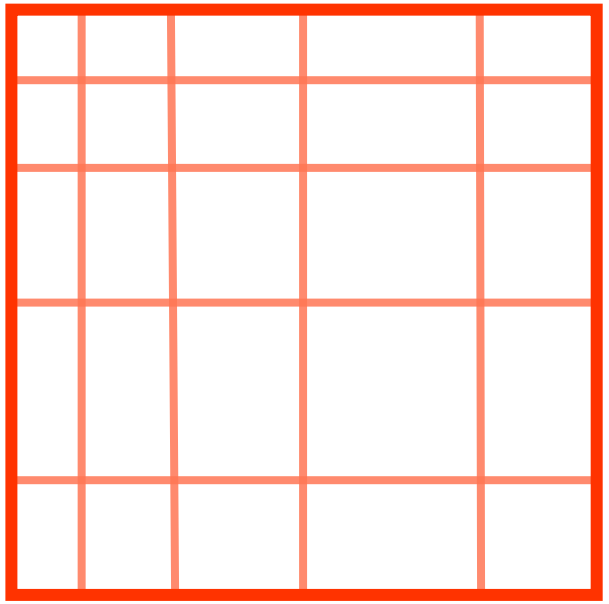


Require multiple indirections.

Adaptive resolution with
differentiable indirection.



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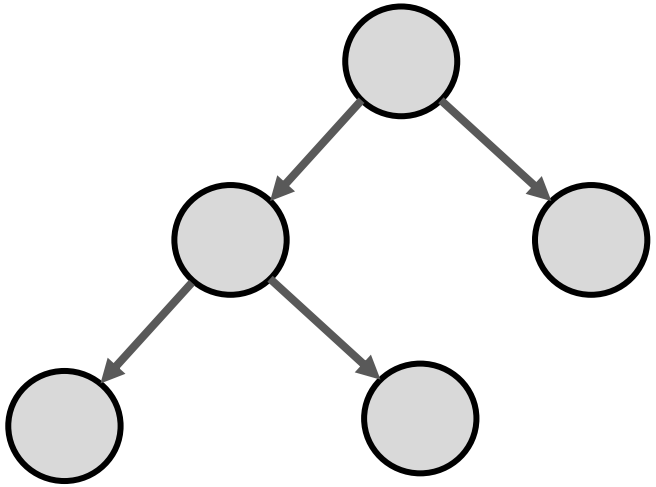

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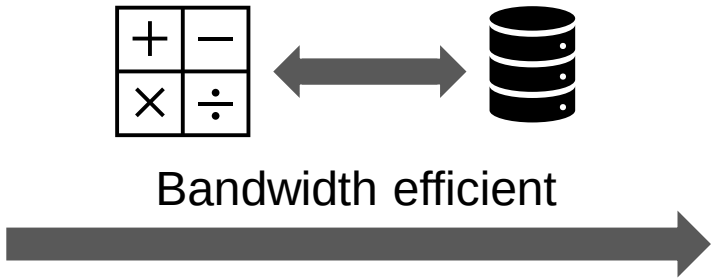

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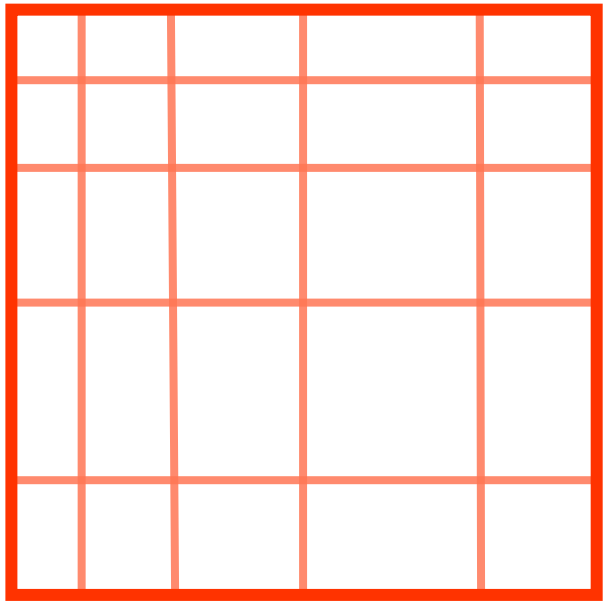

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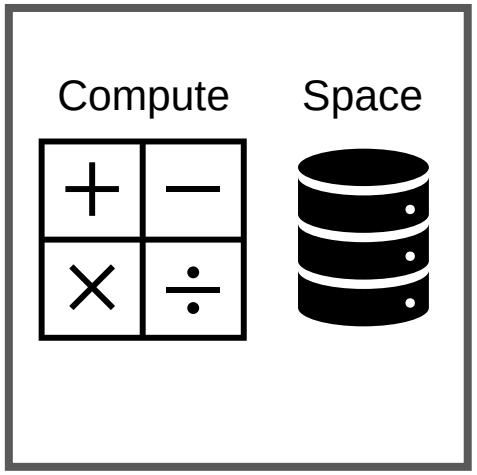
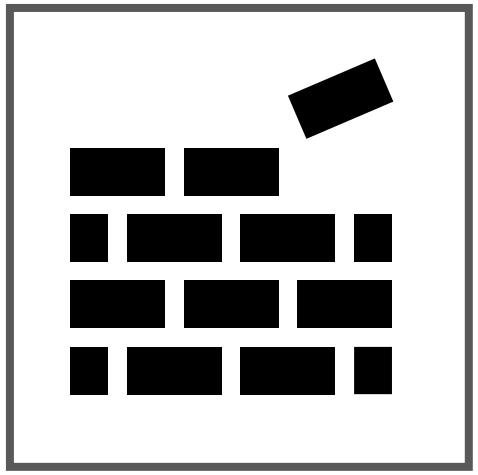
  - Adaptive spatial resolution without tree-structures. More coherent memory access.

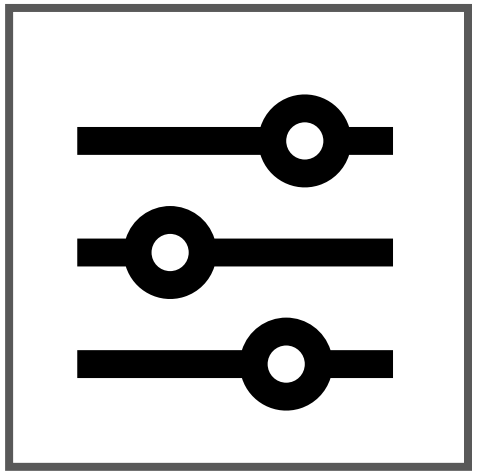
Efficient



Flexible



Adaptive resolution



Technical Summary

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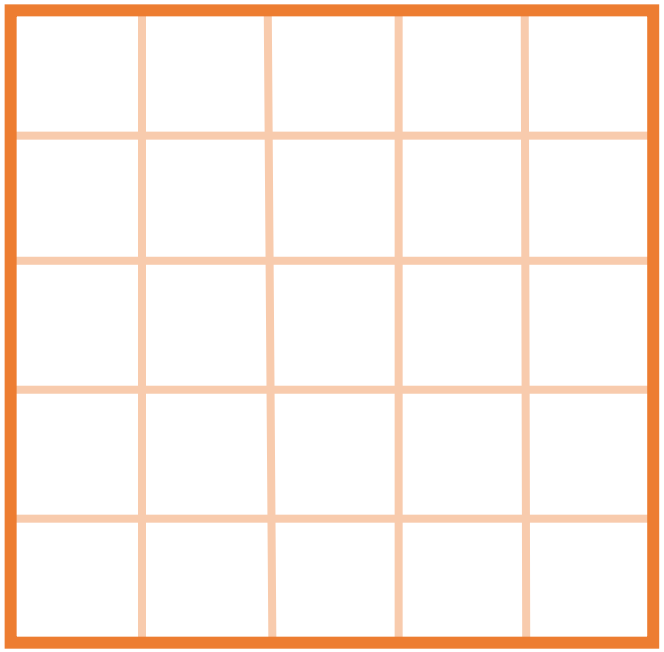
Primary



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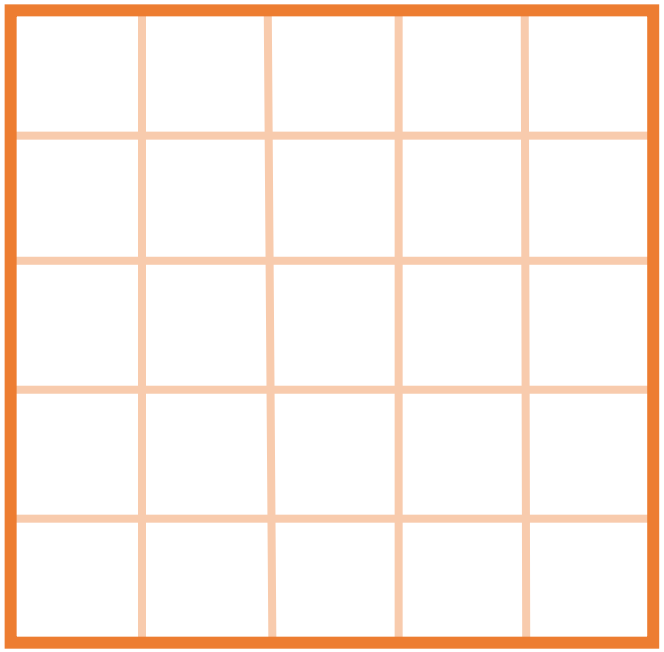
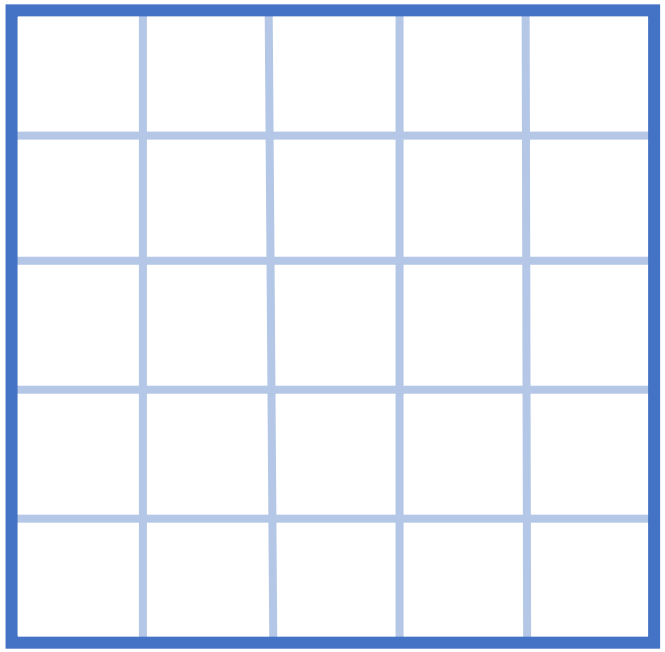
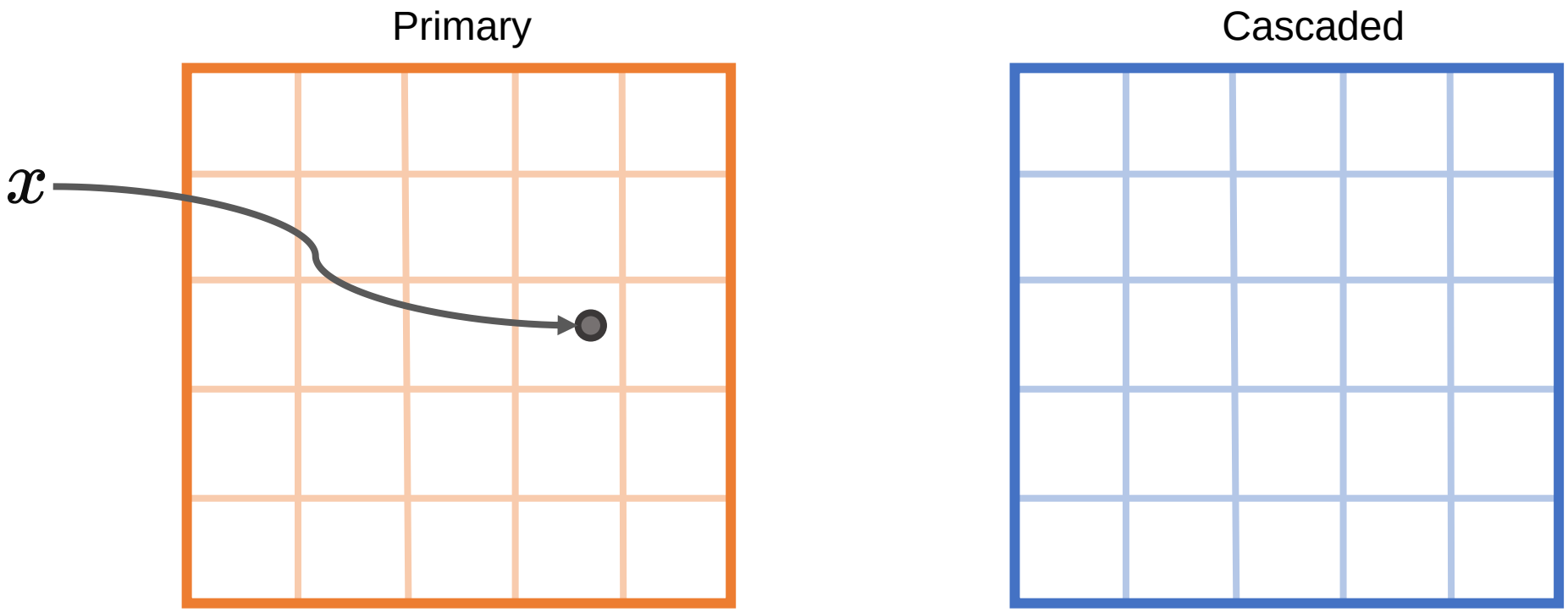


Cascaded



Technical Summary : Forward pass



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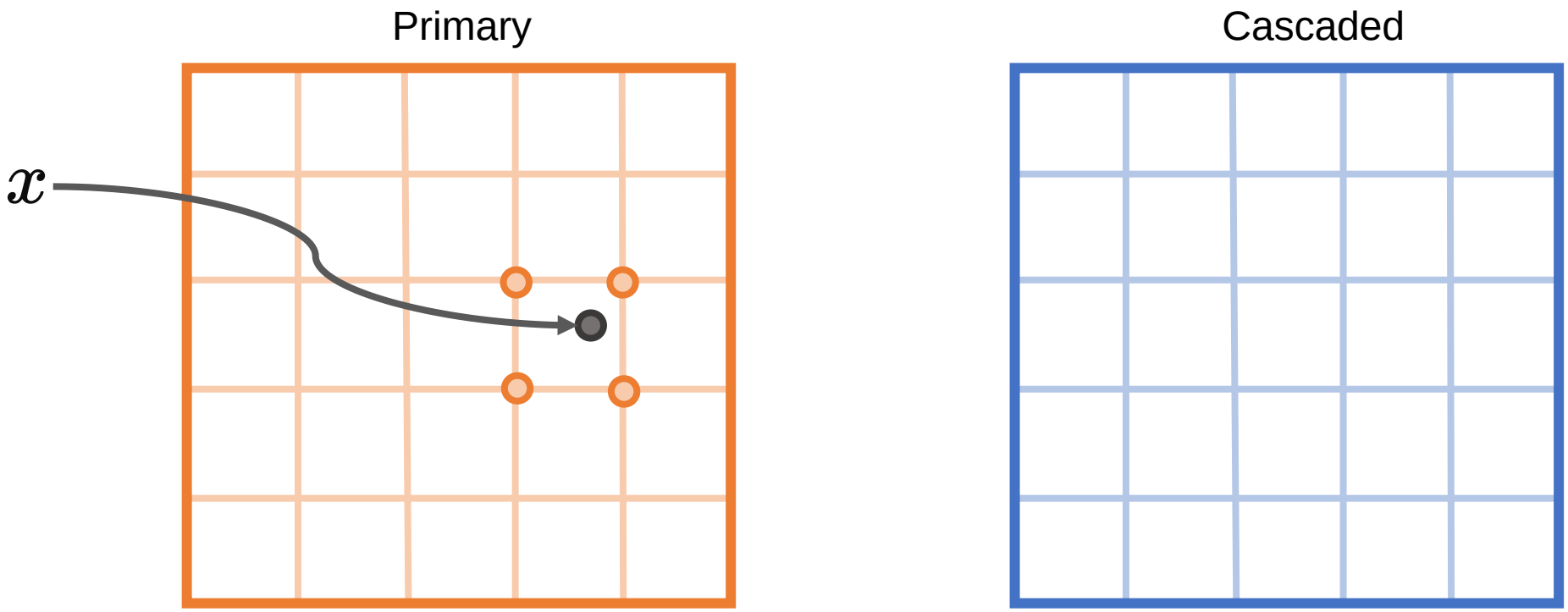

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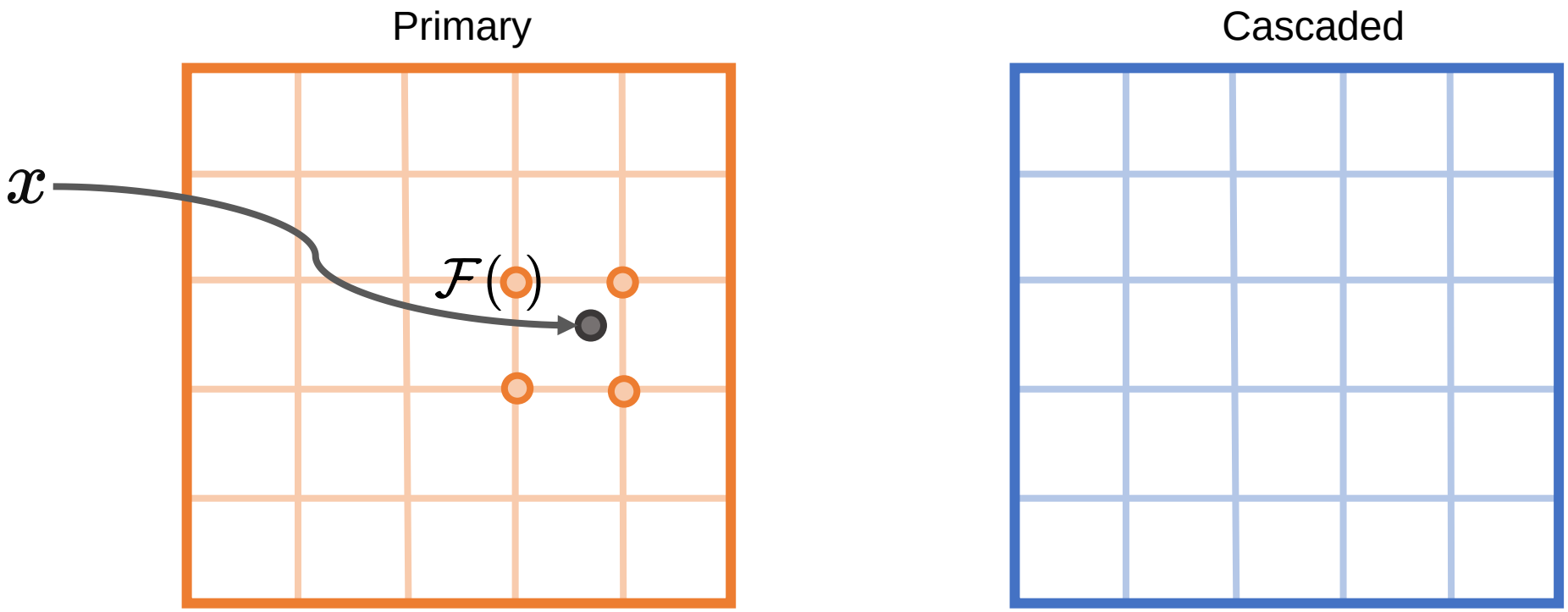

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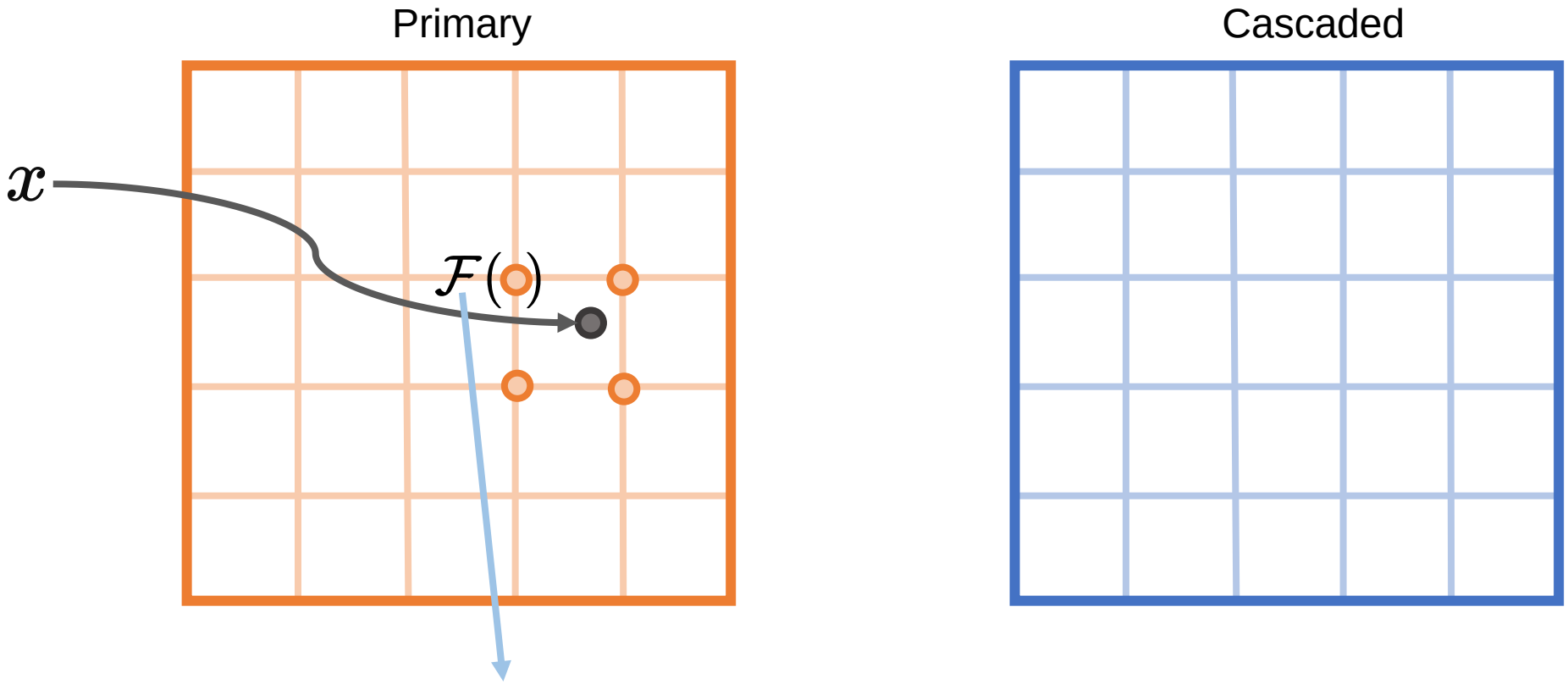

Constraining non-linearity - bounds output values between 0 to 1.

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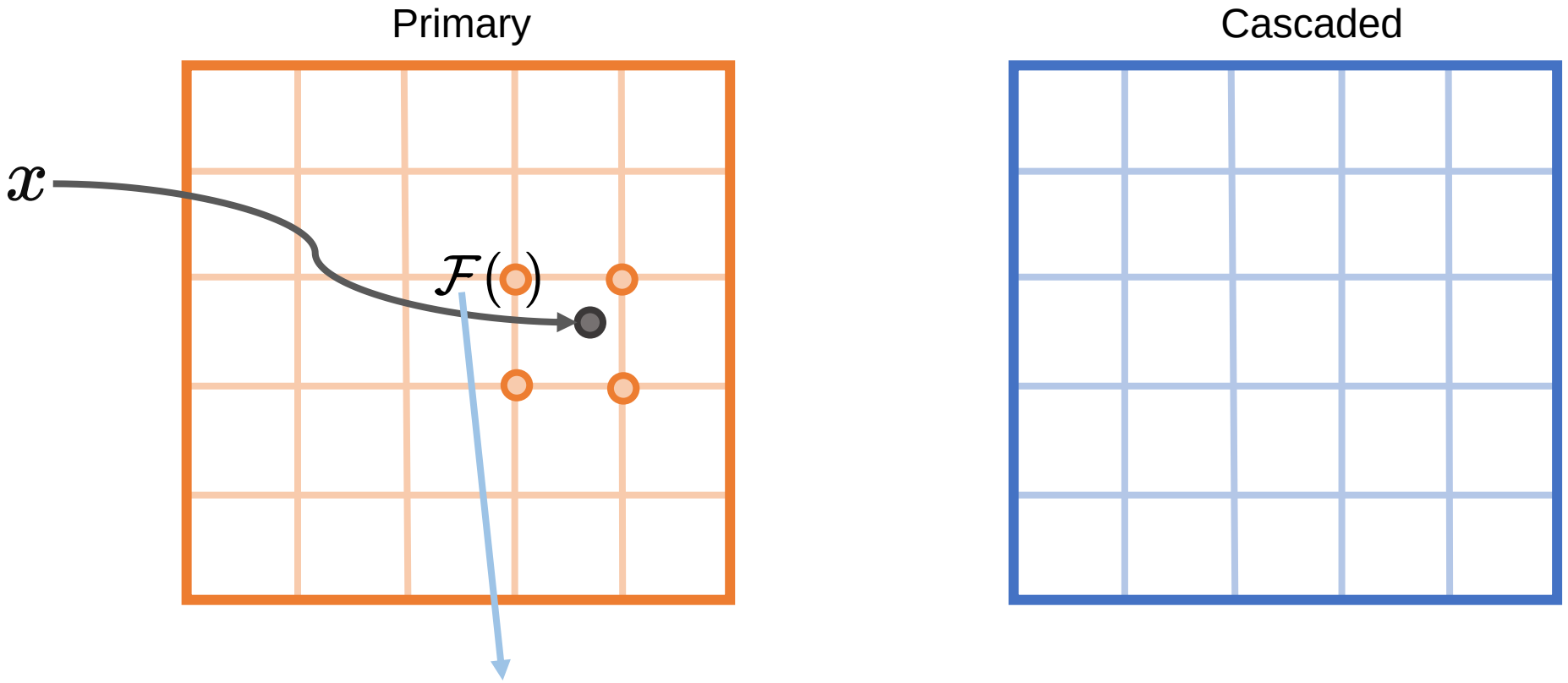

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Inference optimizations:

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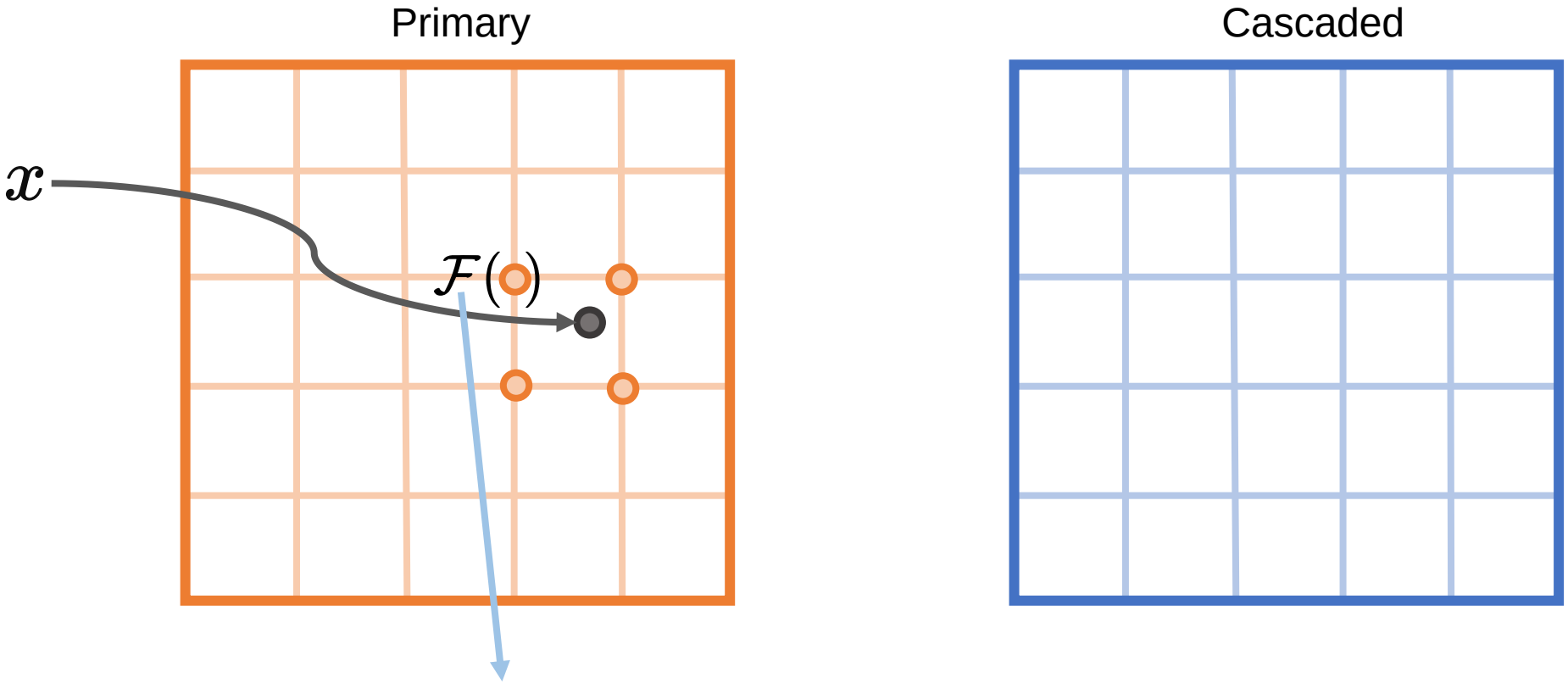

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- Bake-in non-linearity in array cells.
- Quantize array cells.

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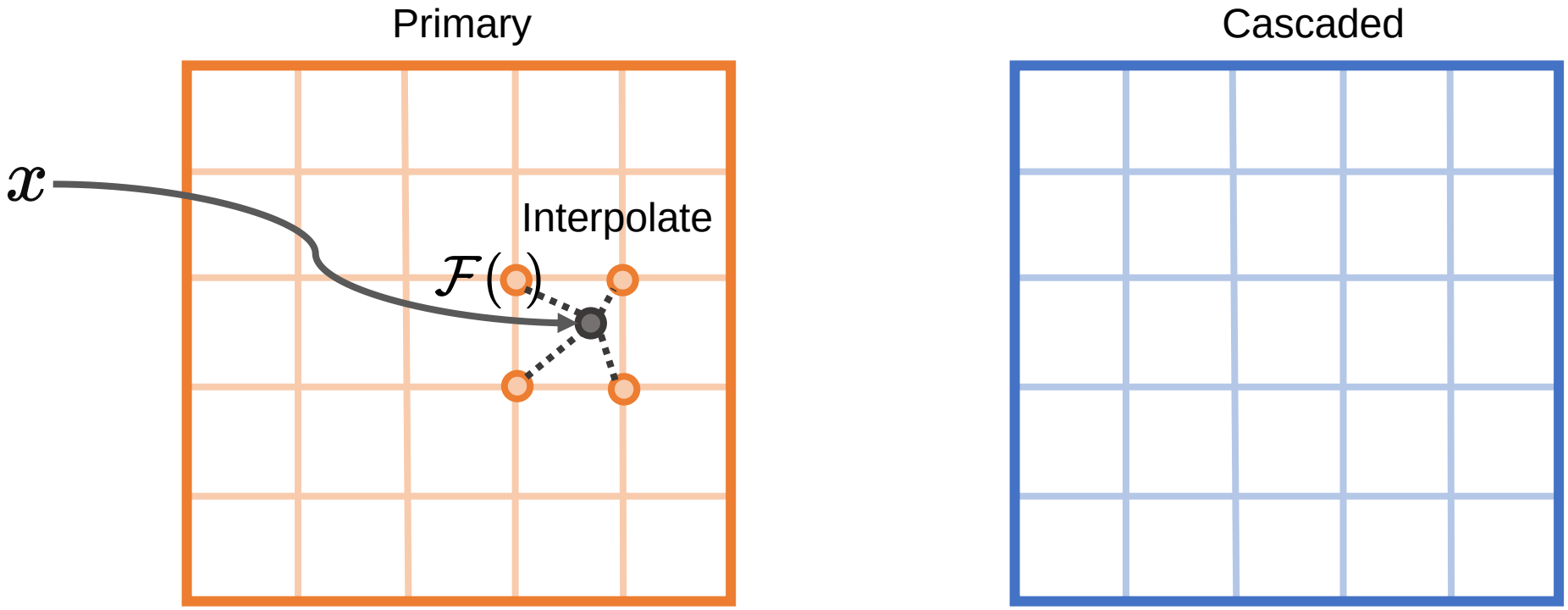

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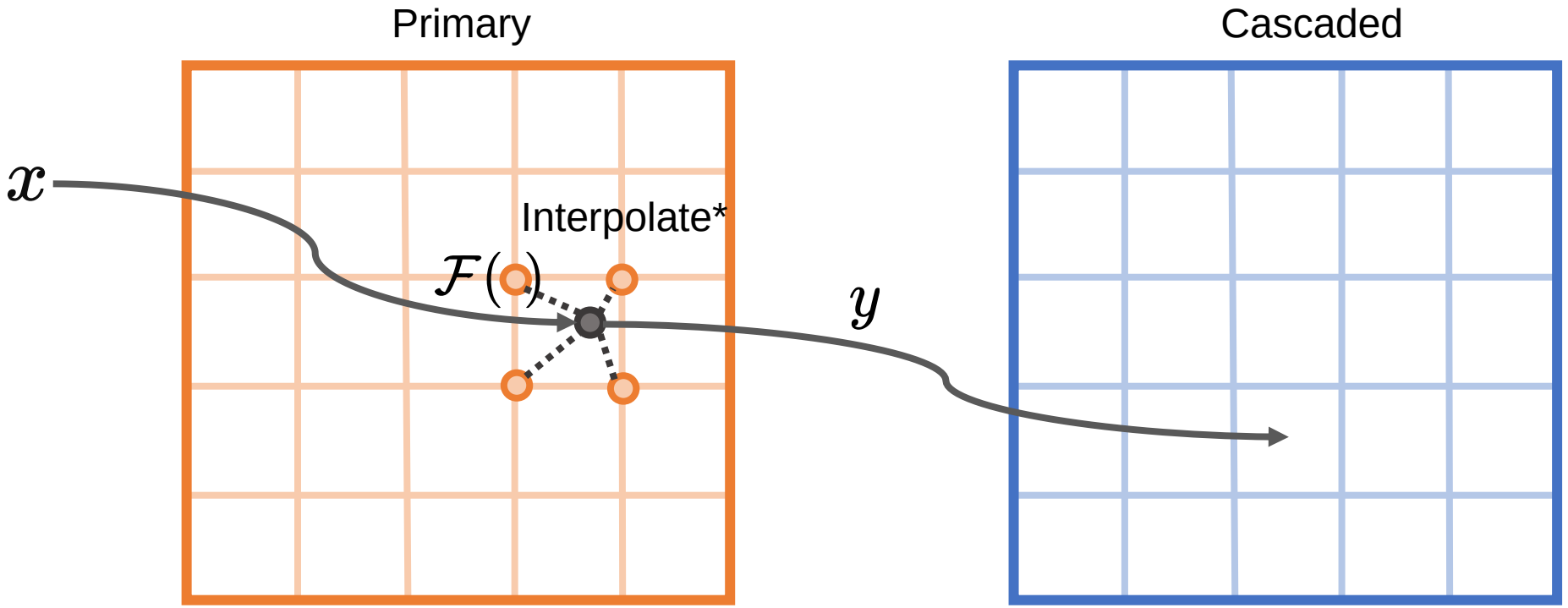

* Linear (tested) or higher order interpolants.

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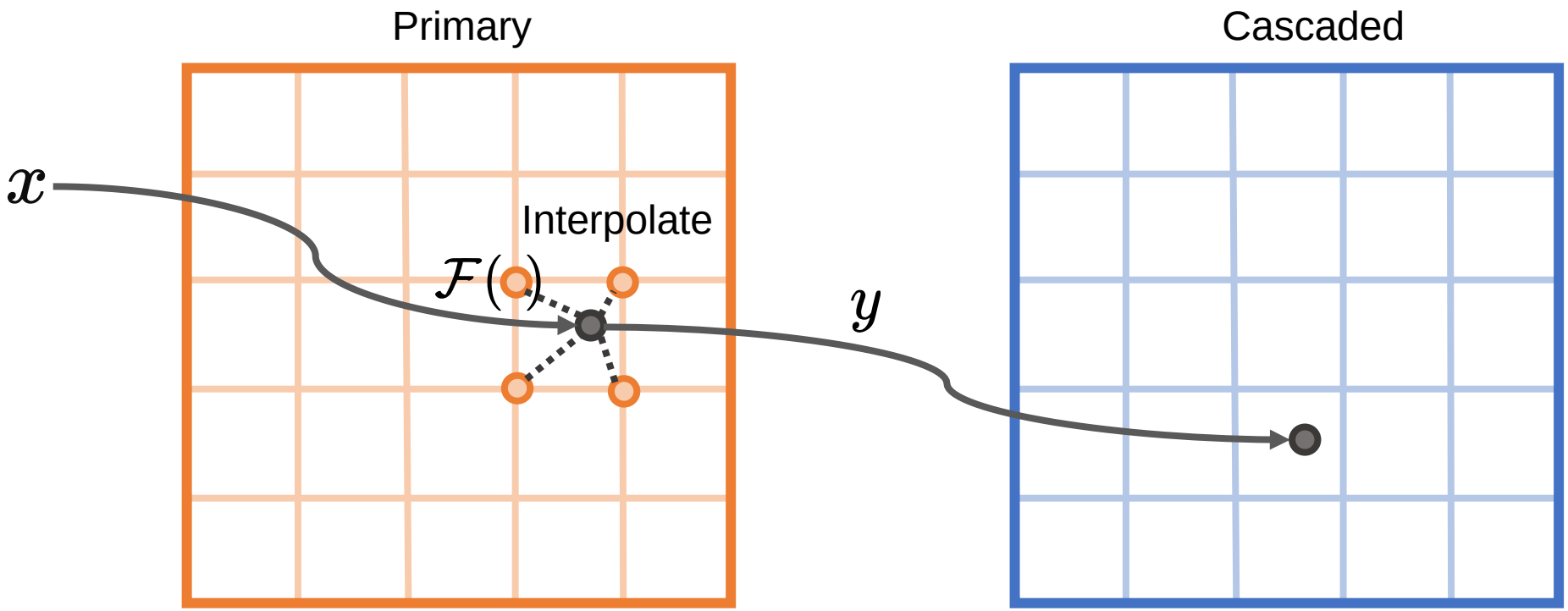

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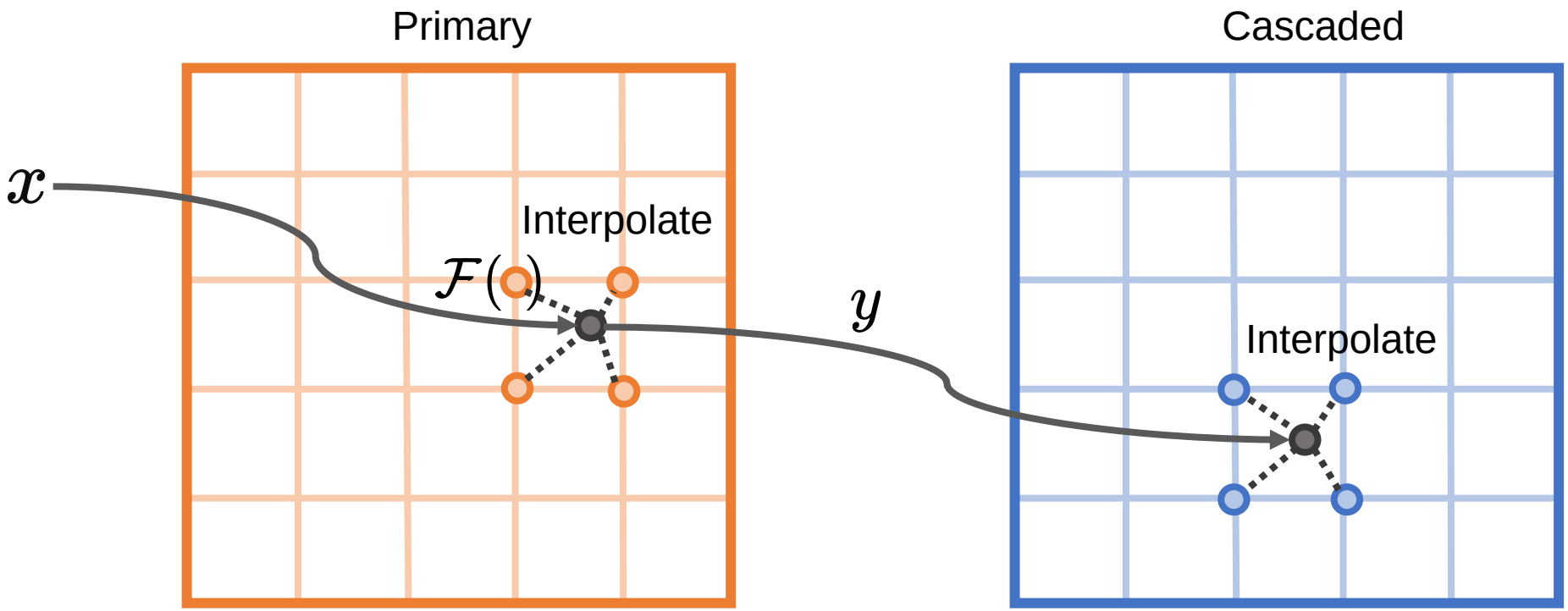

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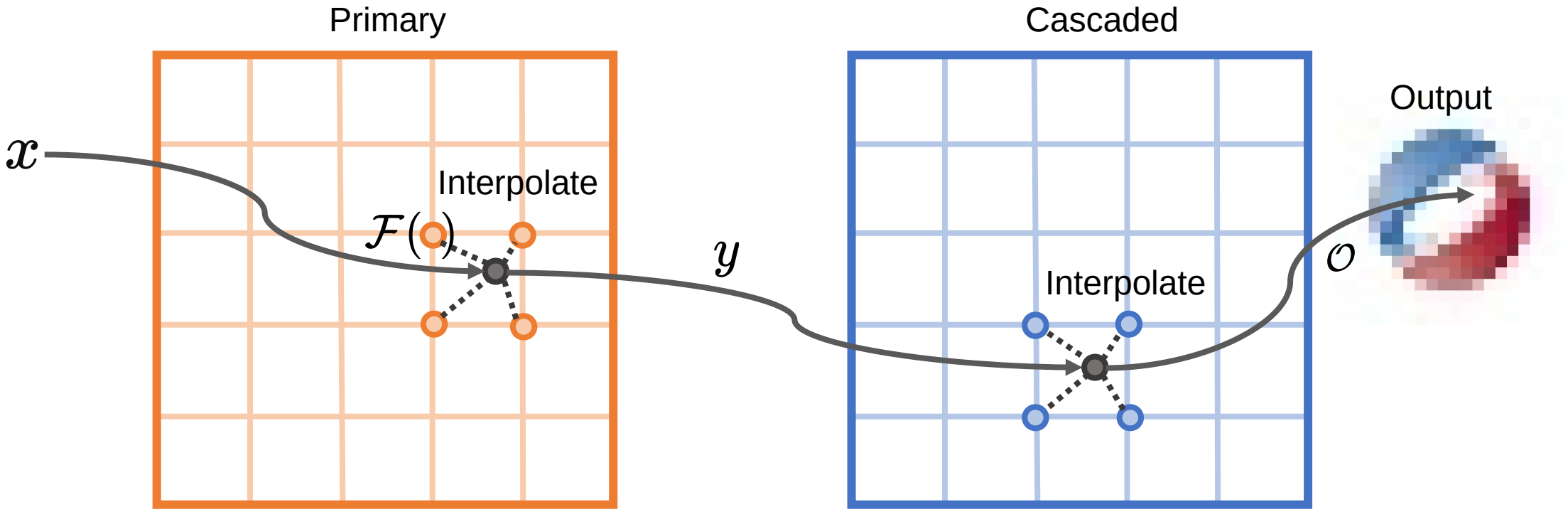

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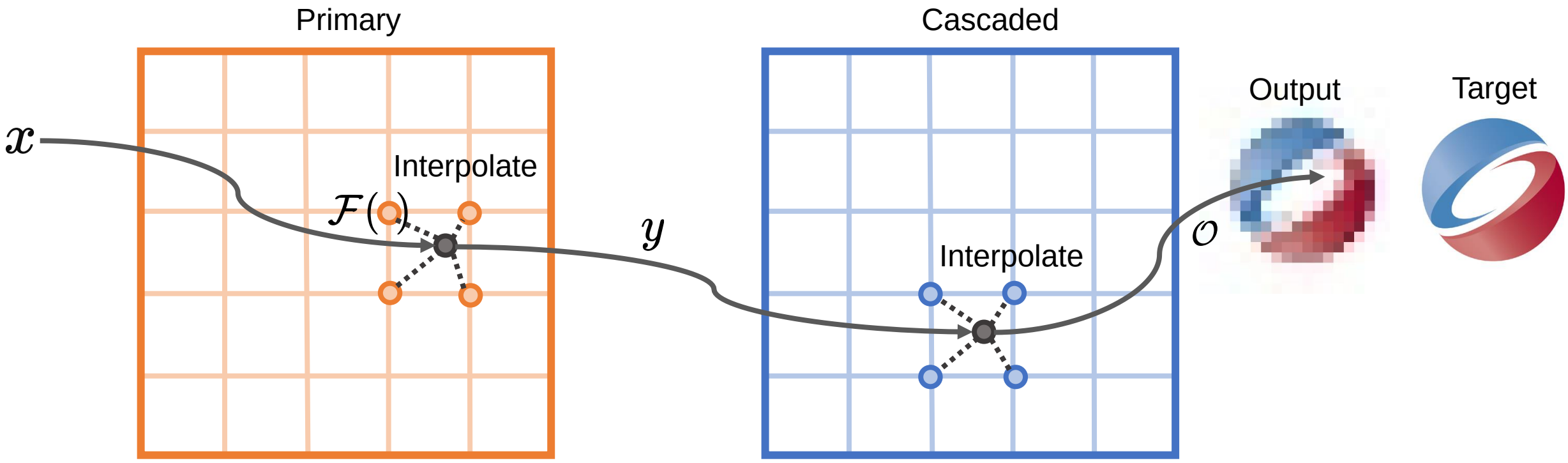

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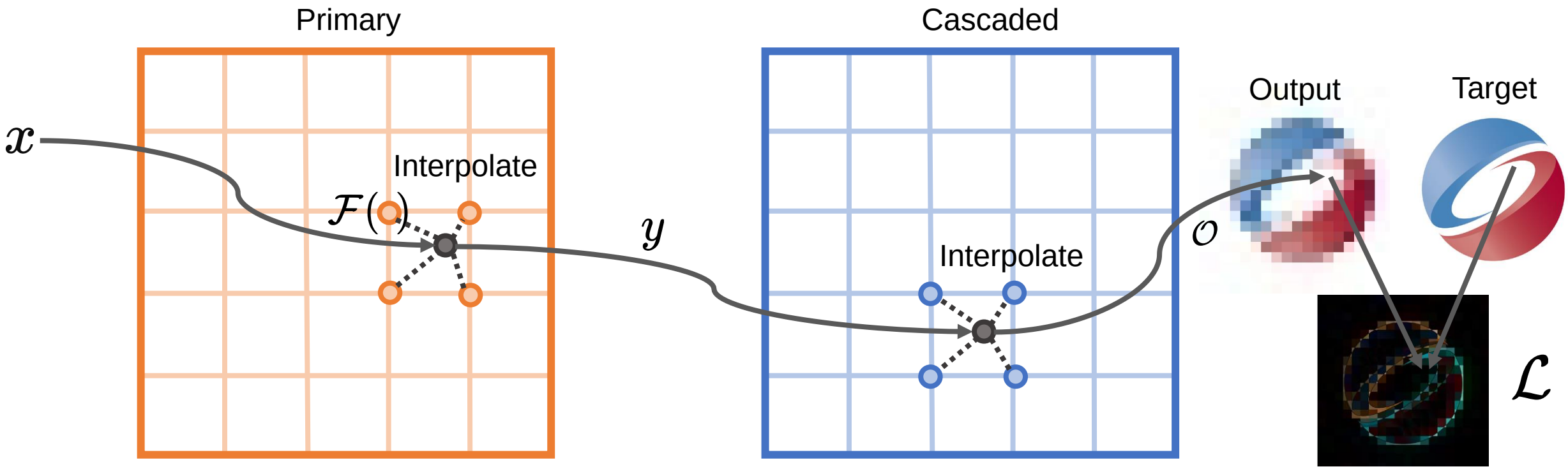

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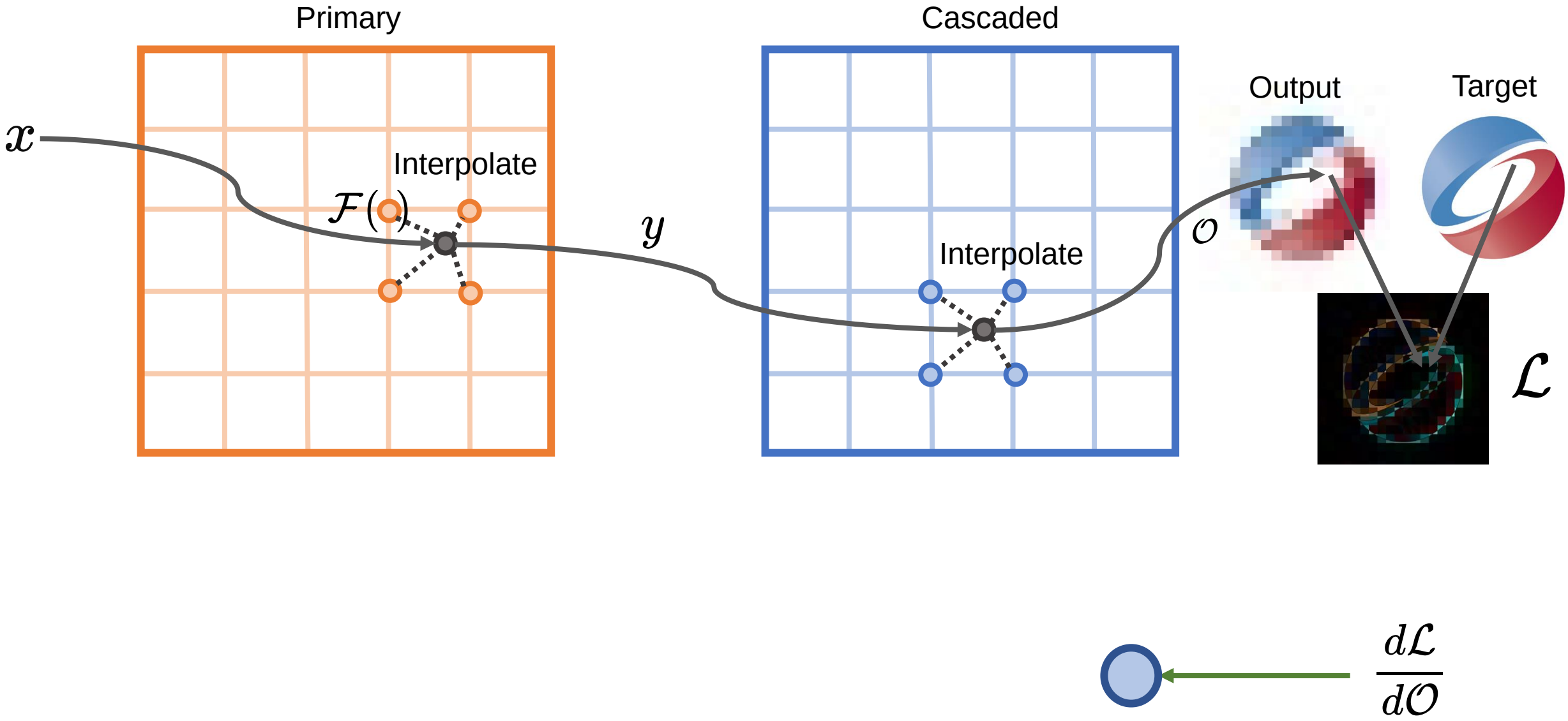

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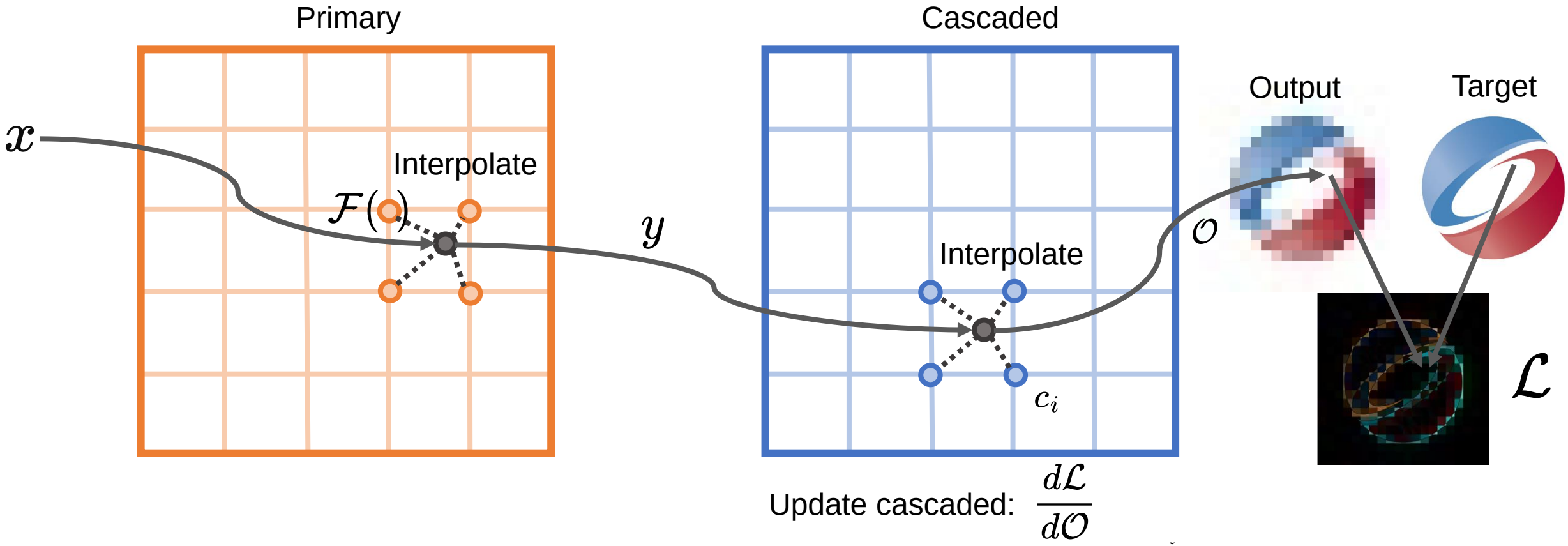

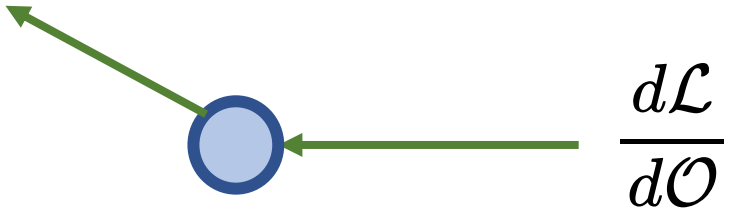

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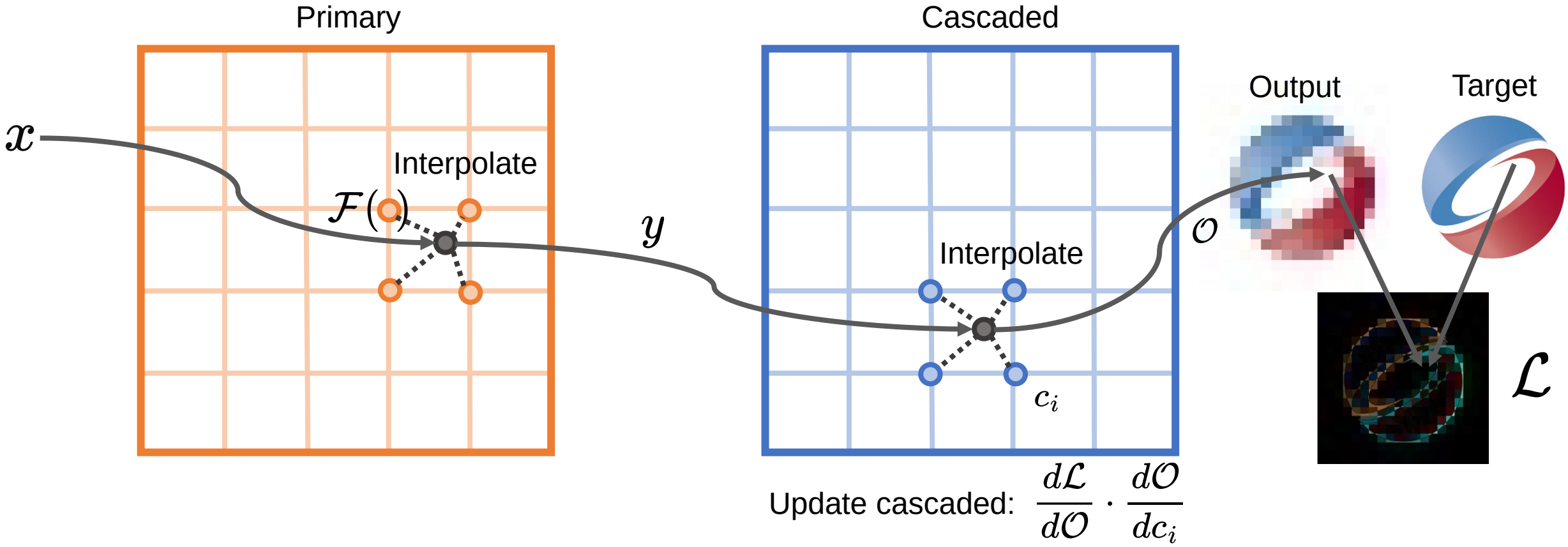

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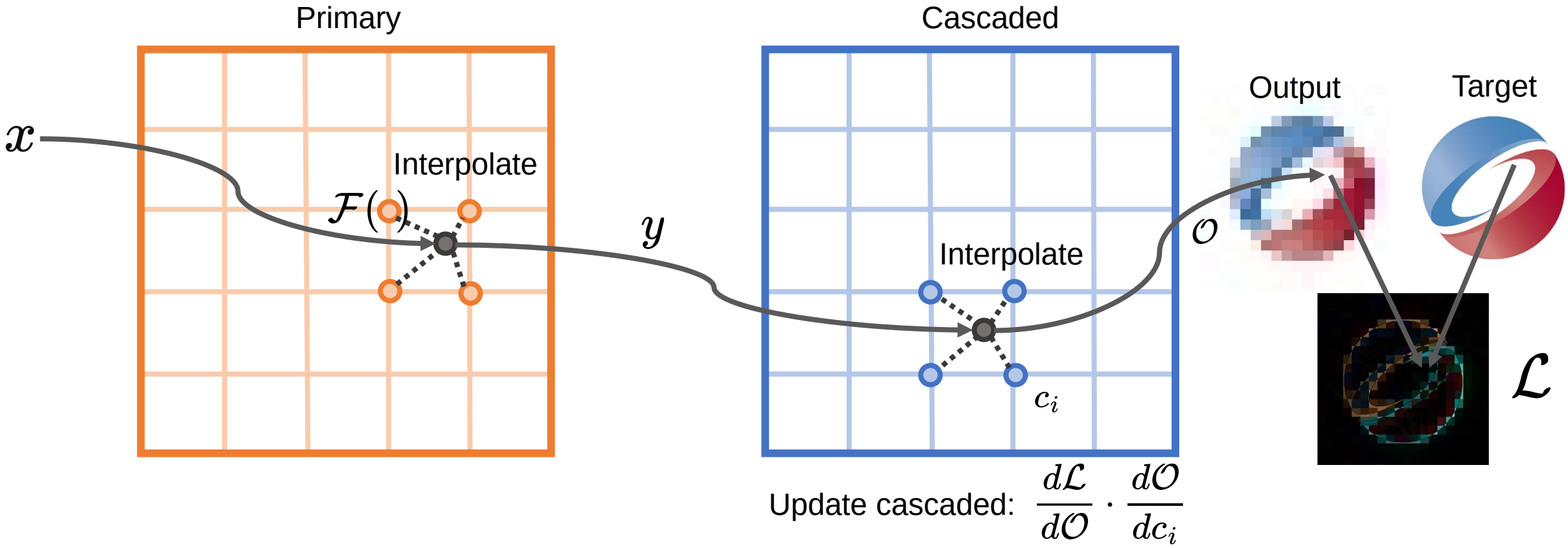
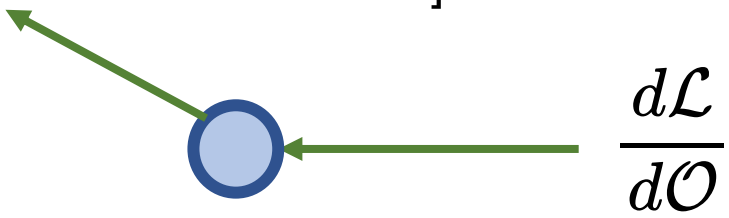


Update cascaded: $\frac{d\mathcal{L}}{d\mathcal{O}} \cdot \frac{d\mathcal{O}}{dc_i}$

[Muller et. al 2022, Kanwar et. al 2022…]



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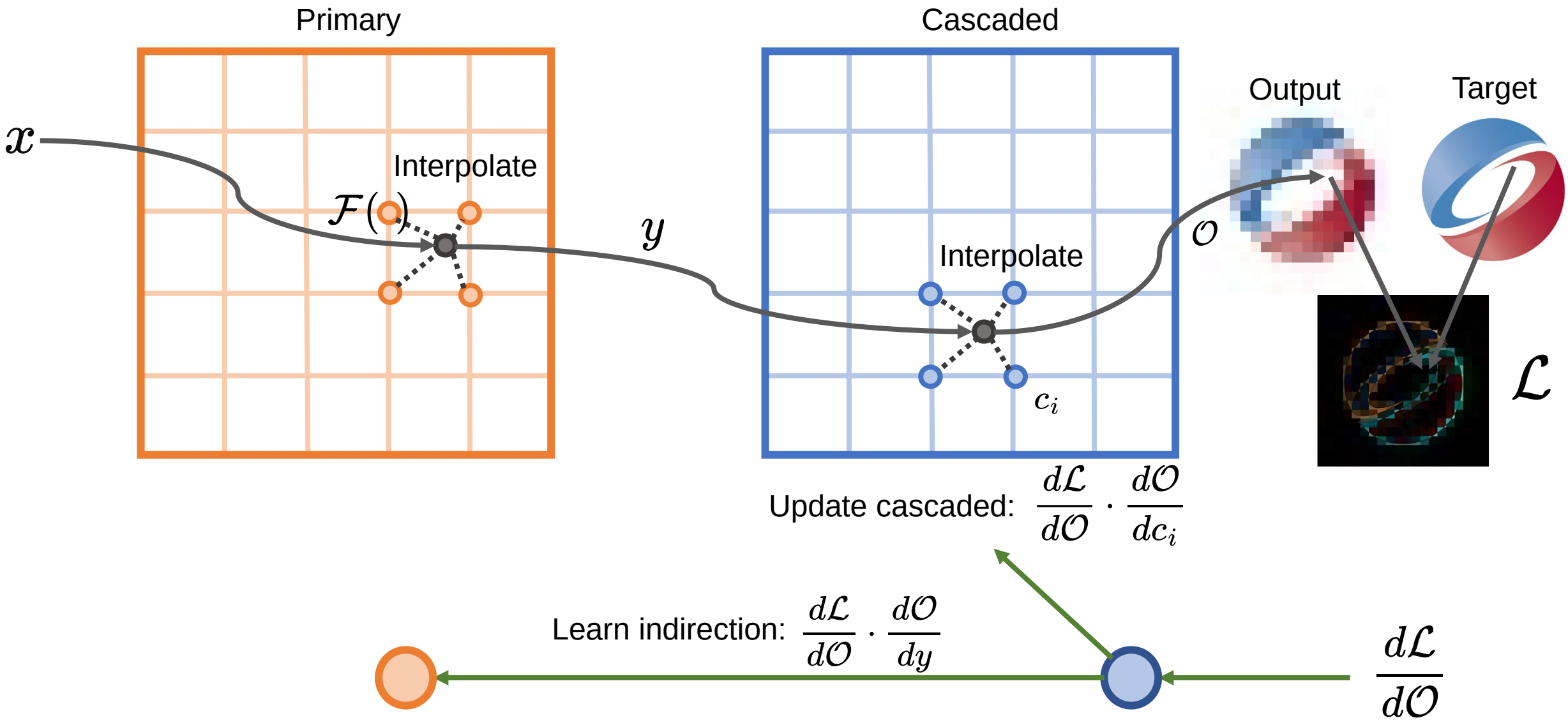
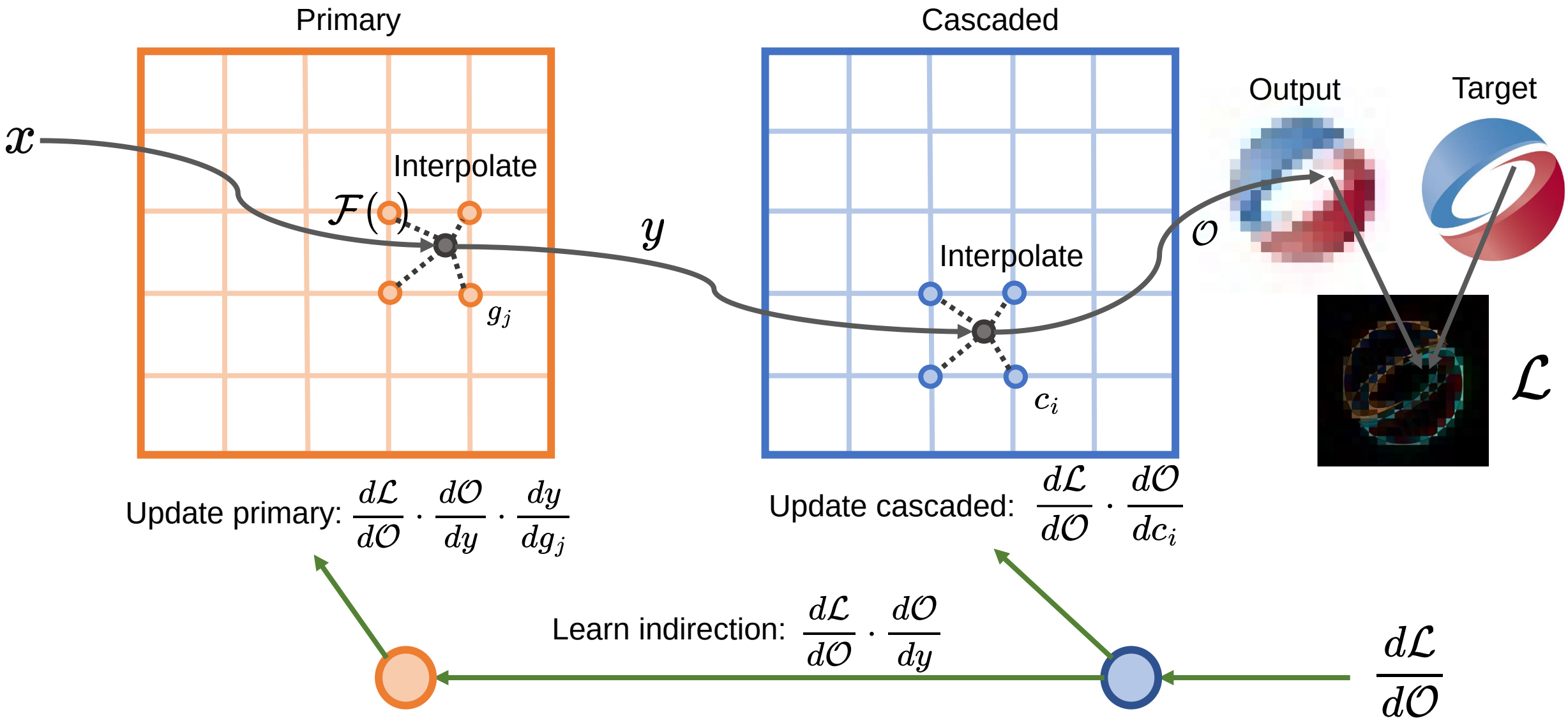
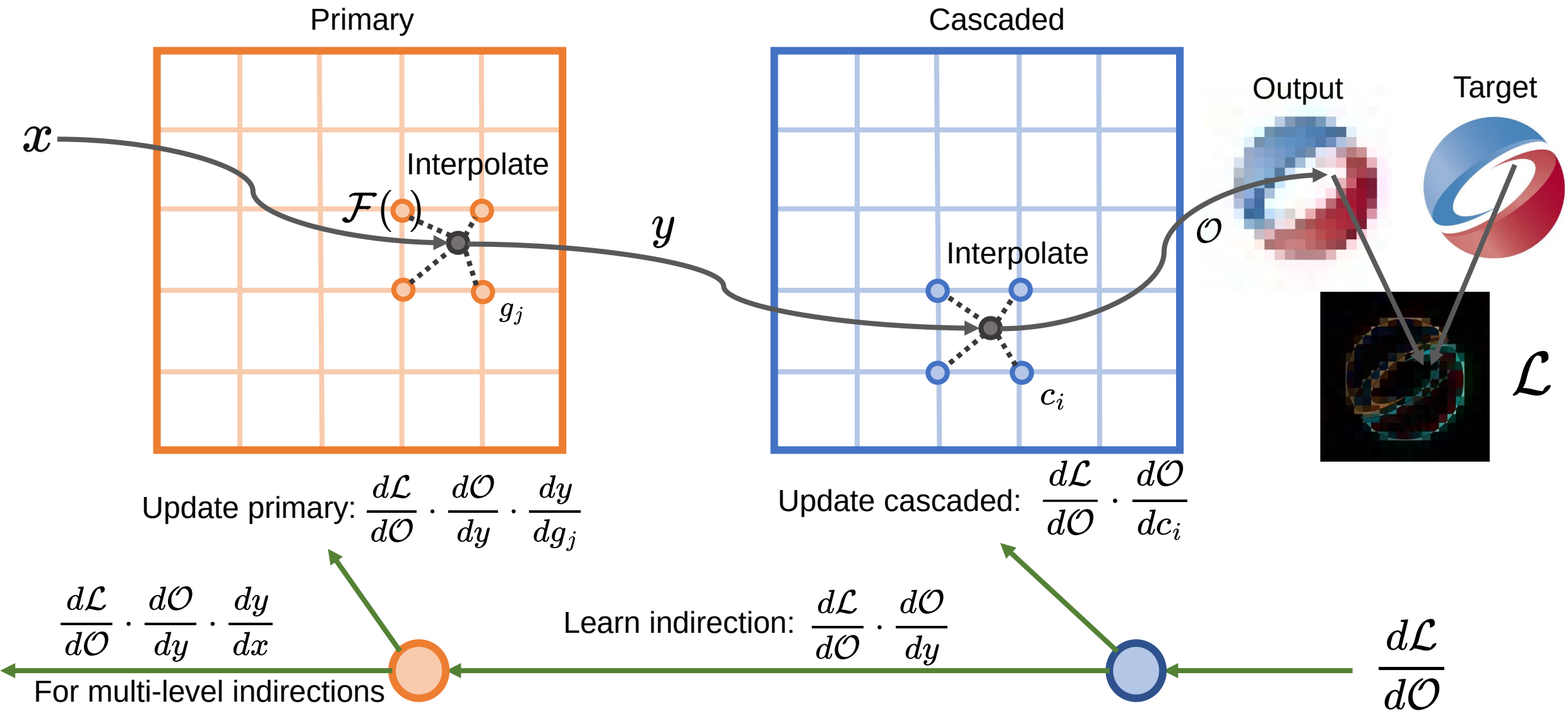


Technical Summary : Backward pass

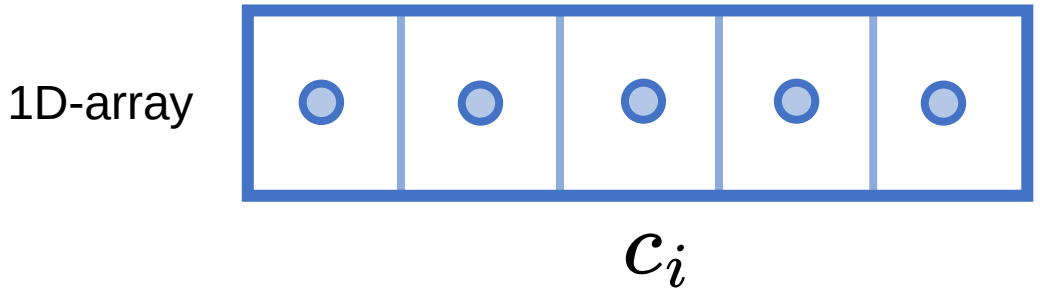


Technical Summary : Backward pass

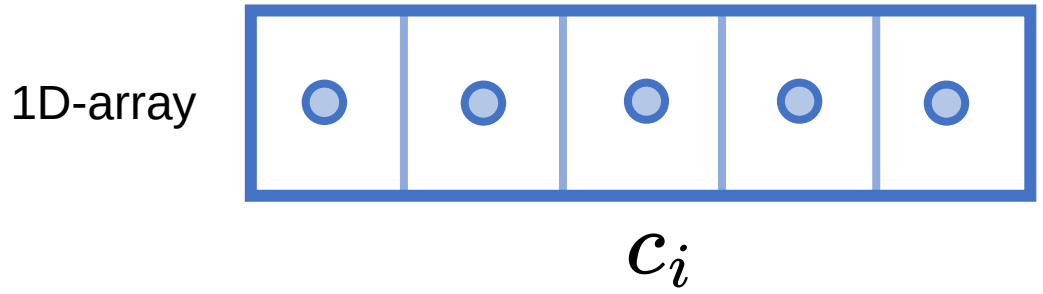


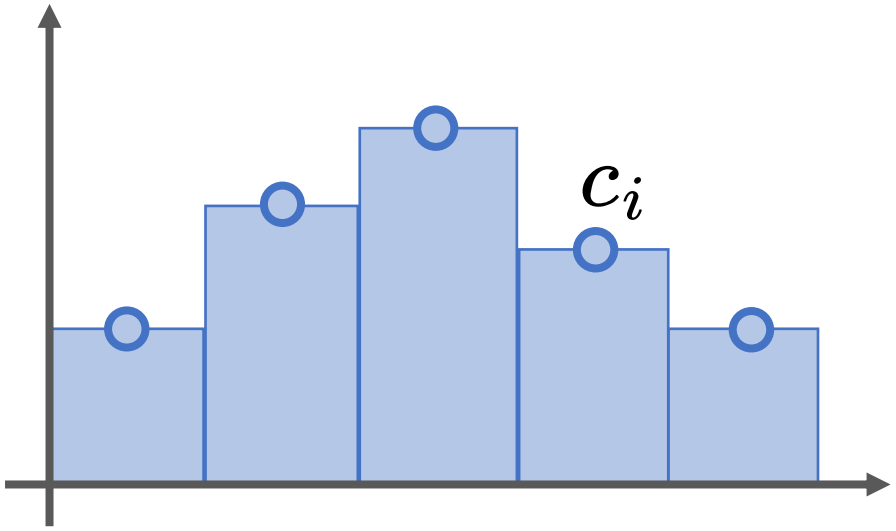
Intuition

Intuition

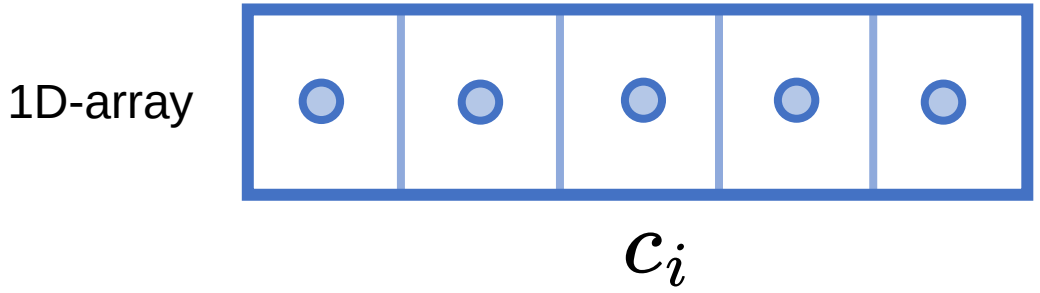


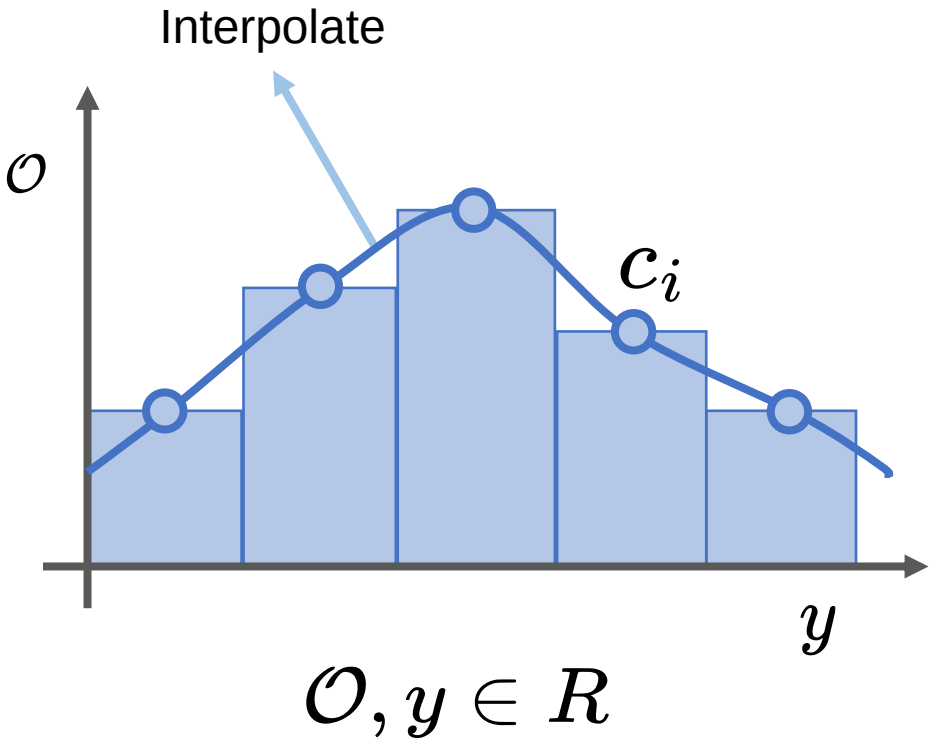
Intuition



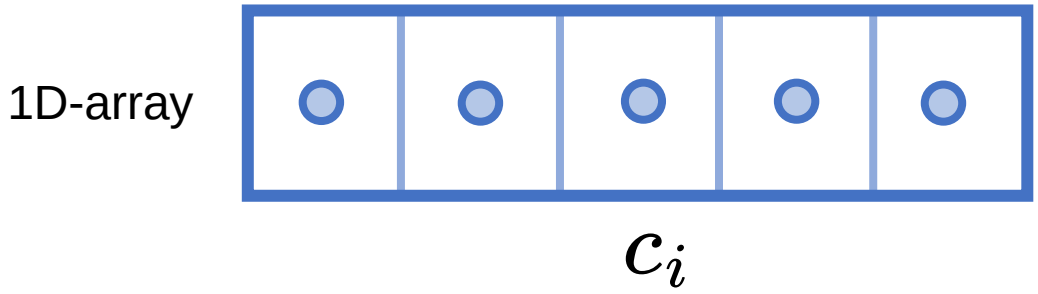


Intuition





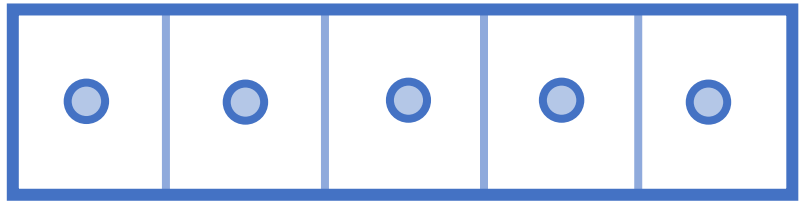
Intuition



Two gradients:

Intuition

1D-array



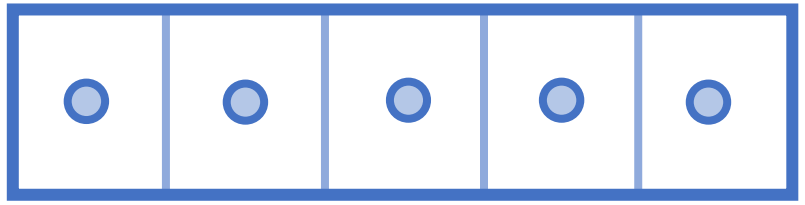
c_i

Two gradients: $\frac{d\mathcal{O}}{dc_i}$

Gradient of output w.r.t. array cell values.

Intuition

1D-array



c_i

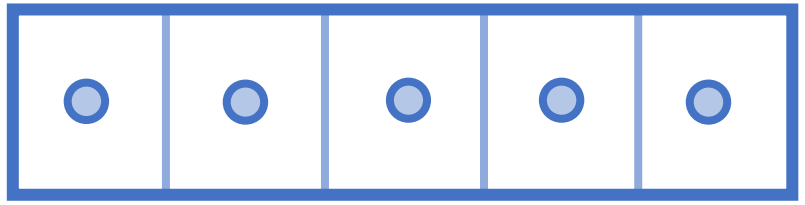
Two gradients: $\frac{d\mathcal{O}}{dc_i}$ $\frac{d\mathcal{O}}{dy}$

Gradient of output w.r.t. array cell values.

Gradient of output w.r.t. array input coordinates.

Intuition

1D-array



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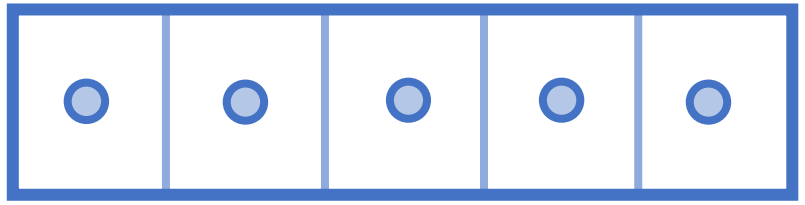
Gradient of output w.r.t. array cell values.
Purpose: Update array cells.

Gradient of output w.r.t. array input coordinates.

Intuition

1D-array



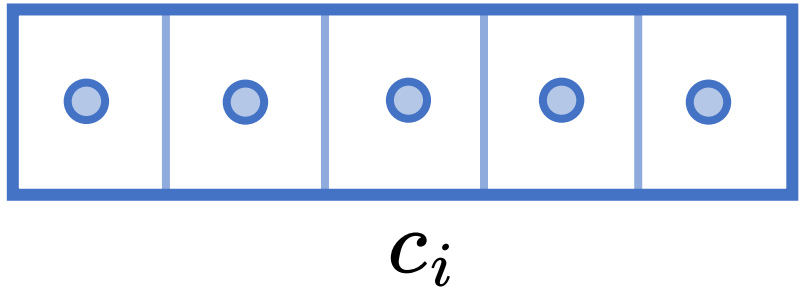
c_i

Two gradients: $\frac{d\mathcal{O}}{dc_i}$ $\frac{d\mathcal{O}}{dy}$

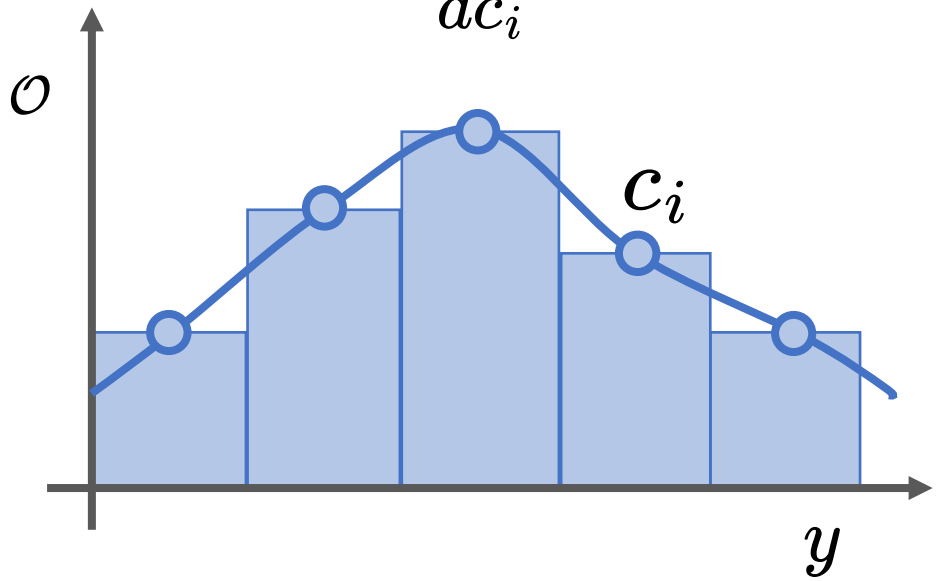
Gradient of output w.r.t. array cell values.
Purpose: Update array cells.

Gradient of output w.r.t. array input coordinates.
Purpose: Learn indirection.

Intuition



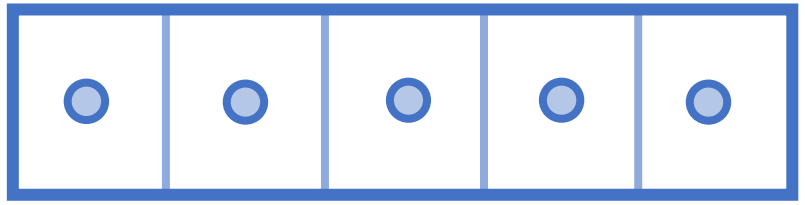
Two gradients: $\frac{d\mathcal{O}}{dc_i}$ $\frac{d\mathcal{O}}{dy}$



Muller et. al 2022, Kanwar et. al 2022…

Intuition

1D-array



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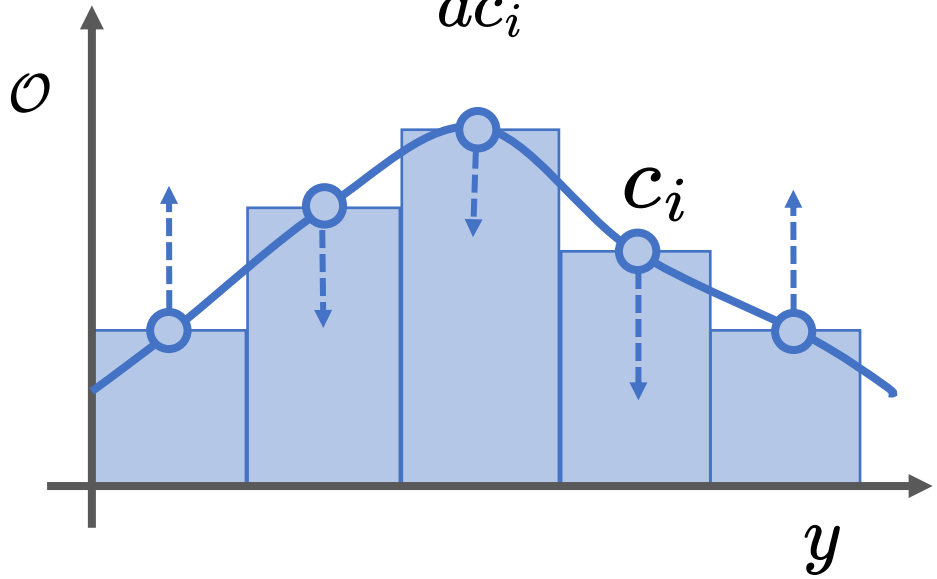
Two gradients: $\frac{d\mathcal{O}}{dc_i}$ $\frac{d\mathcal{O}}{dy}$



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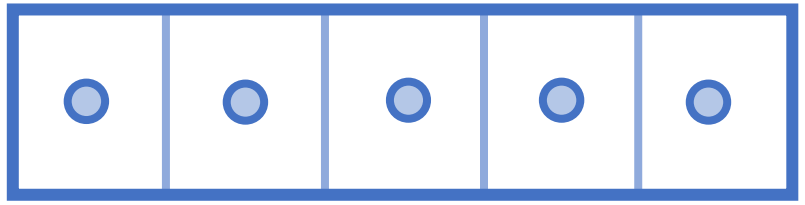

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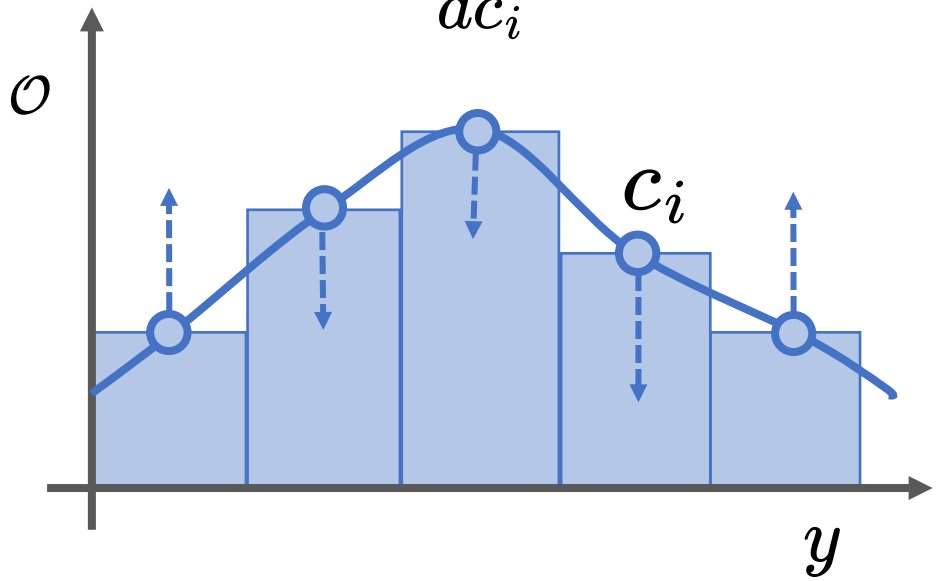
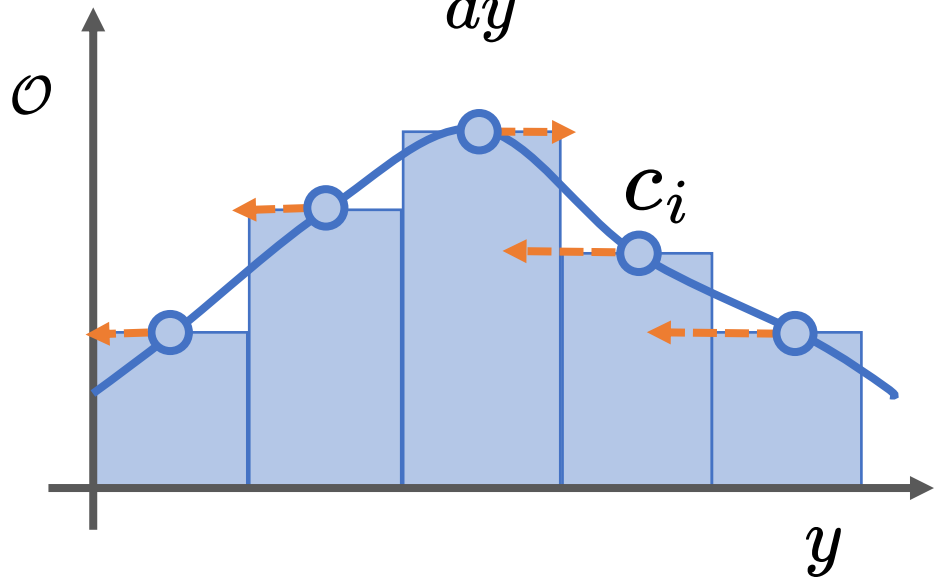


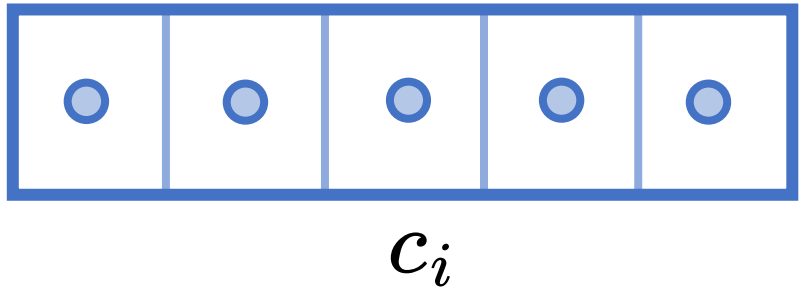
Muller et. al 2022, Kanwar et. al 2022…

$\frac{d\mathcal{O}}{dy}$

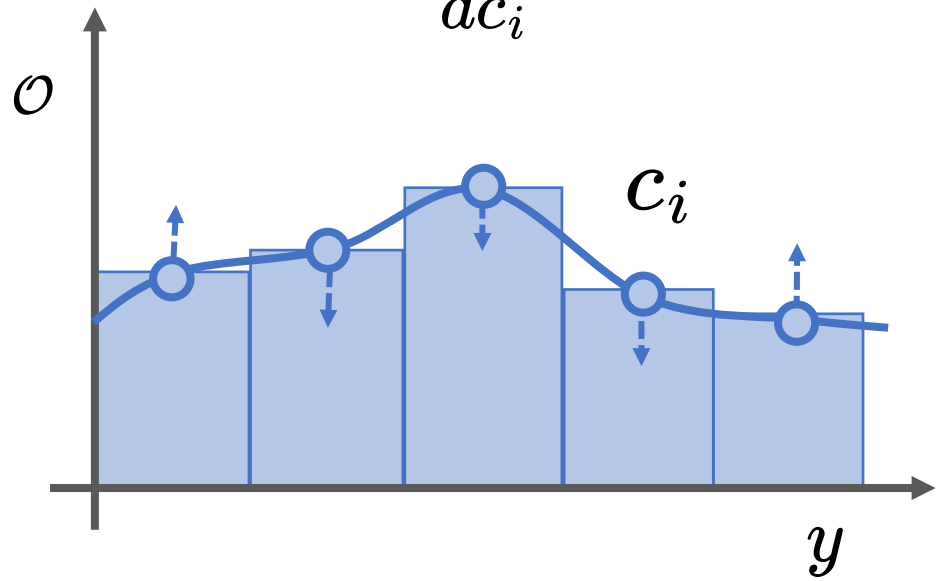


and additionally.

Intuition

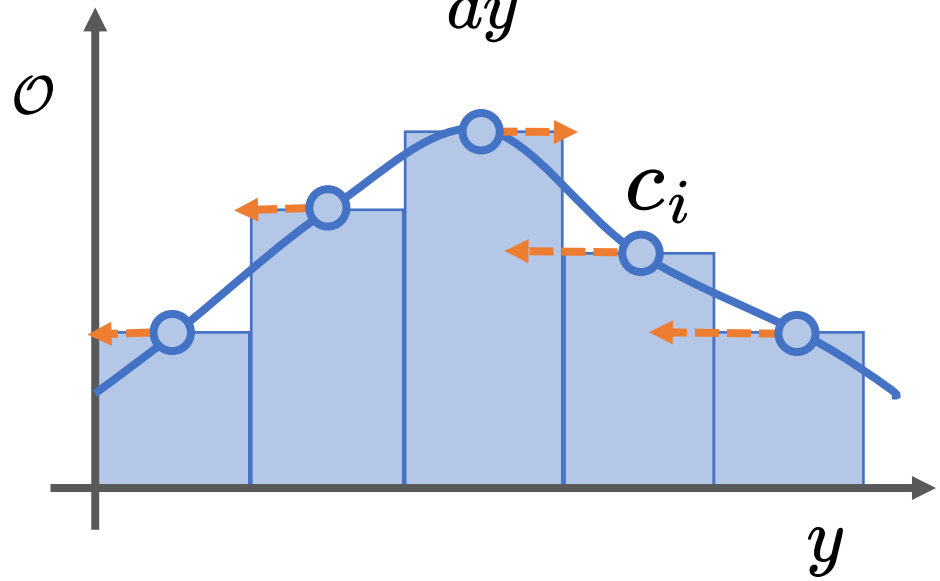


Two gradients: $\frac{d\mathcal{O}}{dc_i}$



Muller et. al 2022, Kanwar et. al 2022…

$\frac{d\mathcal{O}}{dy}$



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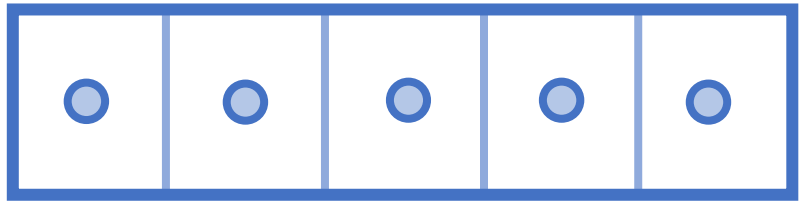
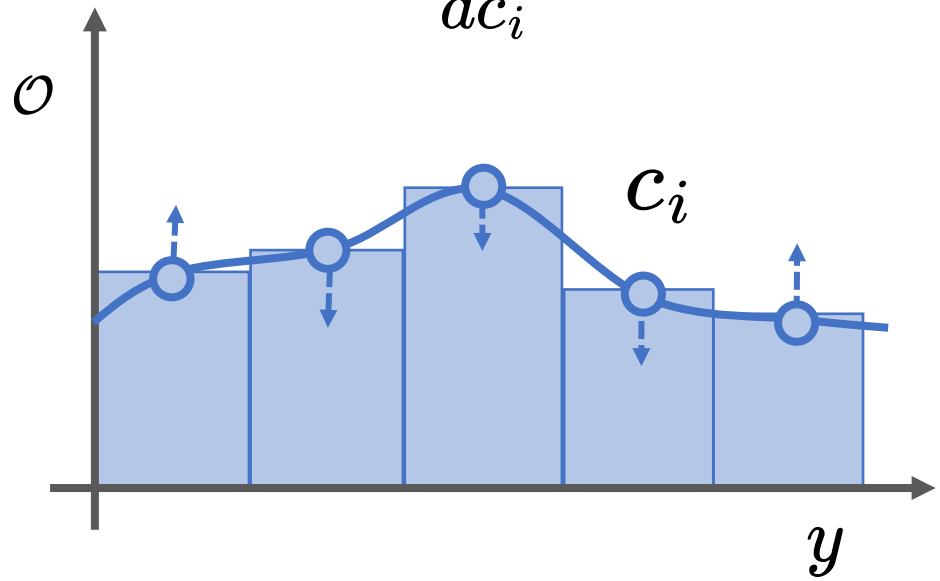


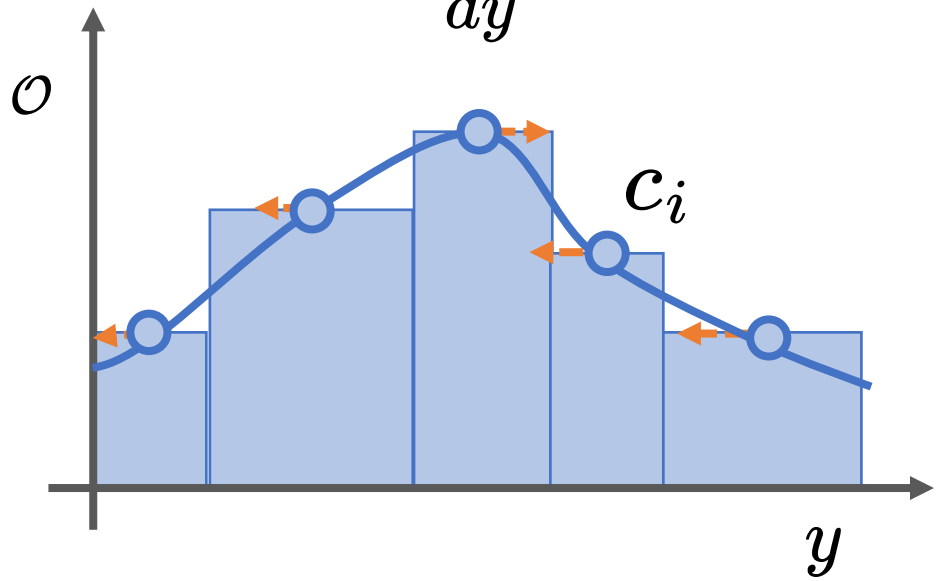
c_i

Two gradients: $\frac{d\mathcal{O}}{dc_i}$



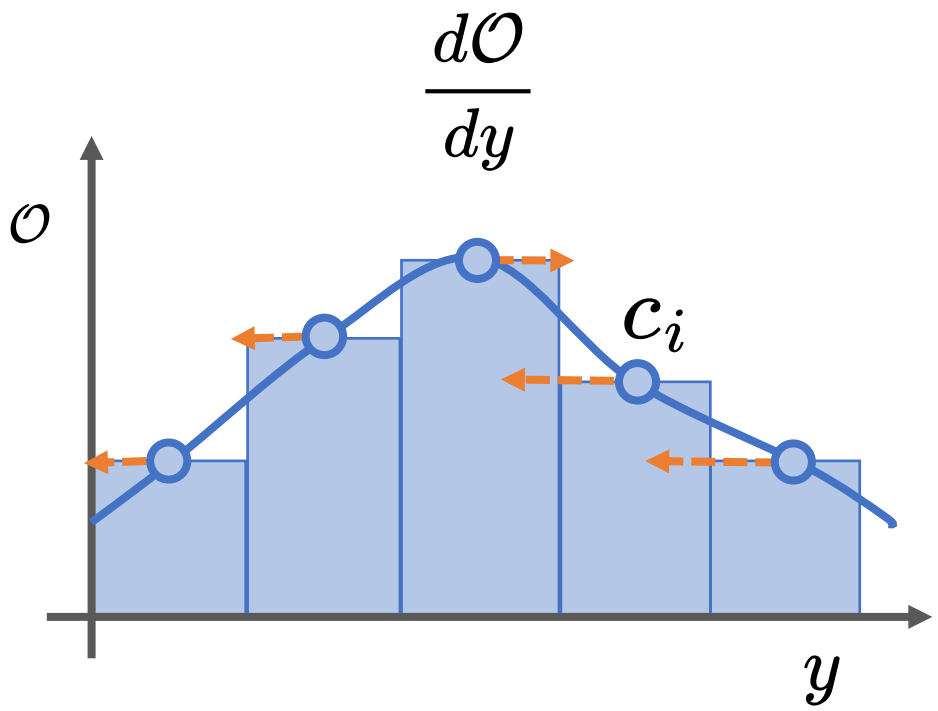
Muller et. al 2022, Kanwar et. al 2022…

$\frac{d\mathcal{O}}{dy}$

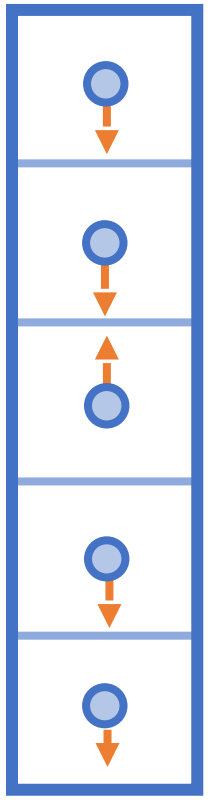


and additionally.

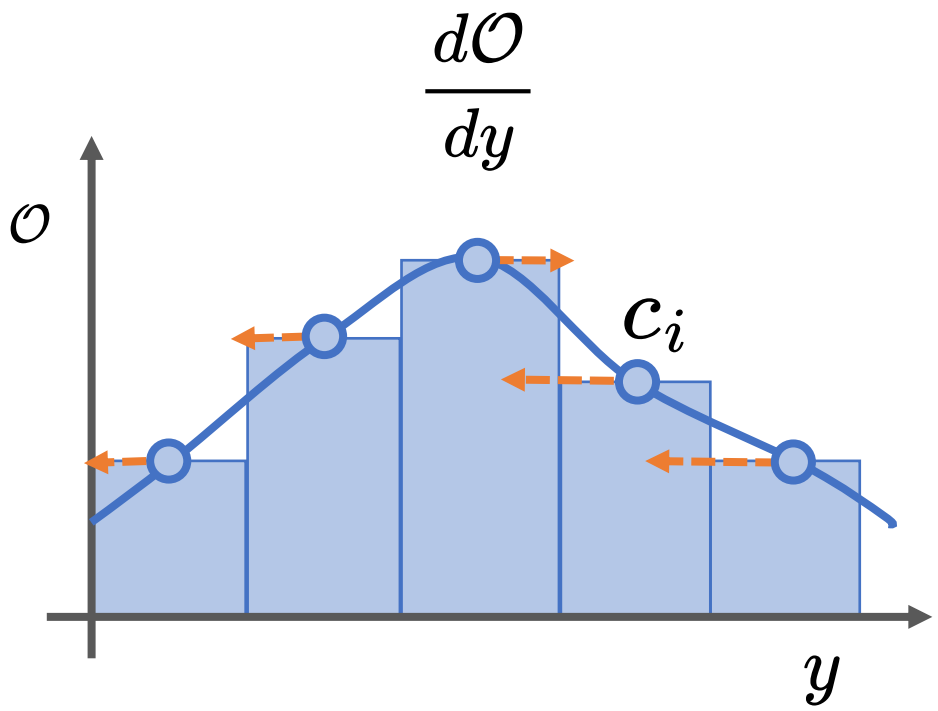
Intuition : Adaptive resolution

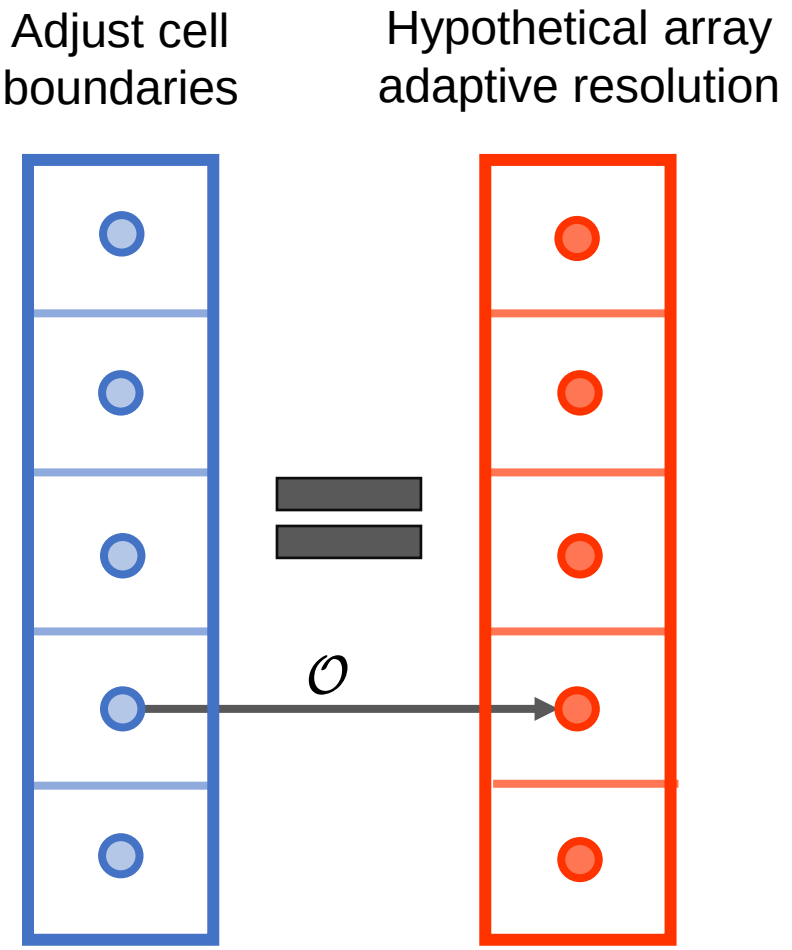


Adjust cell boundaries

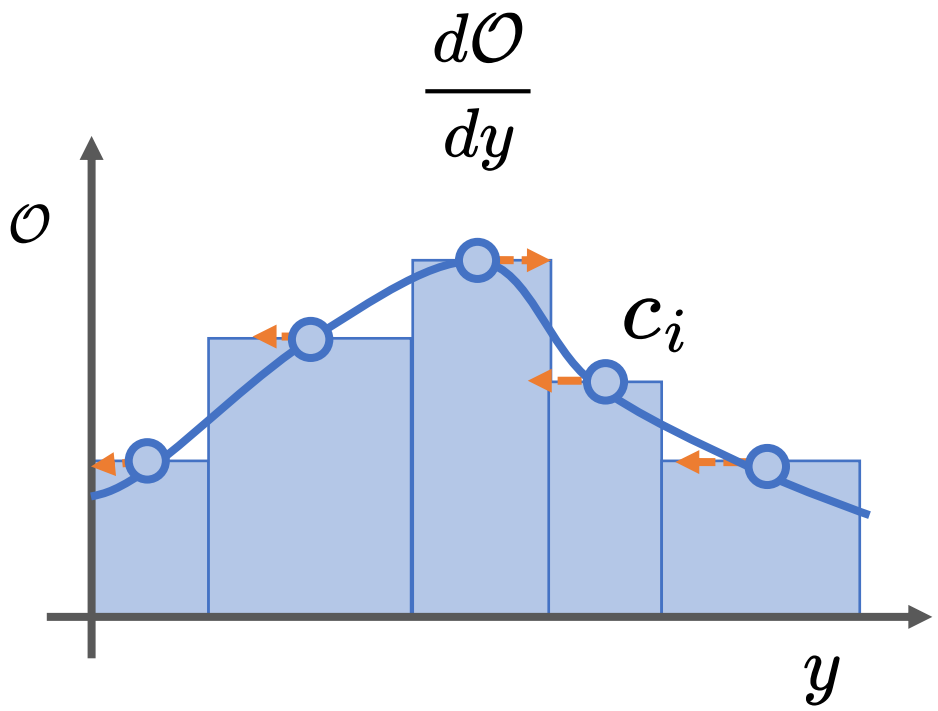


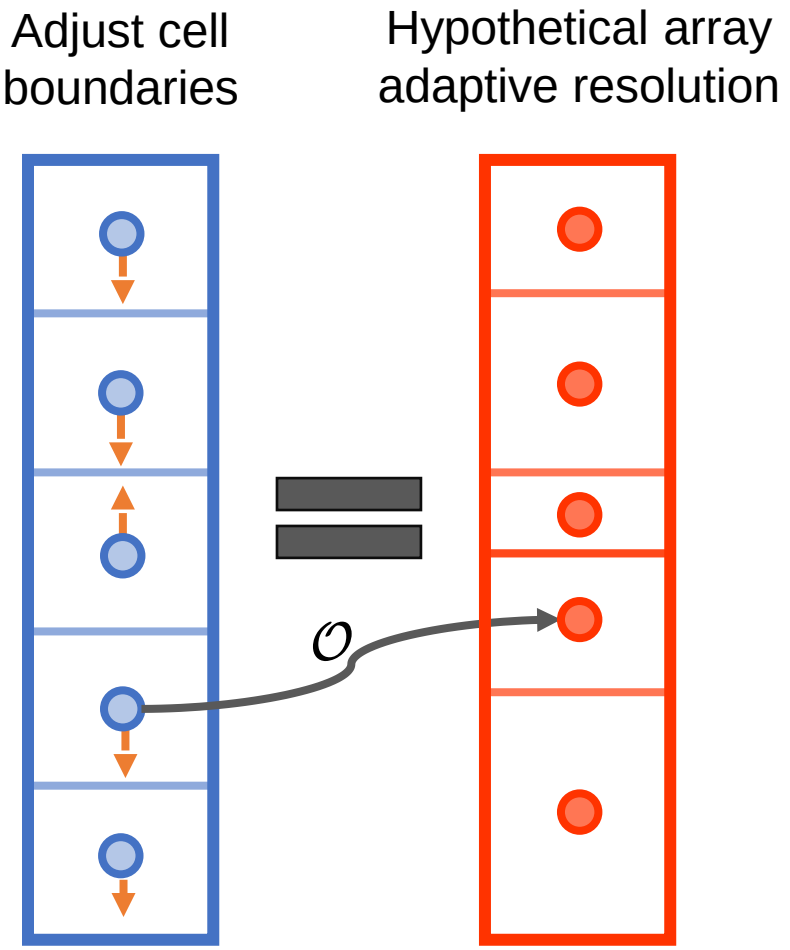
Intuition : Adaptive resolution





Intuition : Adaptive resolution





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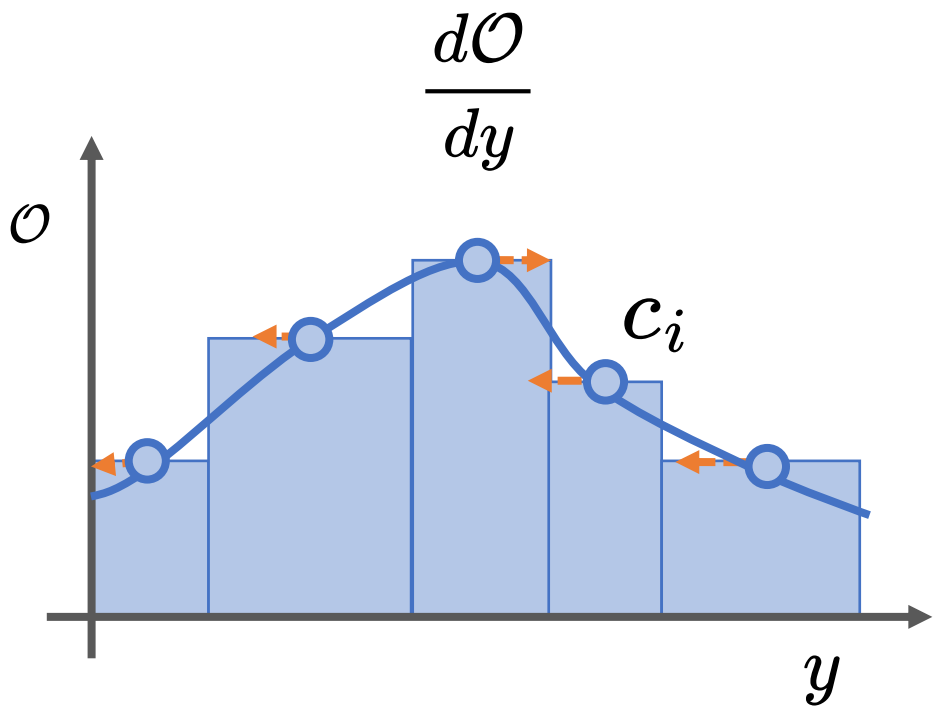

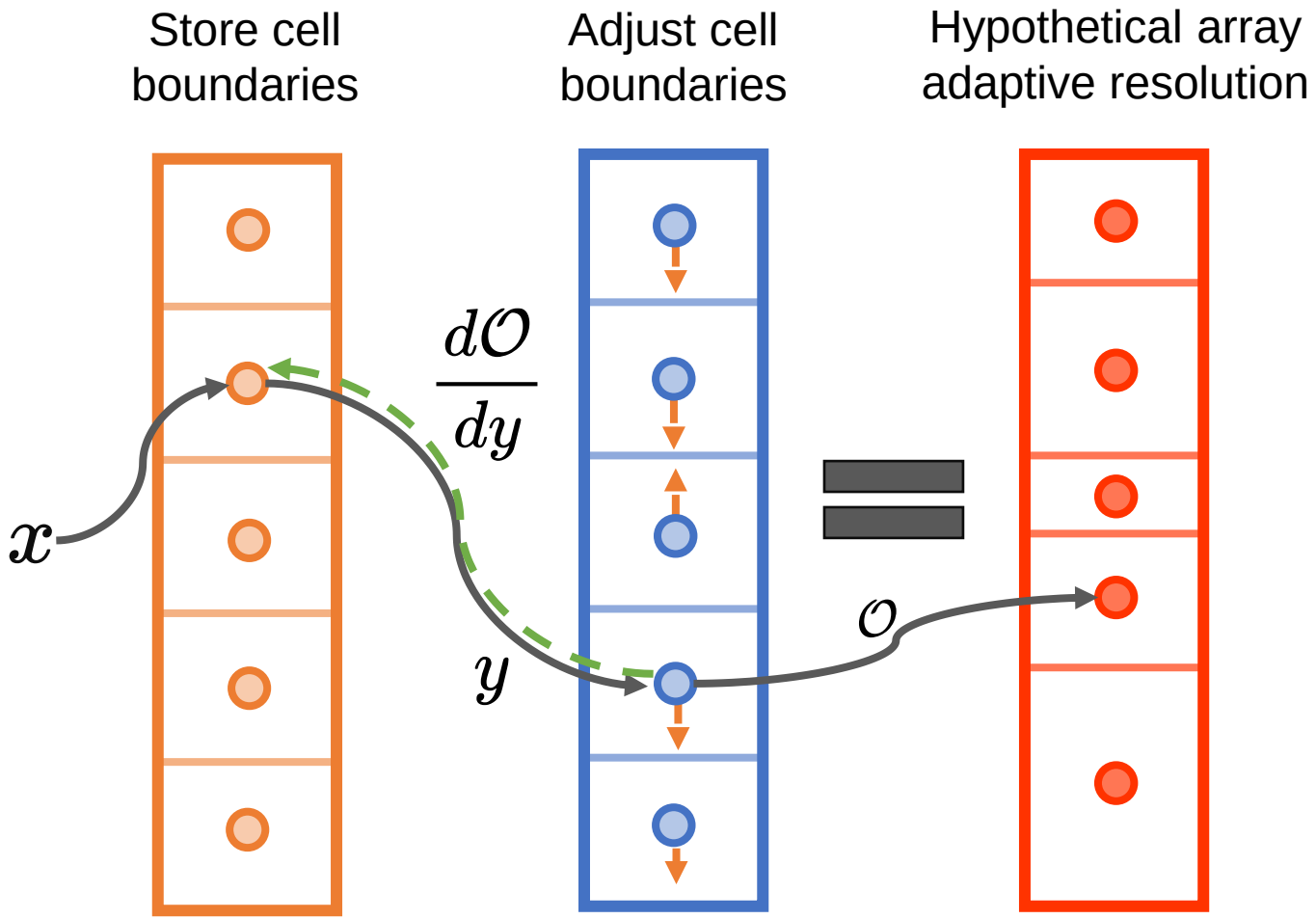

Applications : Network structure

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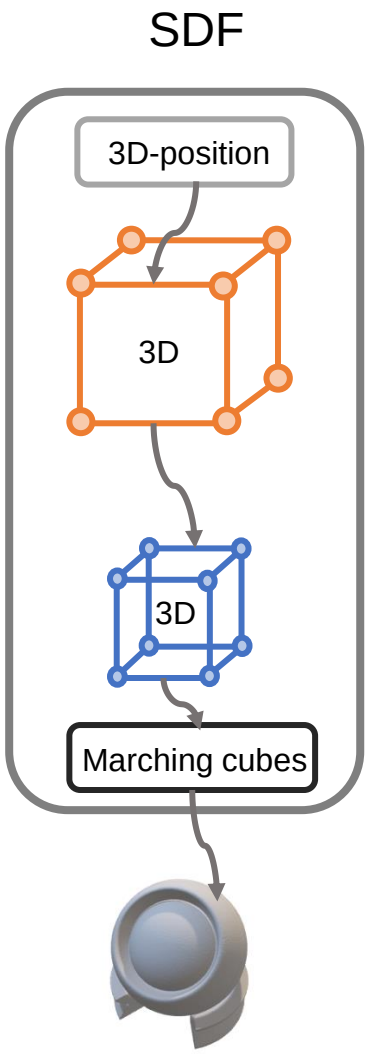

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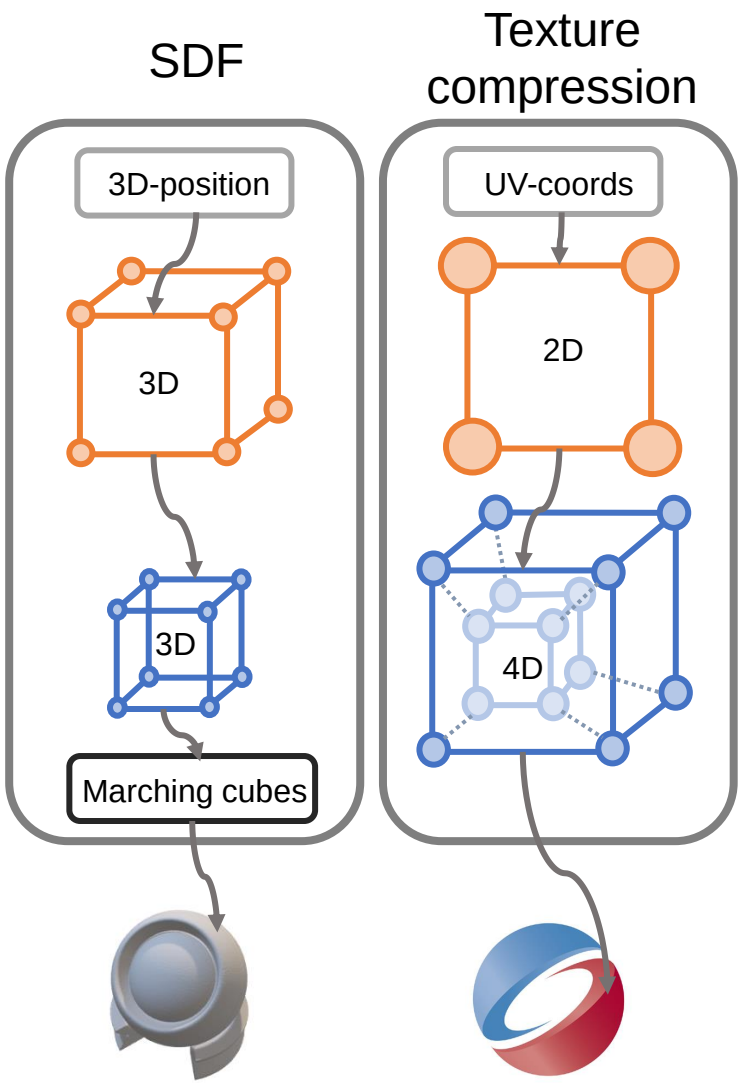

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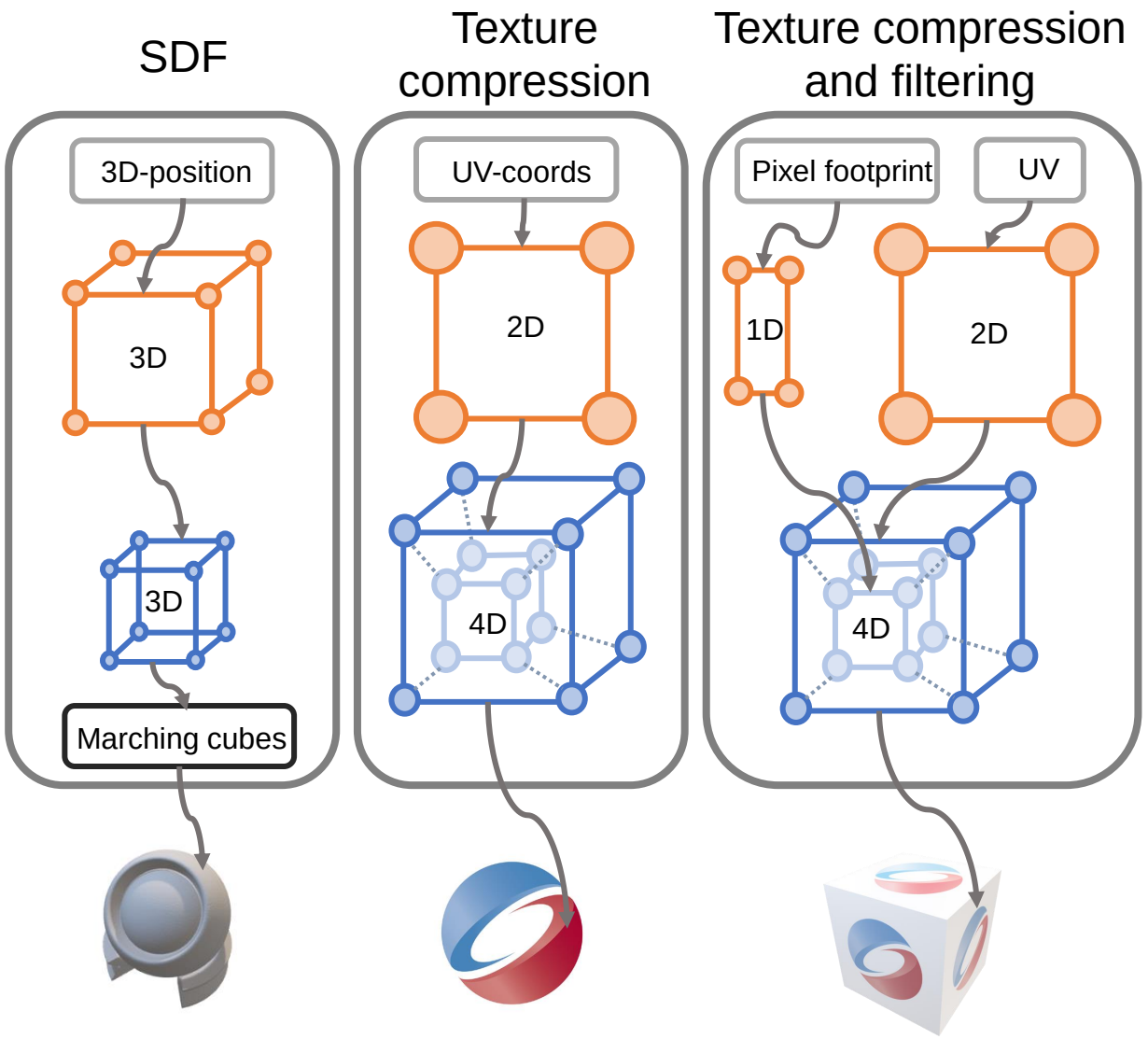
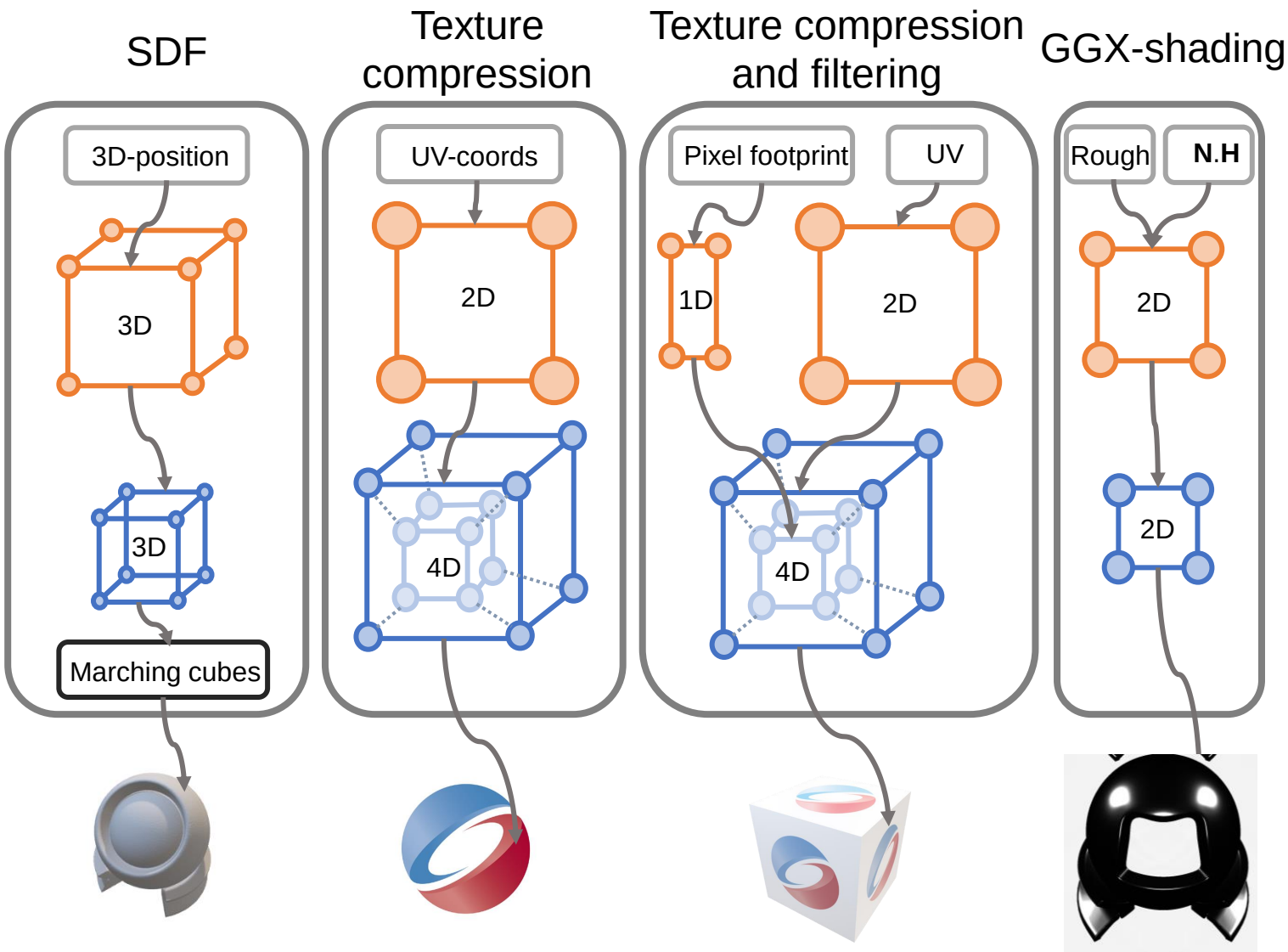


Applications : Network structure



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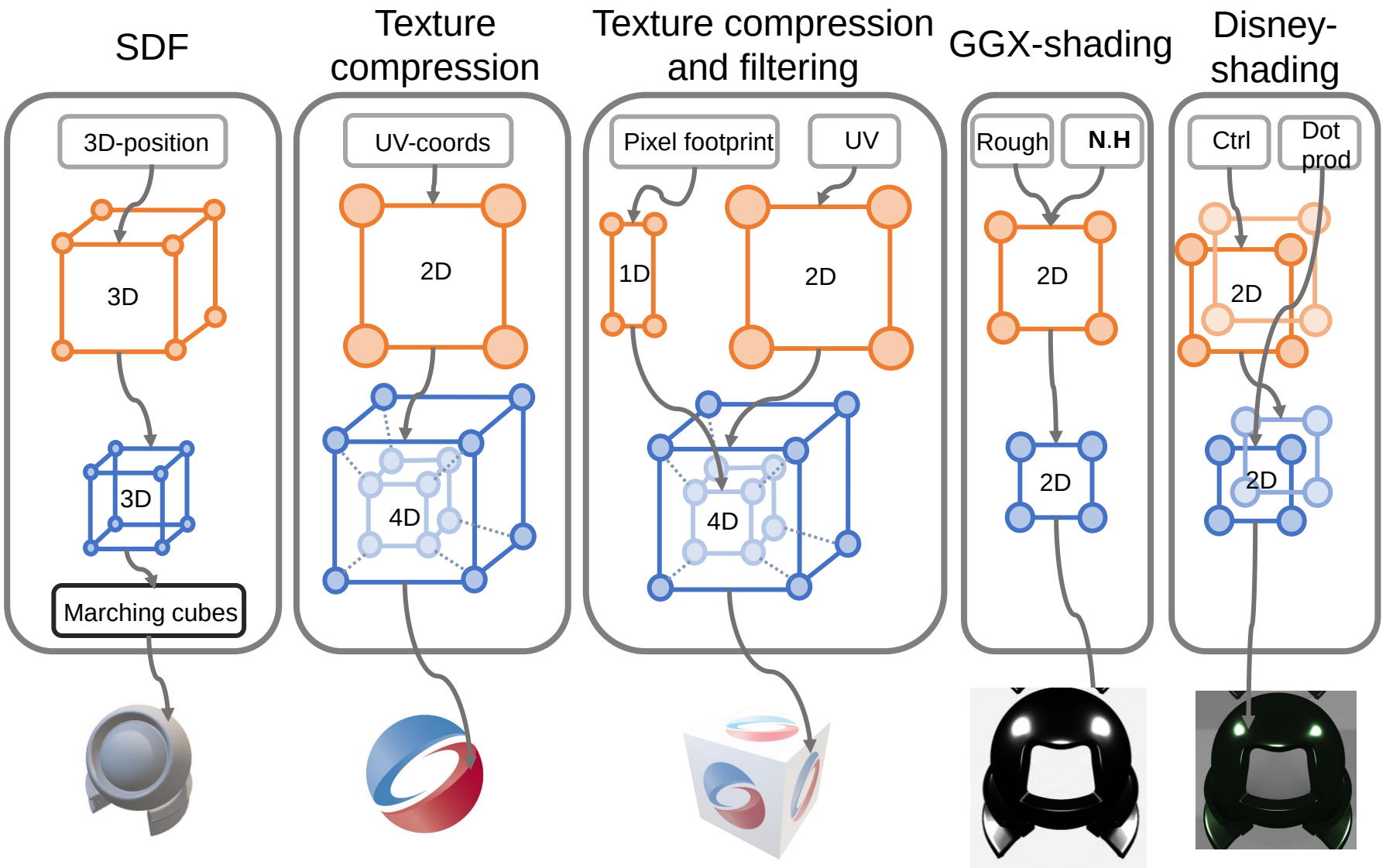
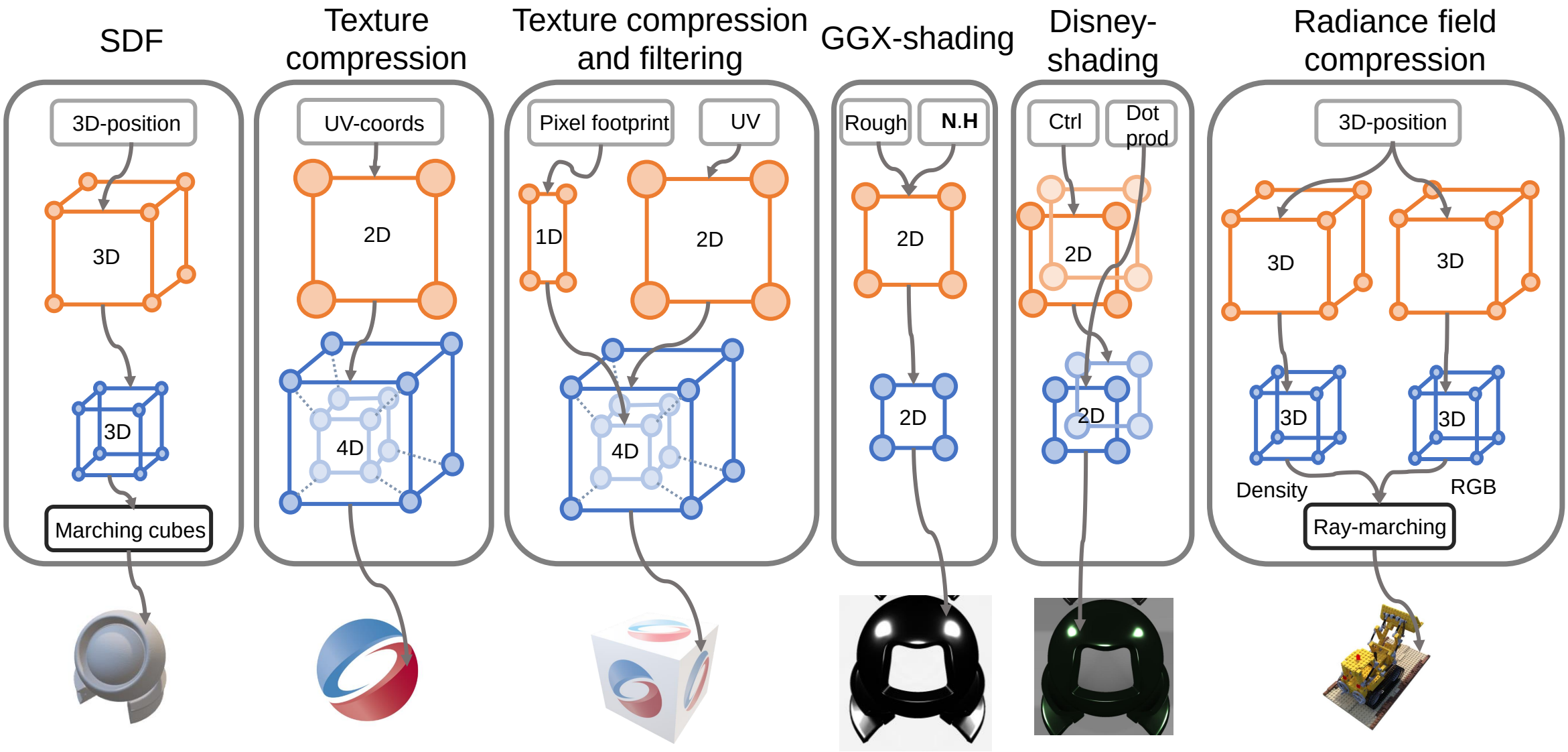


Applications : Network structure



Efficiency

Efficiency

Illustrated through Isotropic GGX approximation.

- A 2D function with highly non-linear scalar output.

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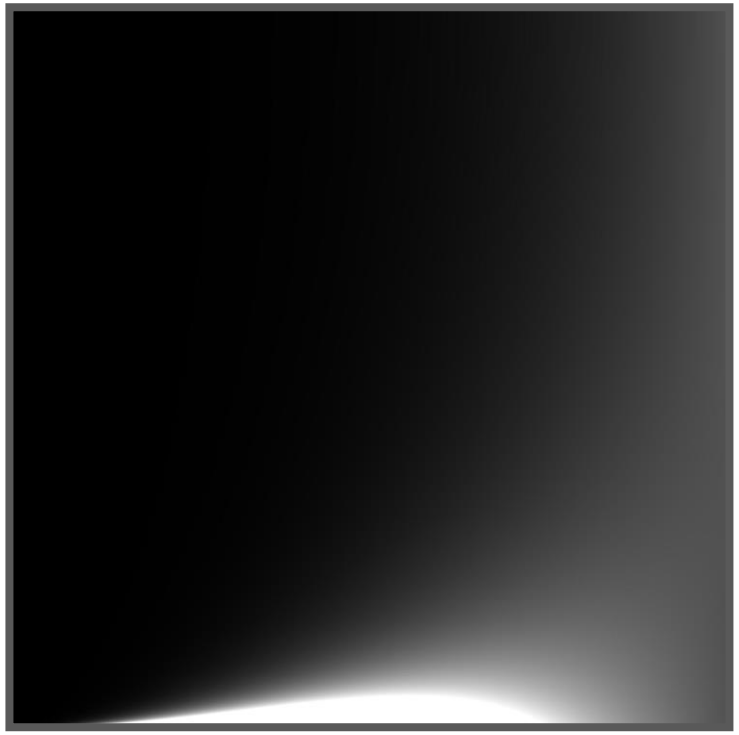
Iso-GGX function as 2D texture



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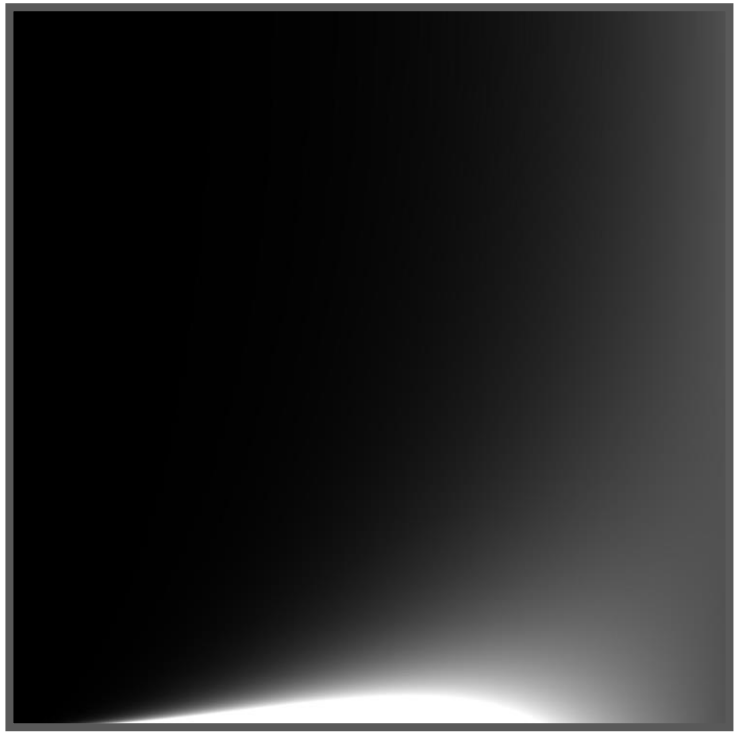
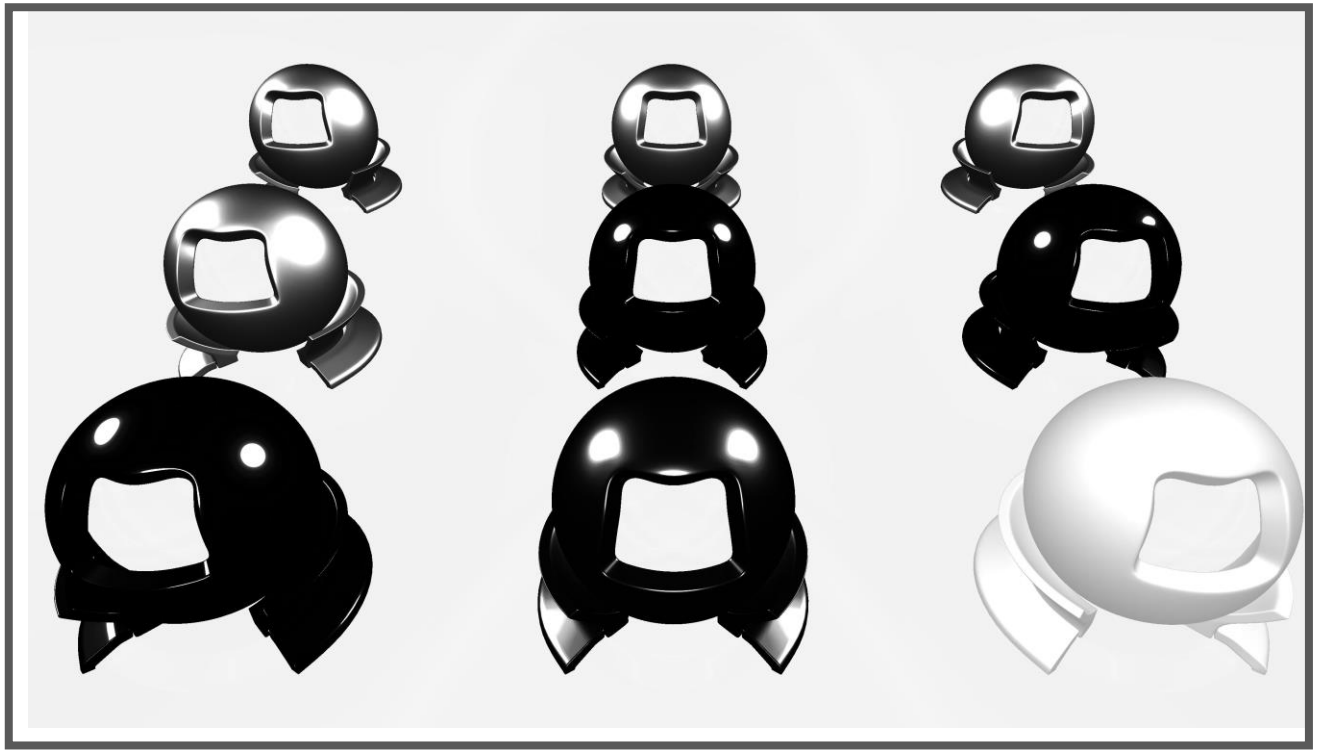


Shade

Scene shaded with Isotropic-GGX function



Efficiency

Approximate Isotropic-GGX with:

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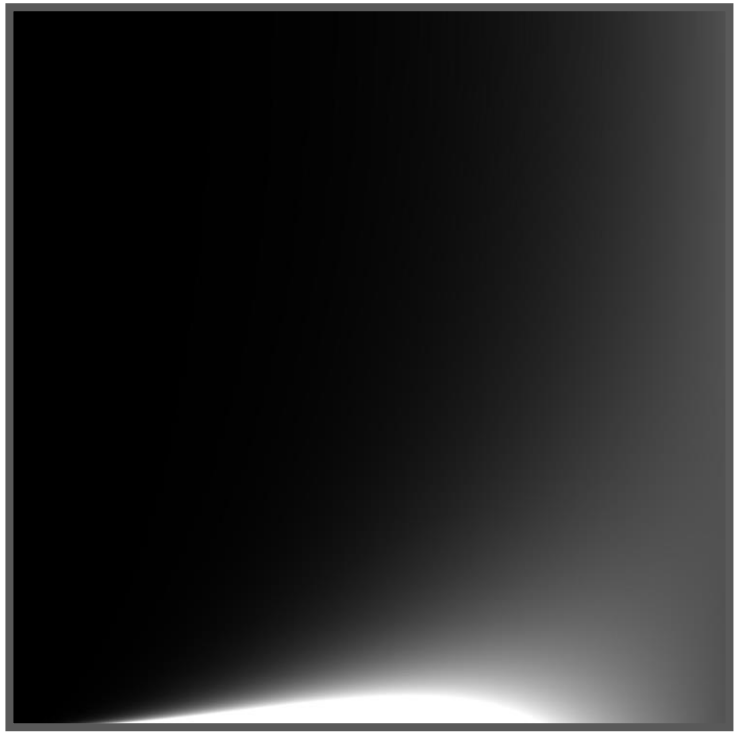
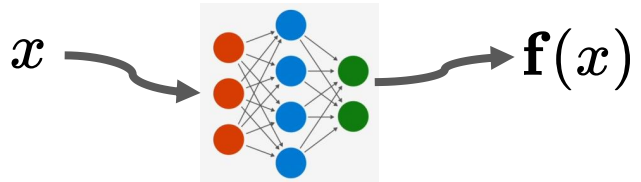


Approximate

Efficiency

Approximate Isotropic-GGX with:

MLP only:



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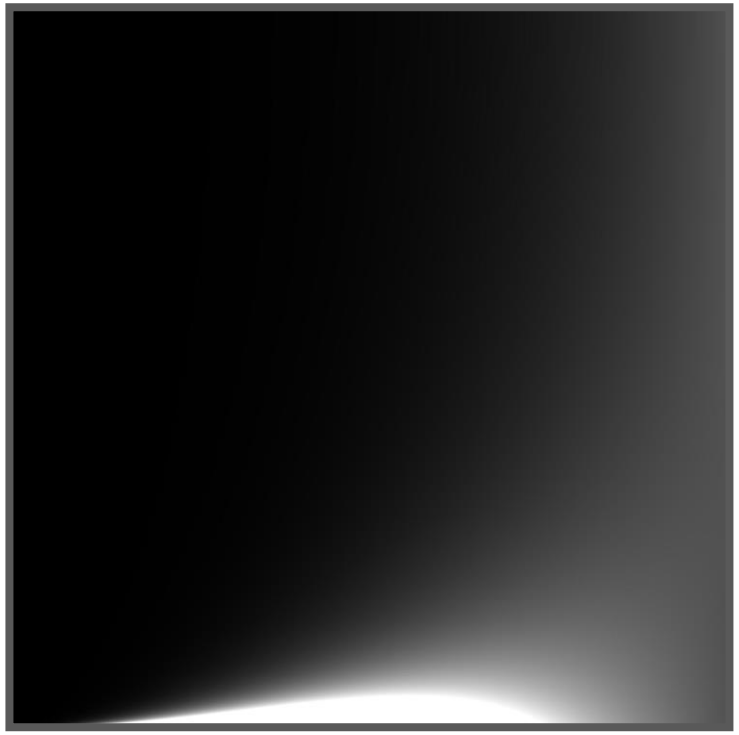

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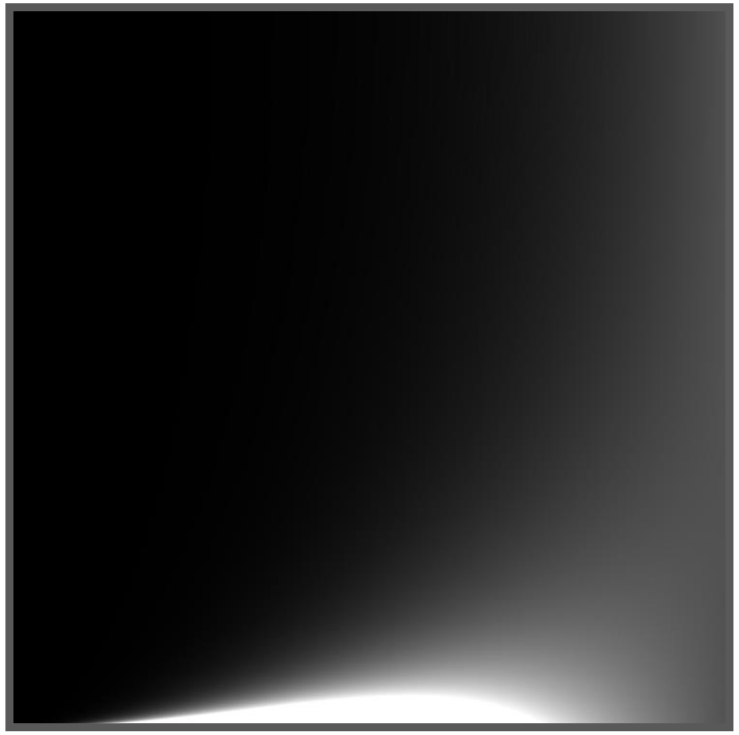

Approximate

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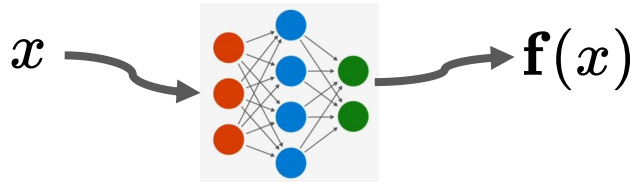
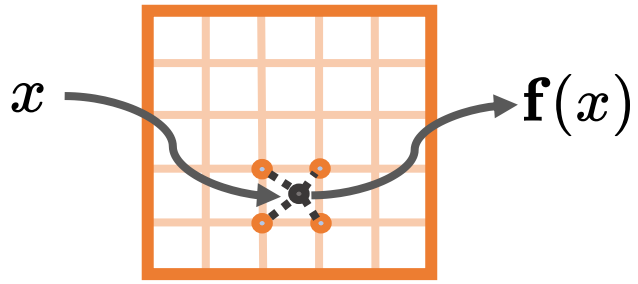


1-level lookup:



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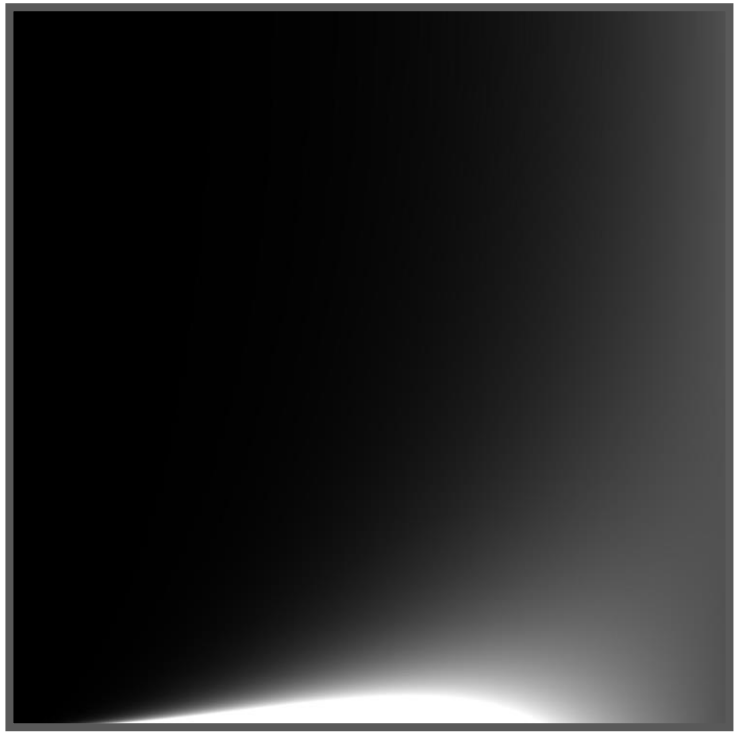

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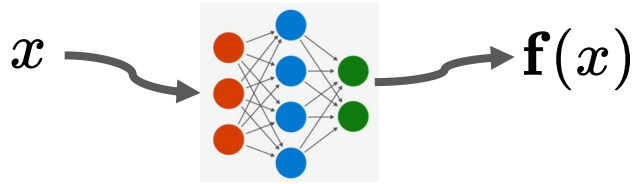

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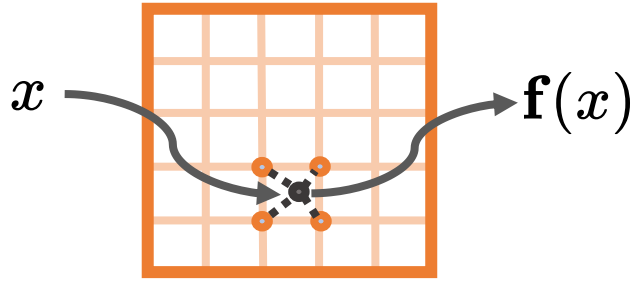
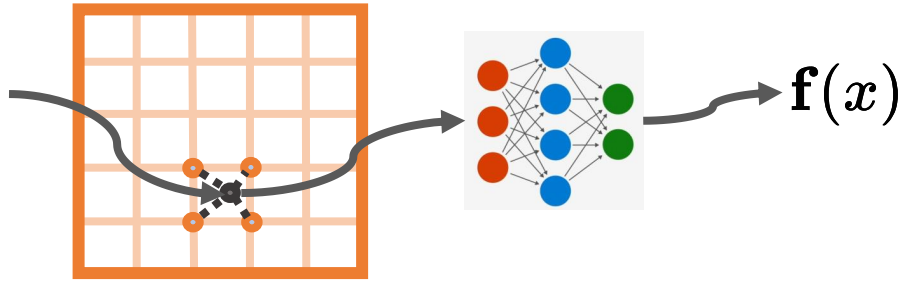


MLP + lookup: x

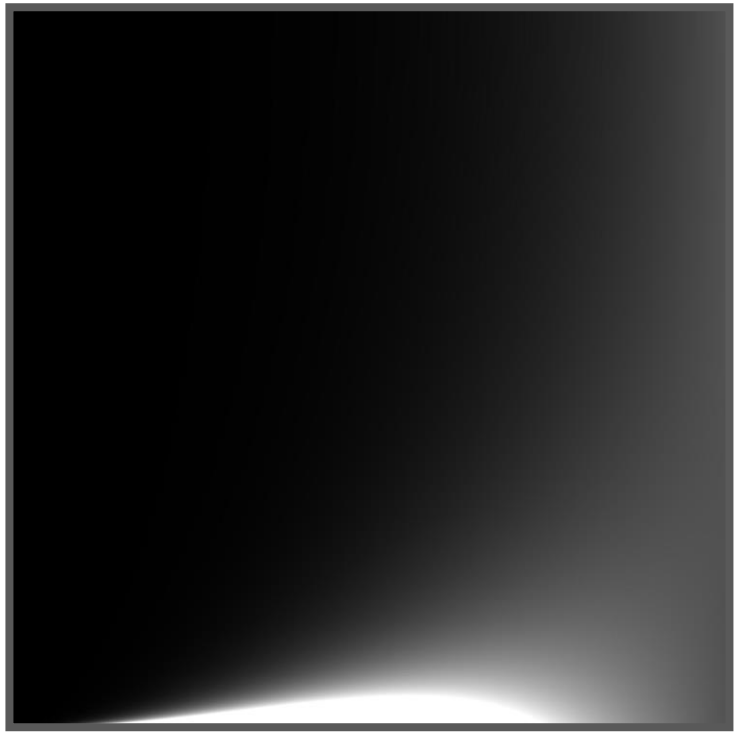


Efficiency

Illustrated through Isotropic GGX approximation.

- A 2D function with highly non-linear scalar output.

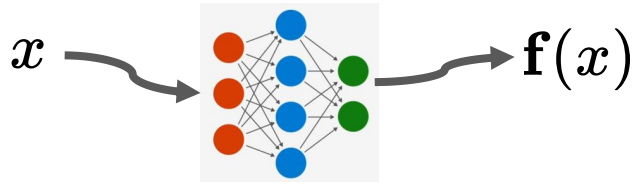
Iso-GGX function as 2D texture



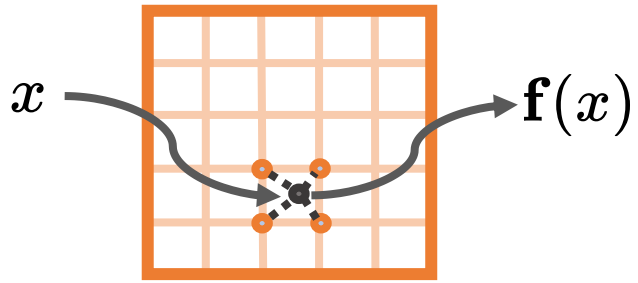
Approximate

Approximate Isotropic-GGX with:

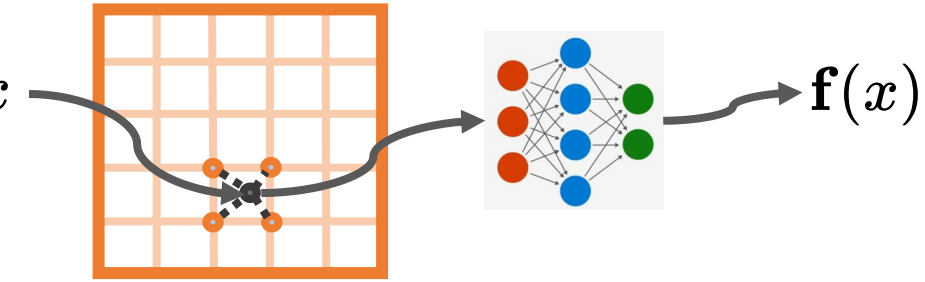
MLP only:



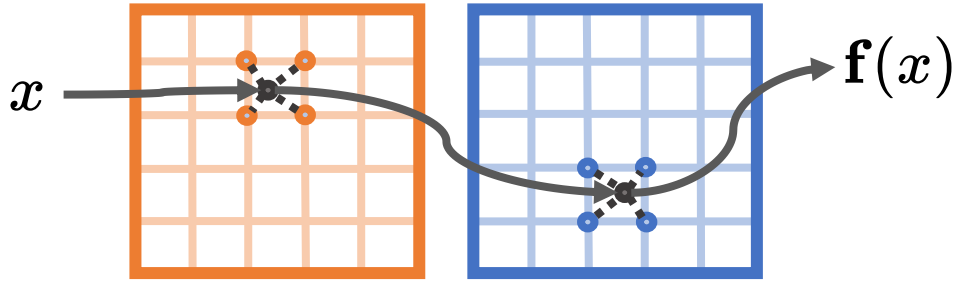
1-level lookup:



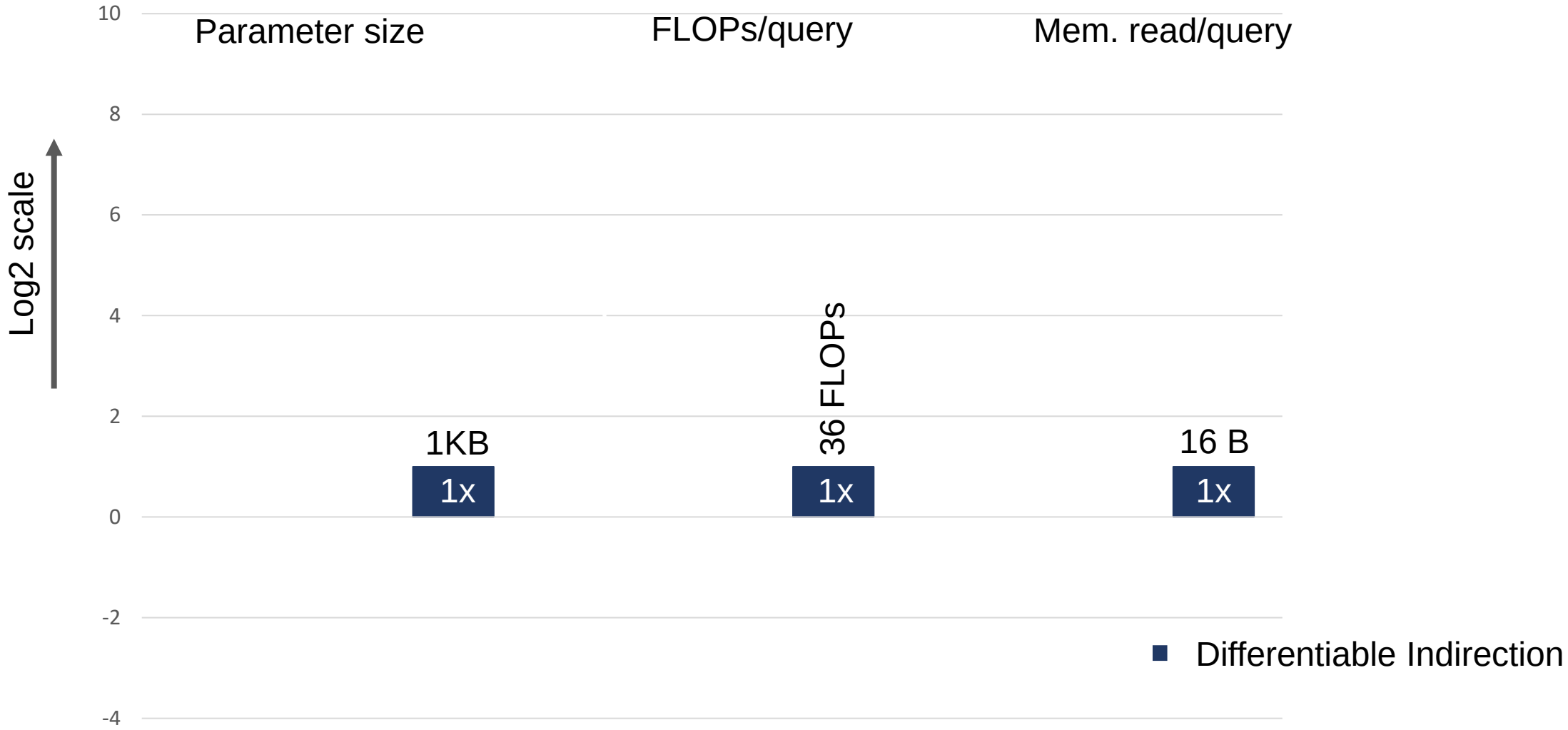
MLP + lookup:



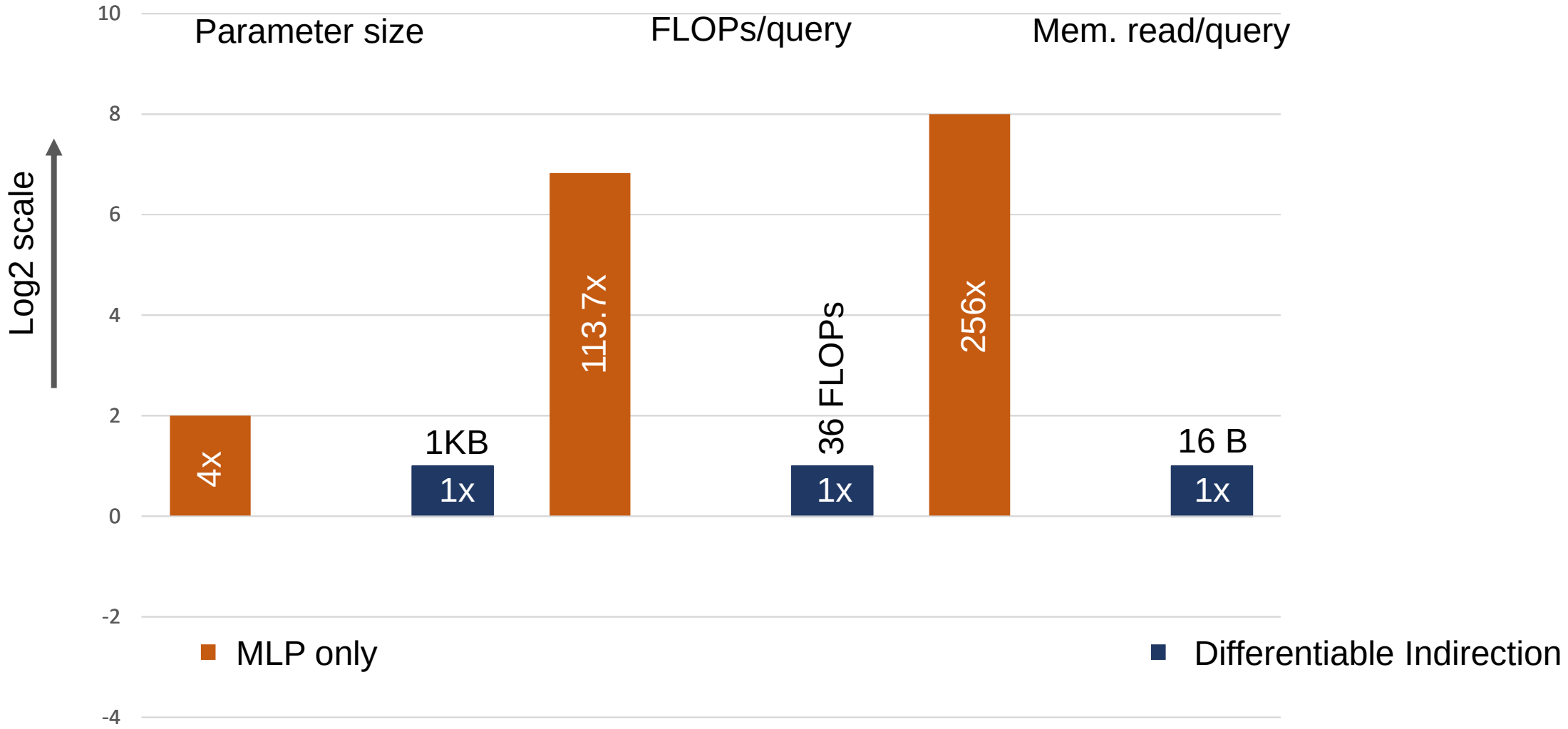
Ours:



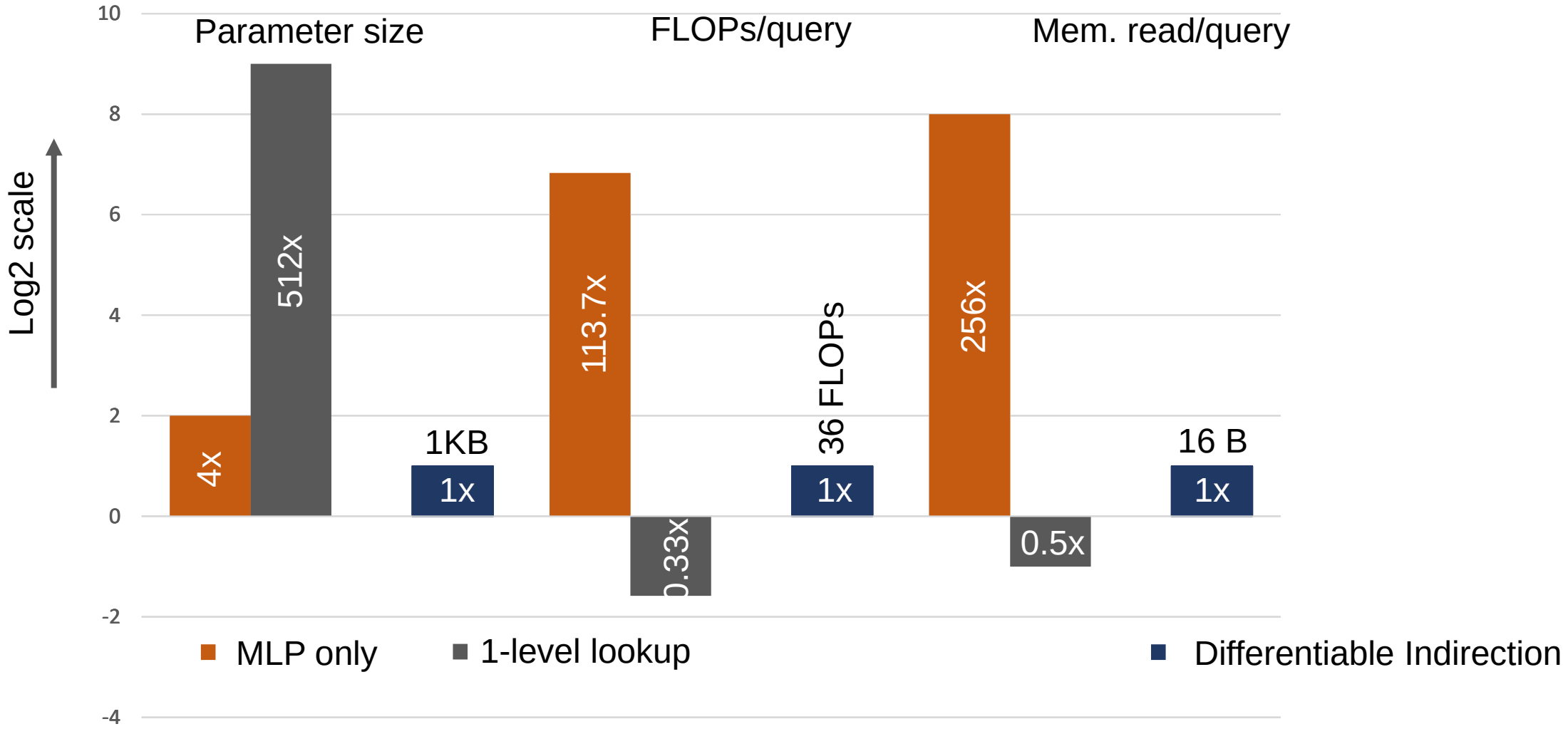
Efficiency


Parameter size
FLOPs/query
Mem. read/query
10
8
6
4
2
0
-2
-4
Log2 scale
1KB
1x
36 FLOPs
1x
16 B
1x
Differentiable Indirection

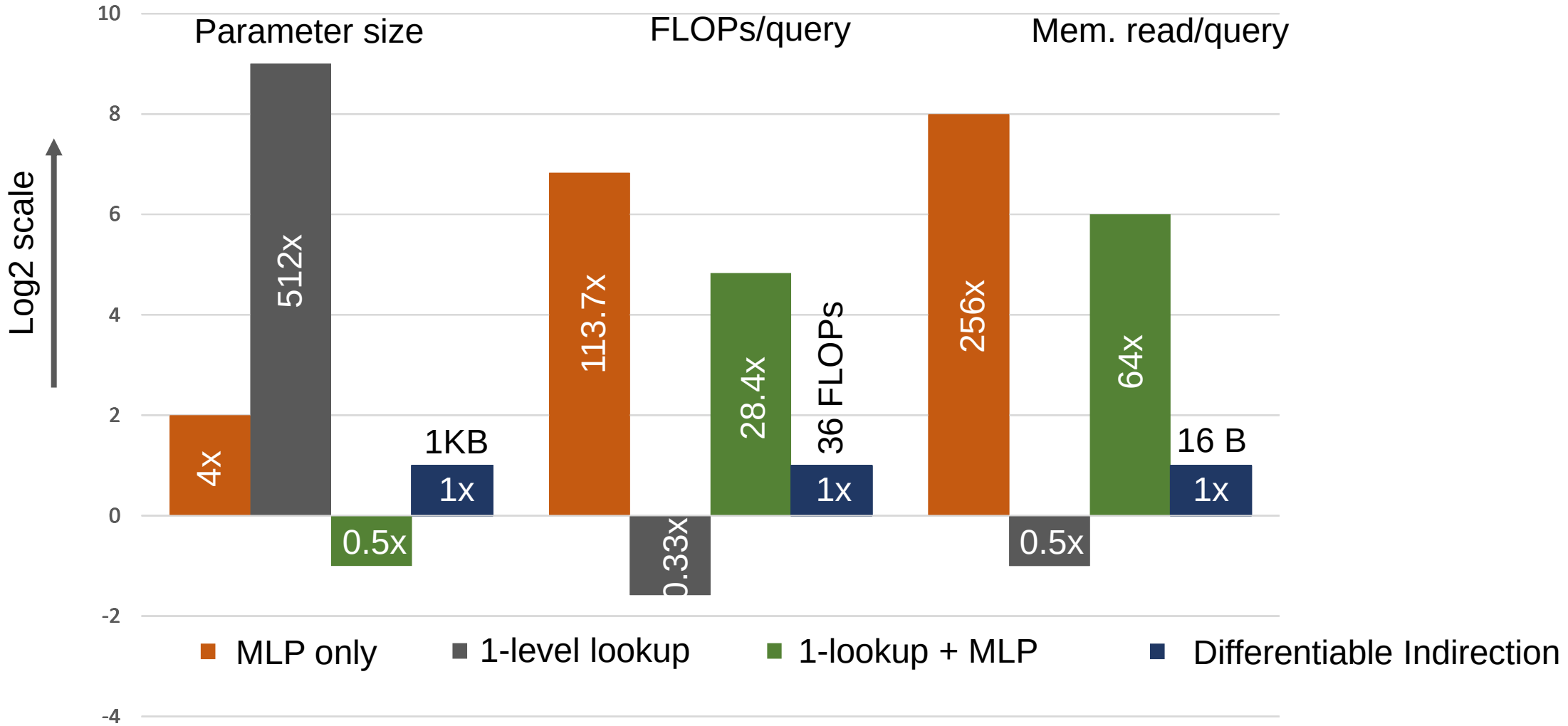
Efficiency


Parameter size
FLOPs/query
Mem. read/query
Log2 scale
10
8
6
4
2
0
-2
-4
4x
1KB
1x
113.7x
36 FLOPs
1x
256x
16 B
1x
MLP only
Differentiable Indirection

Efficiency


Parameter size
FLOPs/query
Mem. read/query
Log2 scale
10
8
6
4
2
0
-2
-4
4x
512x
1KB
1x
113.7x
0.33x
36 FLOPs
1x
256x
0.5x
16 B
1x
MLP only
1-level lookup
Differentiable Indirection

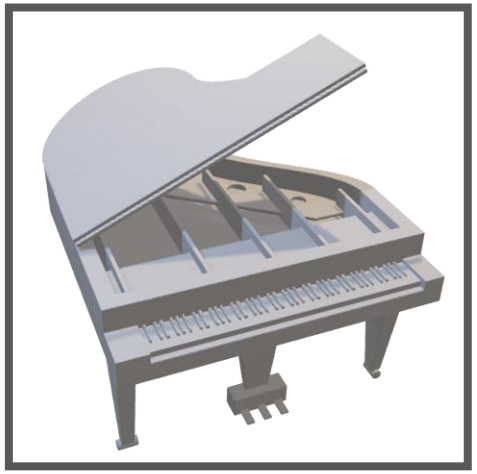
Efficiency


Parameter size
FLOPs/query
Mem. read/query
Log2 scale
10
8
6
4
2
0
-2
-4
4x
512x
0.5x
1KB
1x
113.7x
0.33x
28.4x
36 FLOPs
1x
256x
0.5x
64x
16 B
1x
MLP only
1-level lookup
1-lookup + MLP
Differentiable Indirection

Efficiency : more examples

Efficiency : more examples

SDF

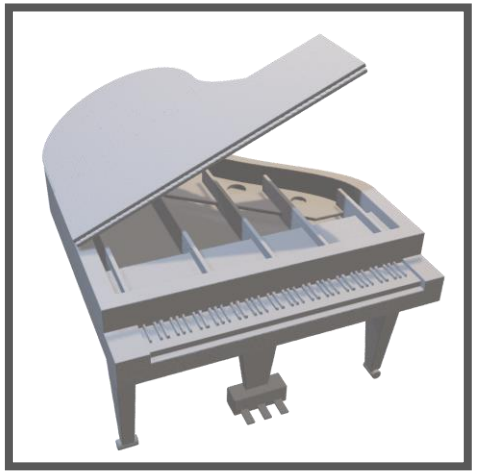


12 GB (Surface samples)

24 MB (IoU: 0.982)

Efficiency : more examples

SDF



12 GB (Surface samples)

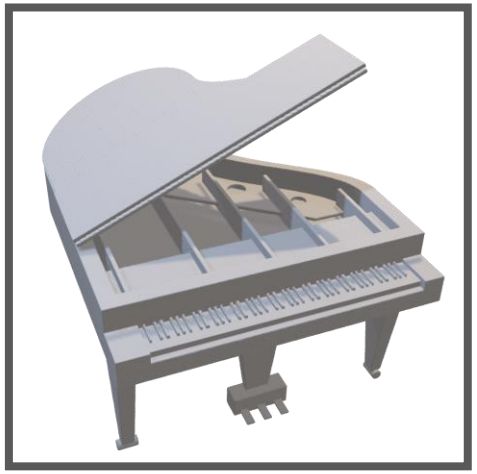
24 MB (IoU: 0.982)

Texture Compression

6x-48x

Efficiency : more examples

SDF



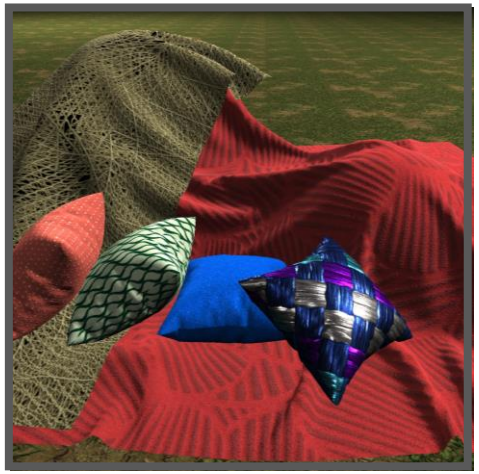
12 GB (Surface samples)

24 MB (IoU: 0.982)

Texture Compression

6x-48x

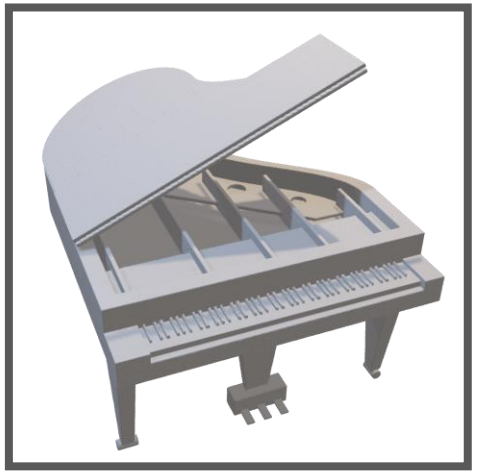
Compression and Filtering



Built-in sampler

Efficiency : more examples

SDF



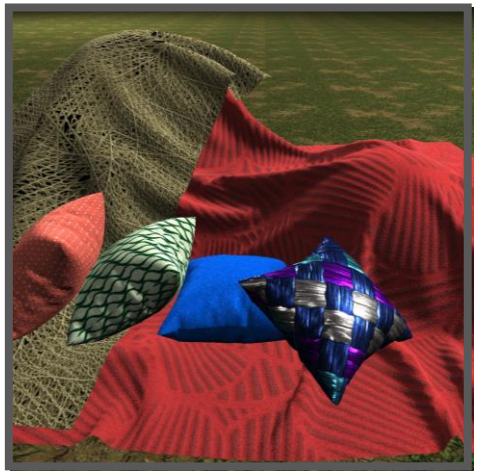
12 GB (Surface samples)

24 MB (IoU: 0.982)

Texture Compression

6x-48x

Compression and Filtering



Built-in sampler

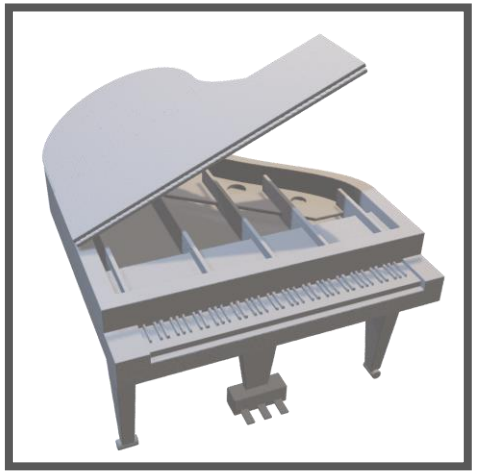
Disney Shading

240+ FLOPs

5 lookups + 41 FLOPs

Efficiency : more examples

SDF



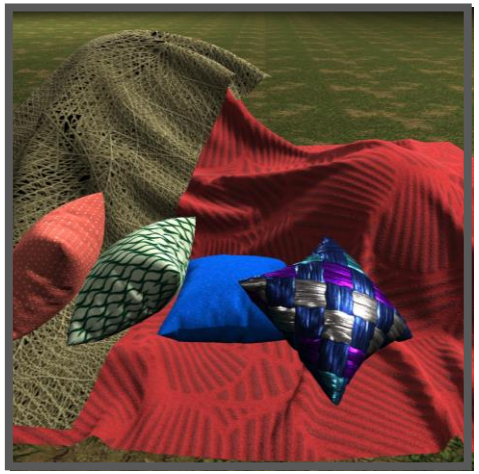
12 GB (Surface samples)

24 MB (IoU: 0.982)

Texture Compression

6x-48x

Compression and Filtering



Built-in sampler

Disney Shading

240+ FLOPs

5 lookups + 41 FLOPs

Radiance Field Compression

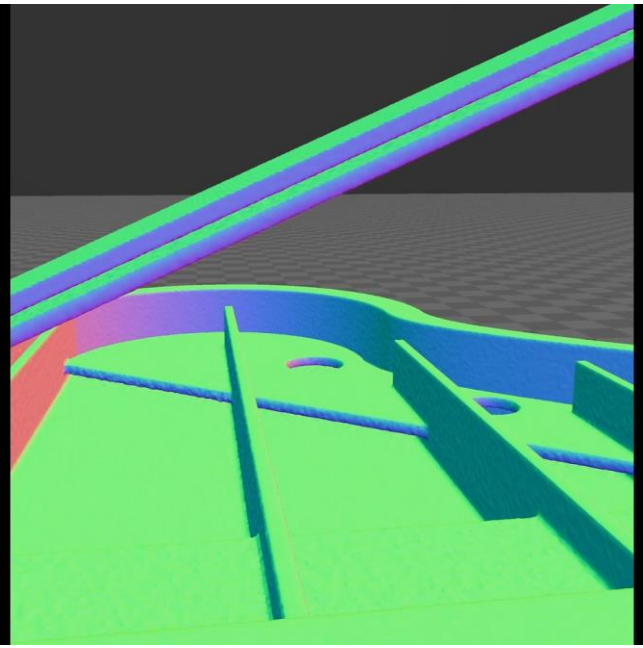
860 MB (PSNR: 33)

89 MB (PSNR: 31)

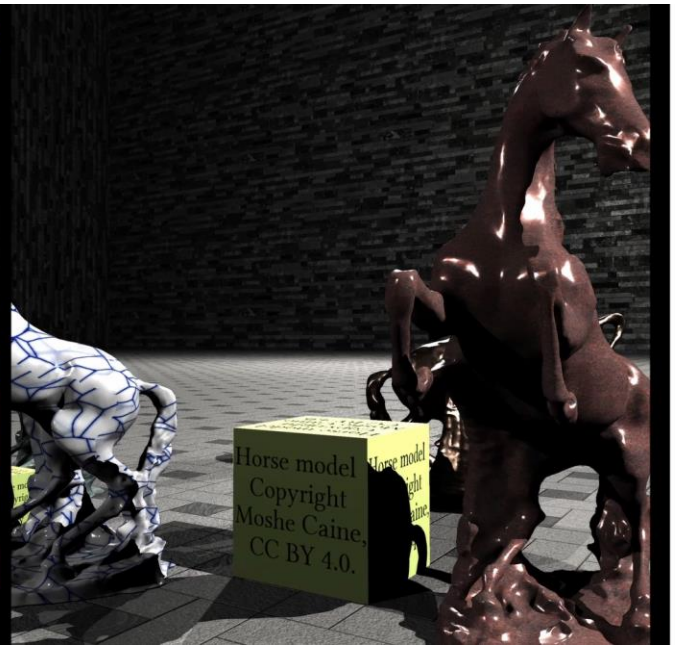
Results

Texture Compression

SDF



Shading and Filtering



Radiance Field Compression

Efficient Graphics Representation with Differentiable Indirection

Conclusion

- Efficient – minimal parameter size, FLOPs, and bandwidth.
- Flexible – several applications in graphics pipeline and potentially beyond.
- Adaptive – supports adaptive spatial resolution.

SIGGRAPH ASIA 2023 SYDNEY

Efficient Graphics Representation with Differentiable Indirection

Scan for details:

Thank you.