Paparazzi: Surface Editing by way of Multi-View Image Processing

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University of Toronto

Image Filters

Image Filters

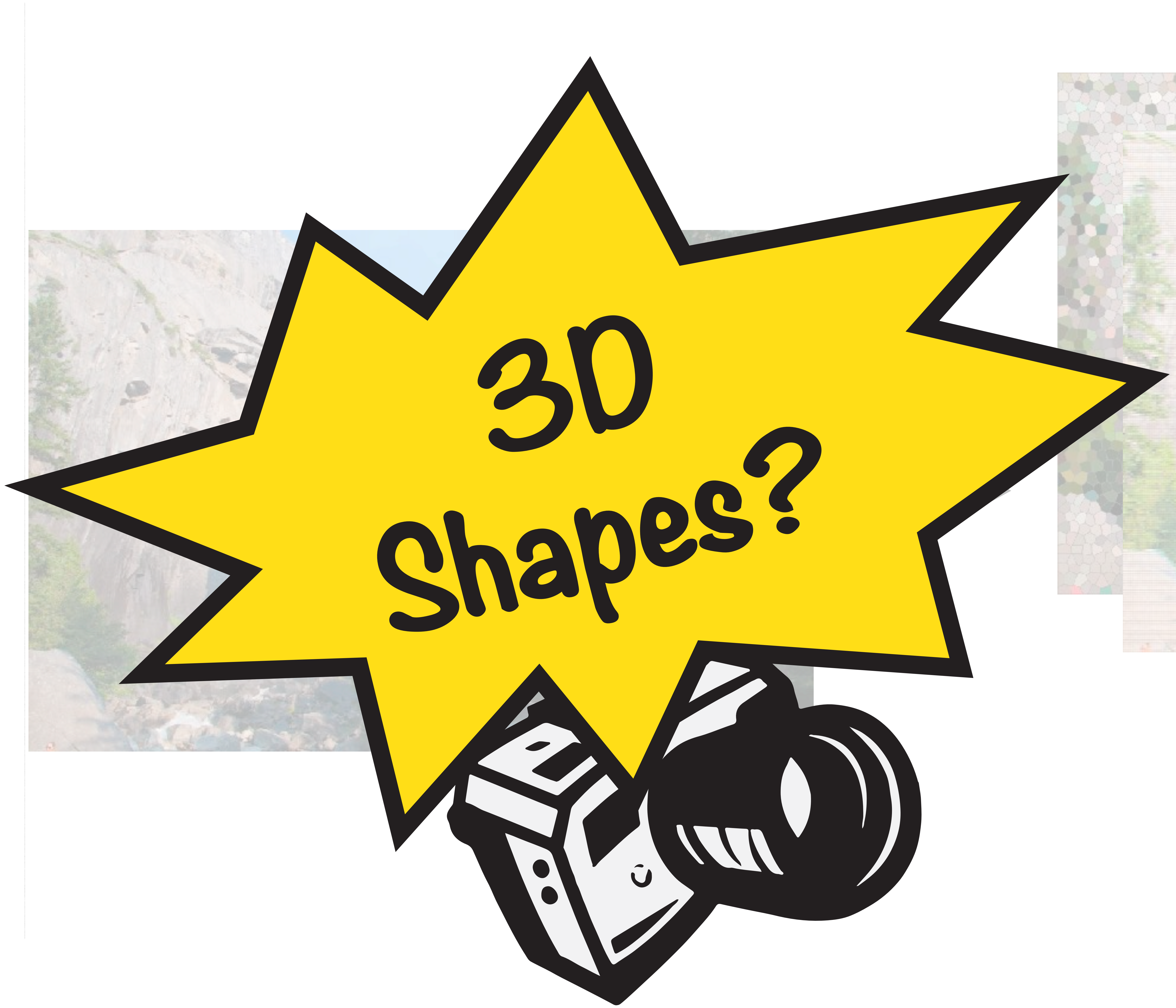
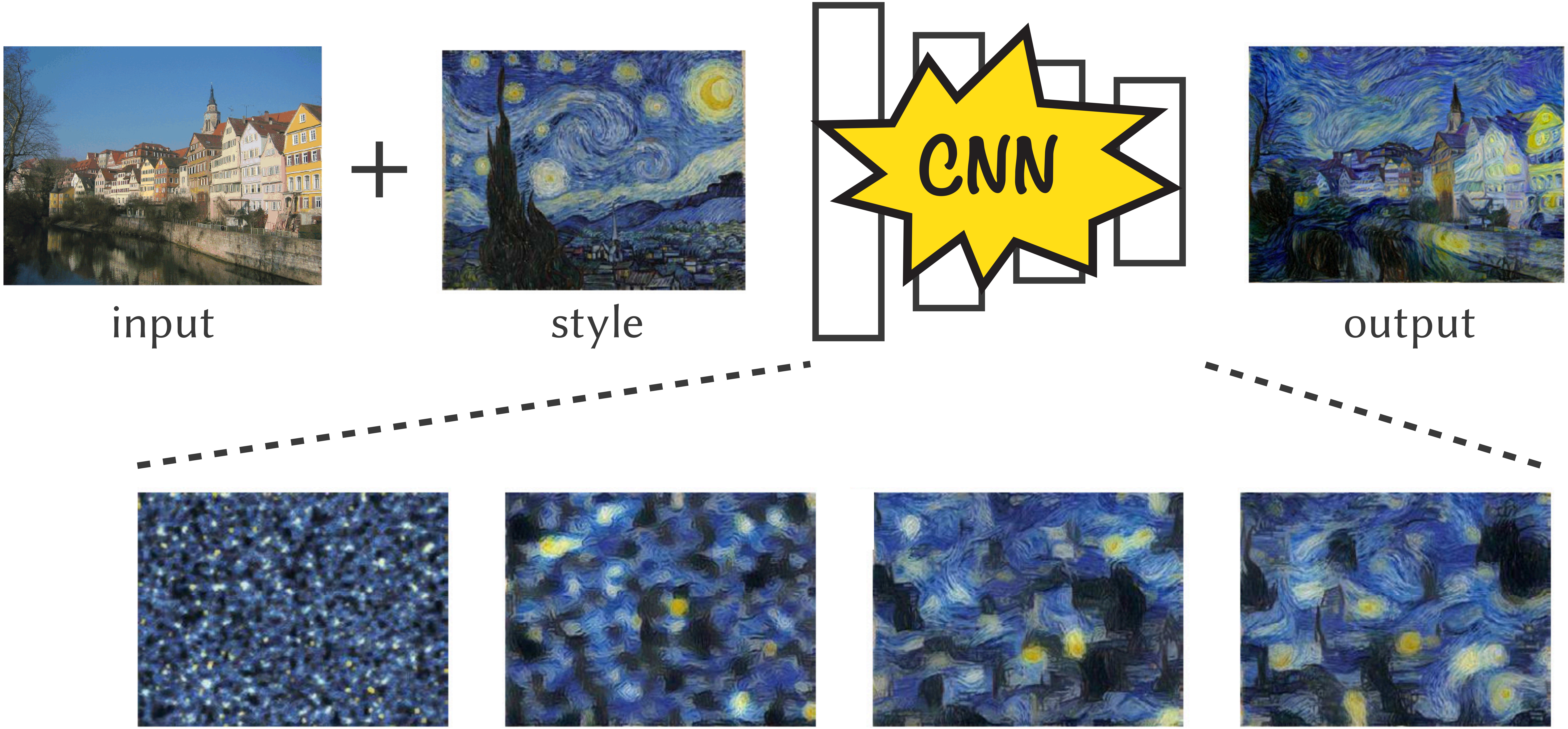
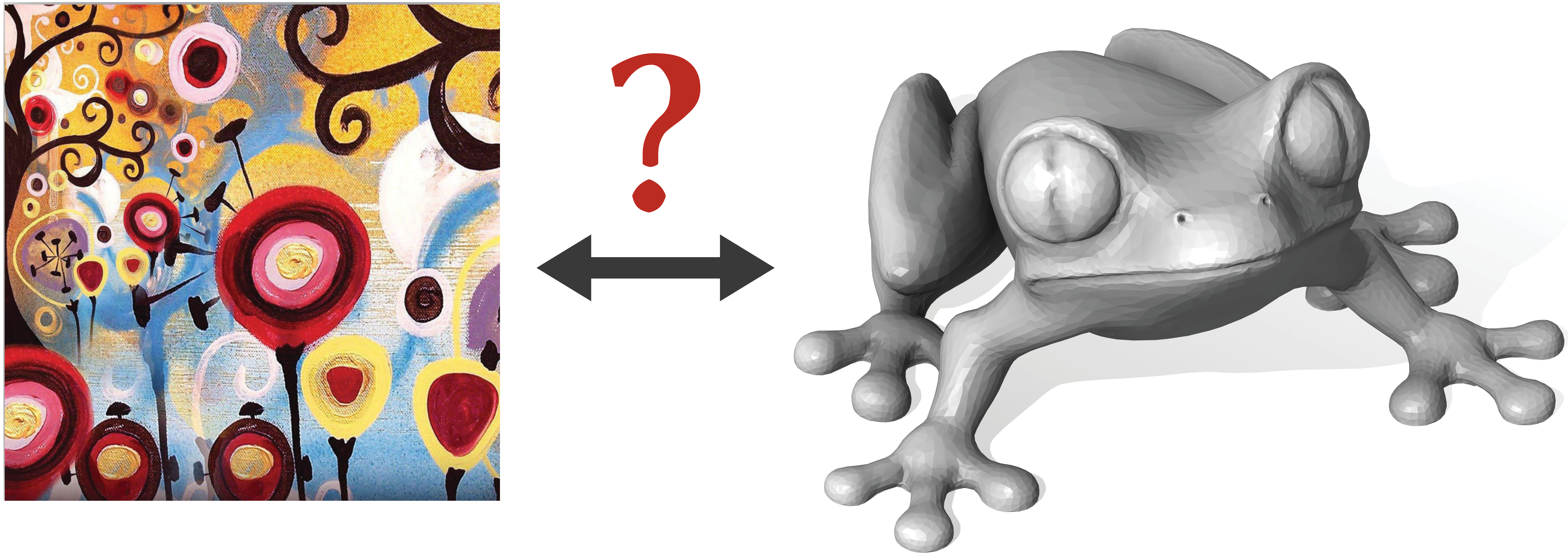


Image Style Transfer [Gatys et al. 2016]

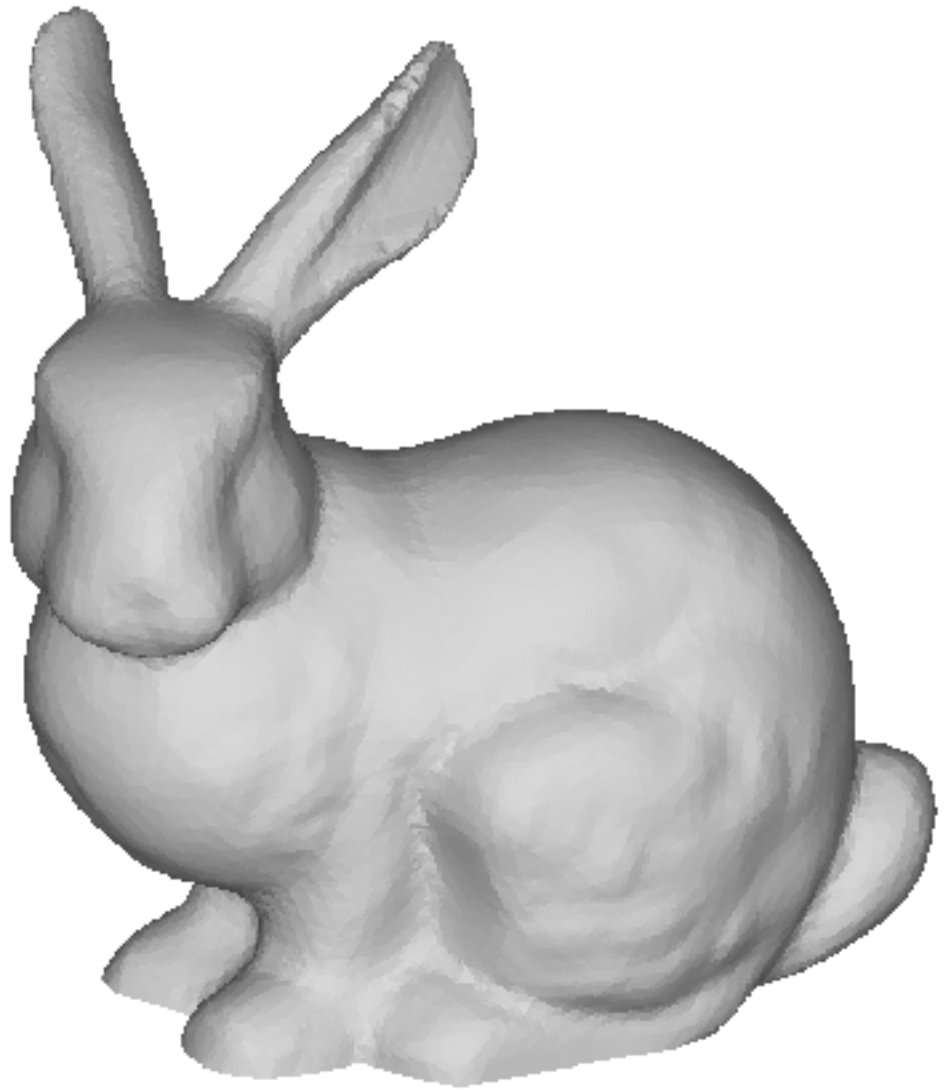


Style Transfer for 3D Triangle Meshes



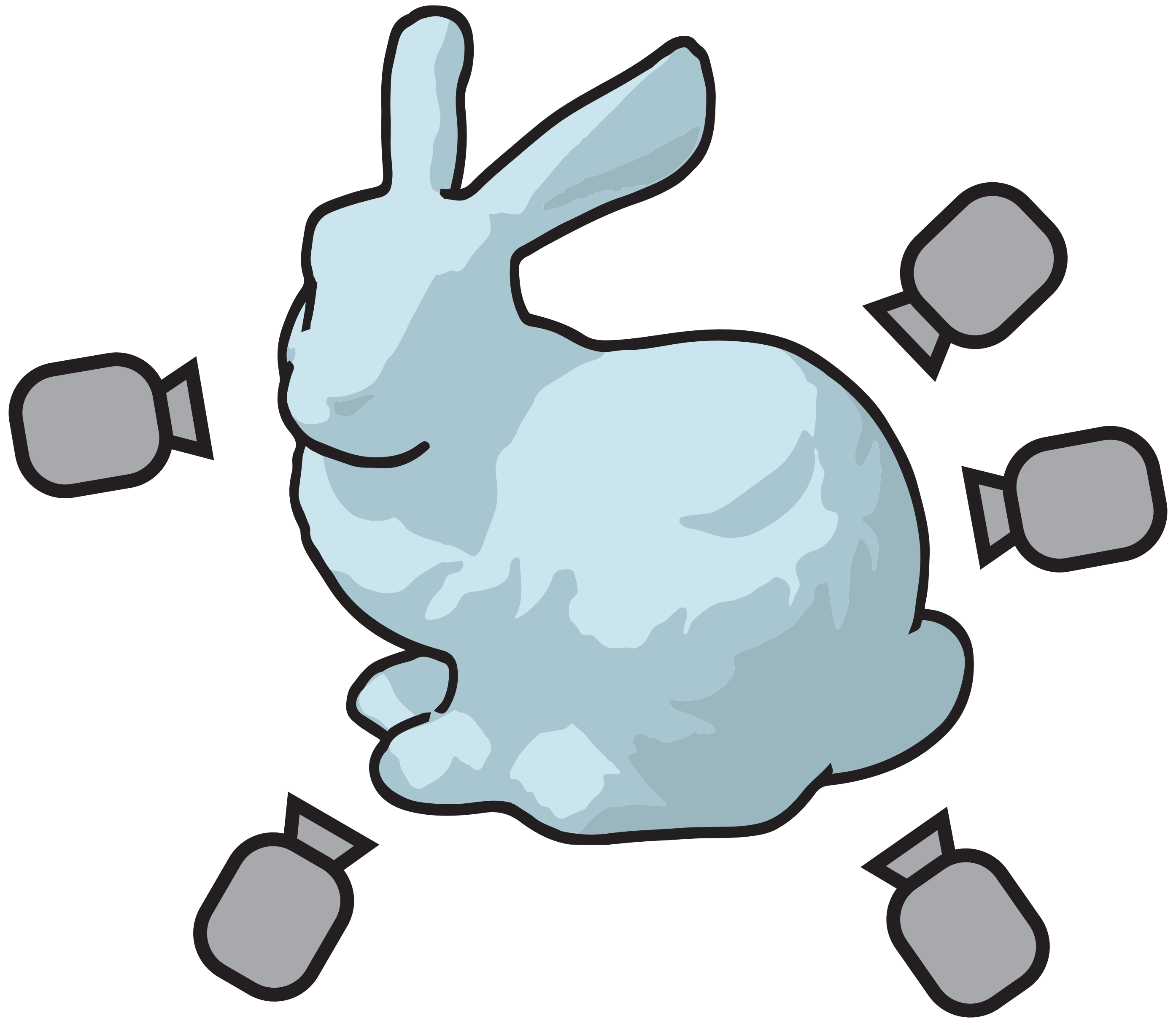

L0 smoothing
superpixel
style transfer

Main Idea: Shape Optimization

$E_{3\mathrm{D}}\Big($  $\Big) := \int_{\text{camera}}$  $E_{2\mathrm{D}}\Big($  $\Big)$

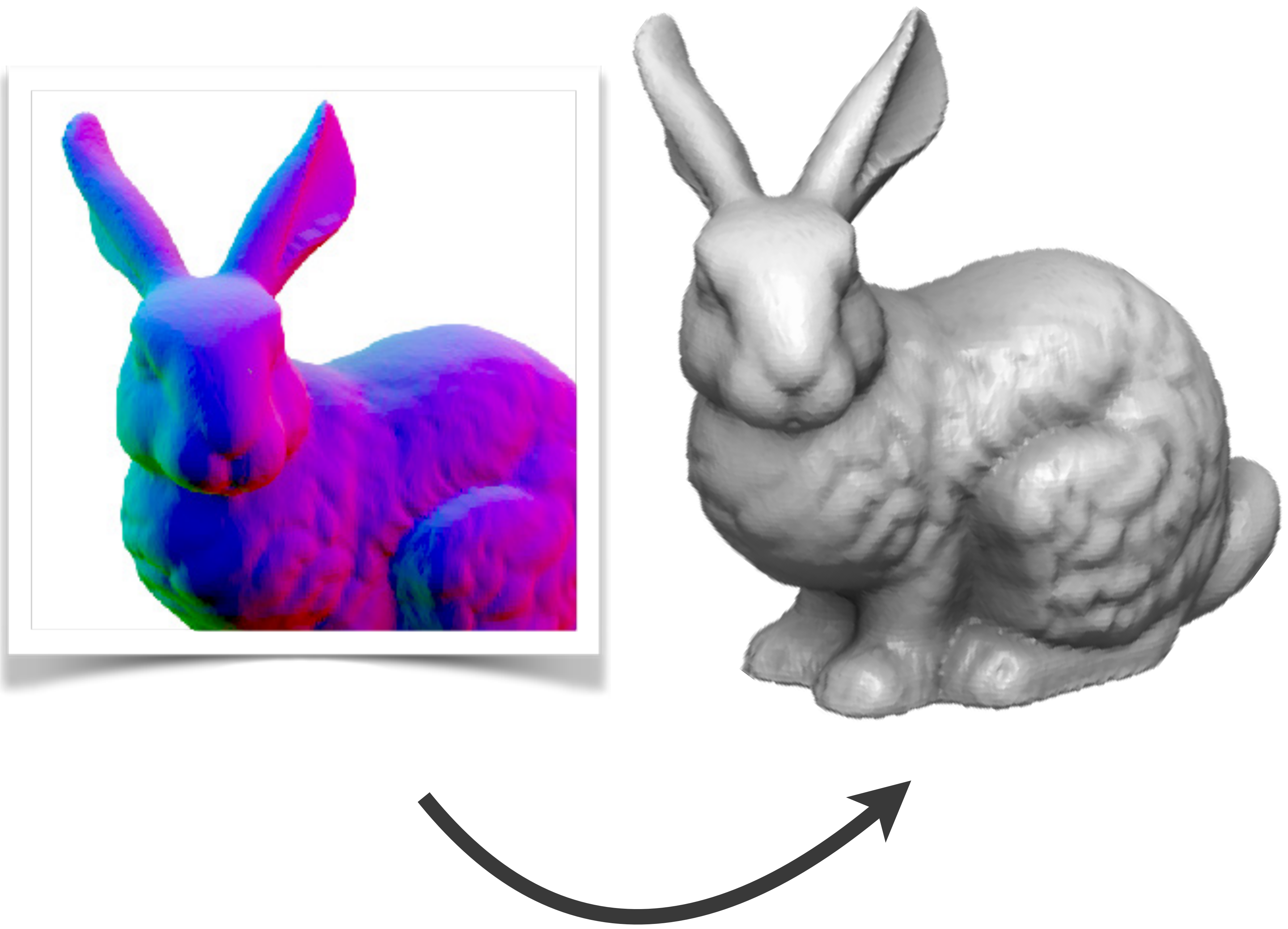
Key Steps

3. Multiview optimization

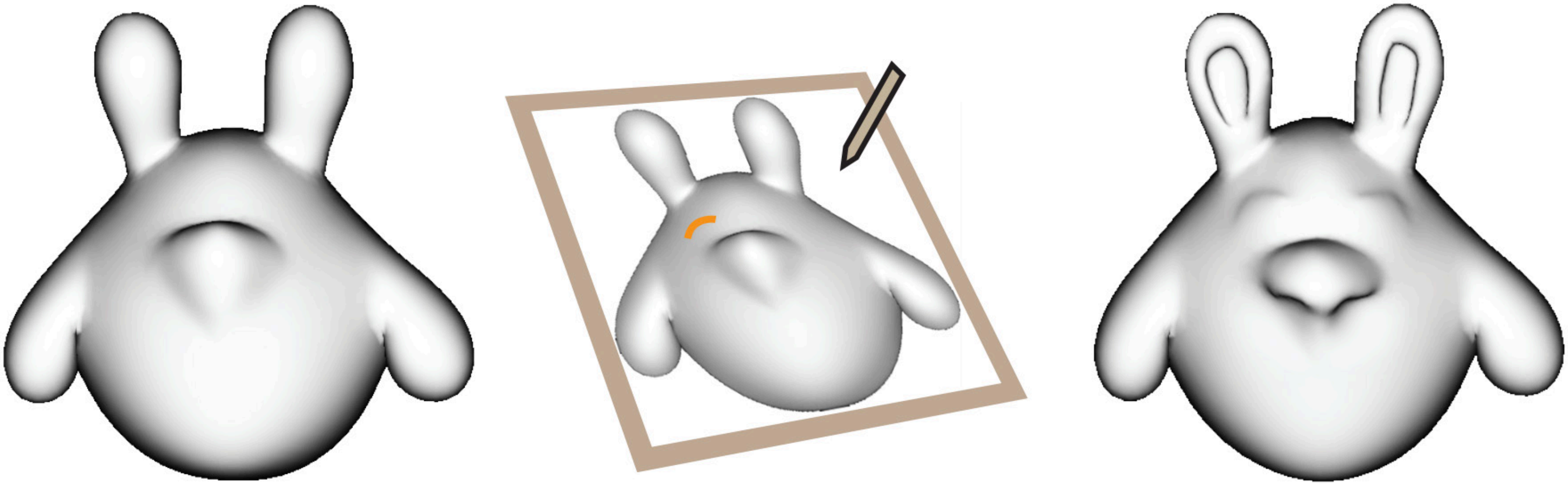


1. Process renderings

2. Differentiable renderer



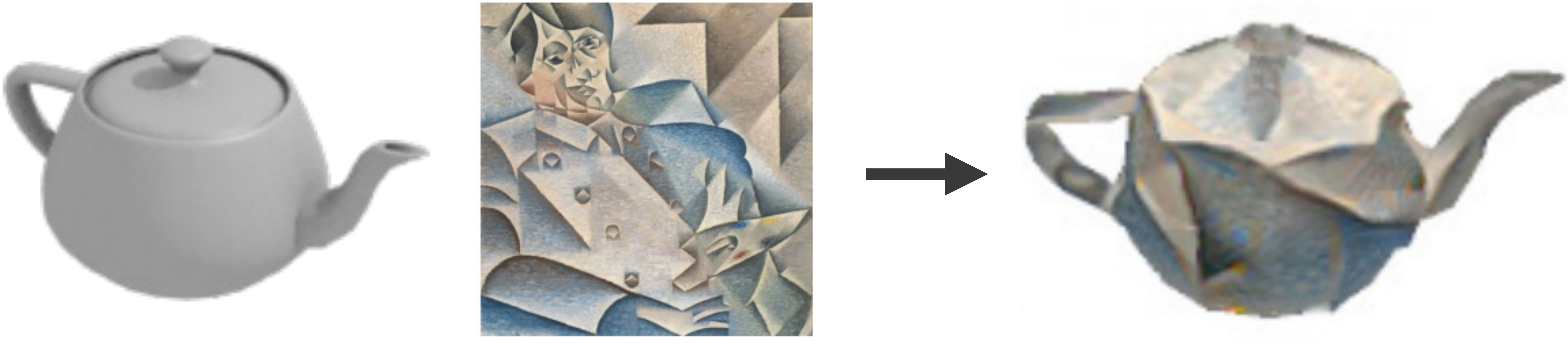
Shading-Based Surface Editing



[Gingold et al. 2008]

Previous Differentiable Renderers

- Automatic differentiation [Loper Black 2014, Genova et al. 2018]
- Rendering networks [Eslami et al. 2016, Liu et al. 2017, Richardson et al. 2017, Wu et al. 2017]
- Neural 3D mesh renderer [Kato et al. 2018]



source: Kato et al. 2018

Paparazzi

- More general than shading-based editing
- Tailor-made novel differentiable renderer for 3D shapes
- **Analytical** derivative (faster, less memory)

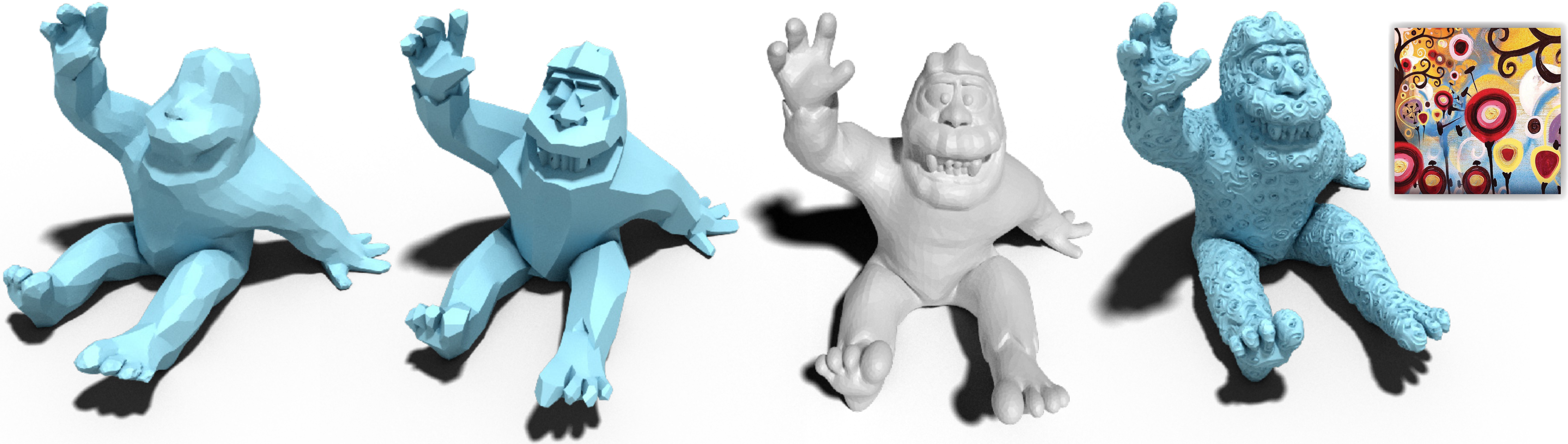
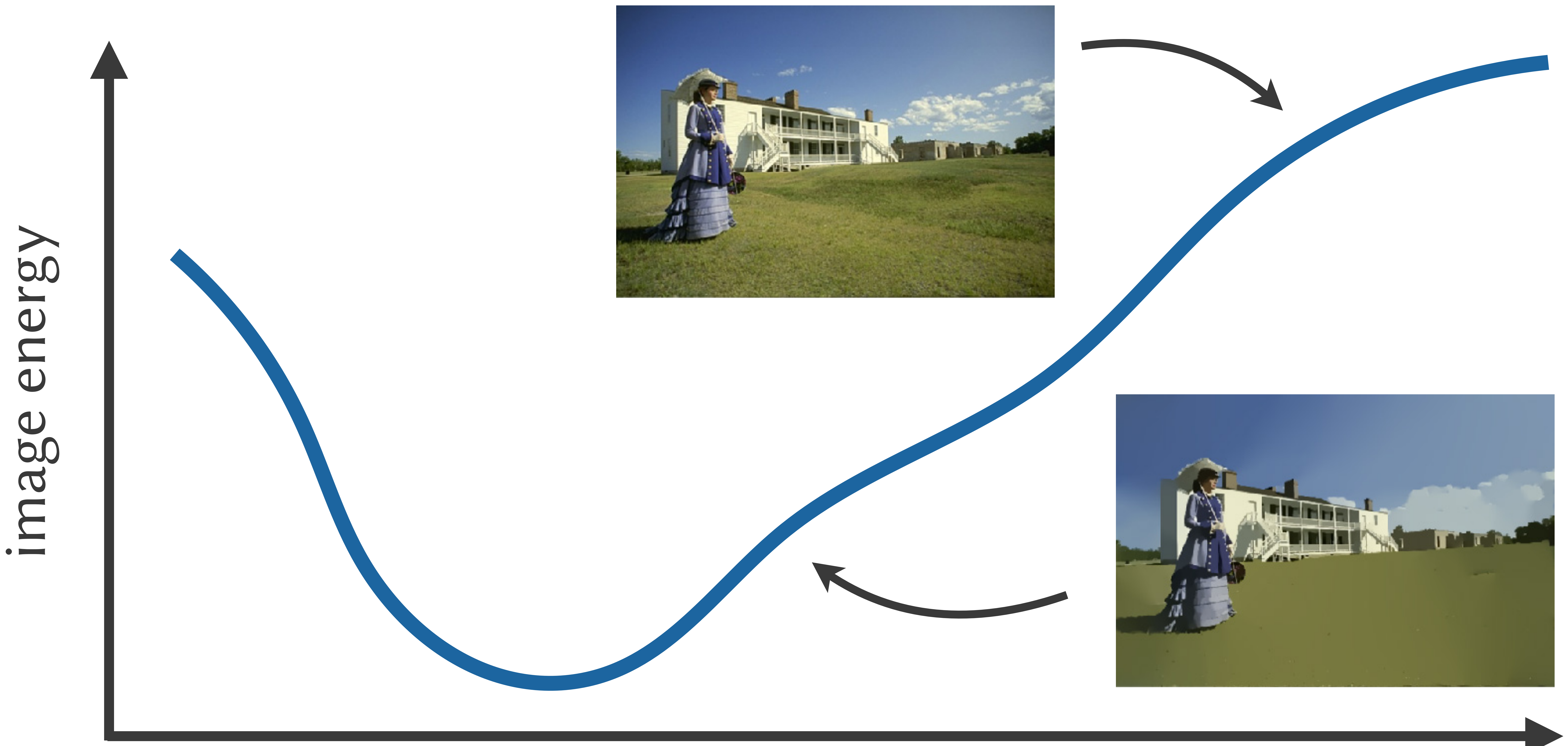
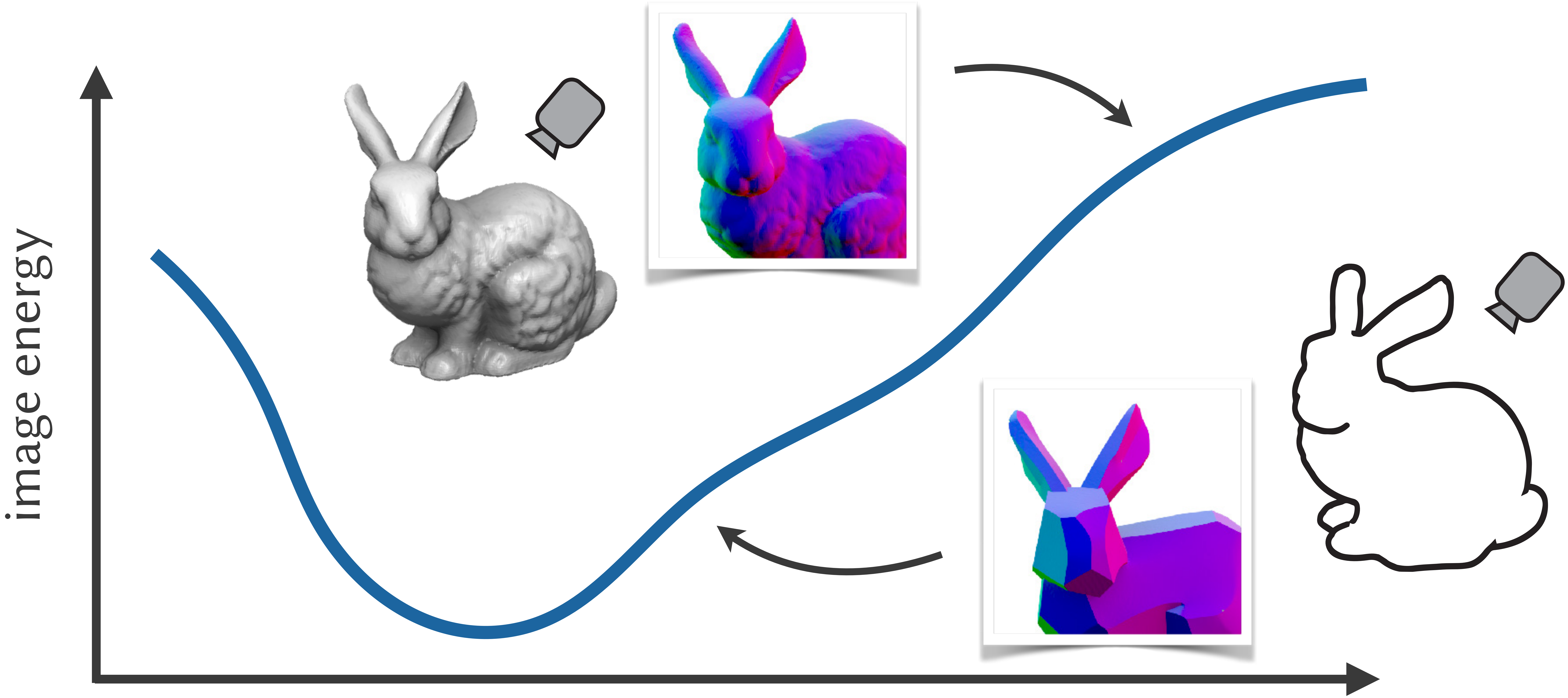


Image Optimization



Paparazzi Shape Optimization



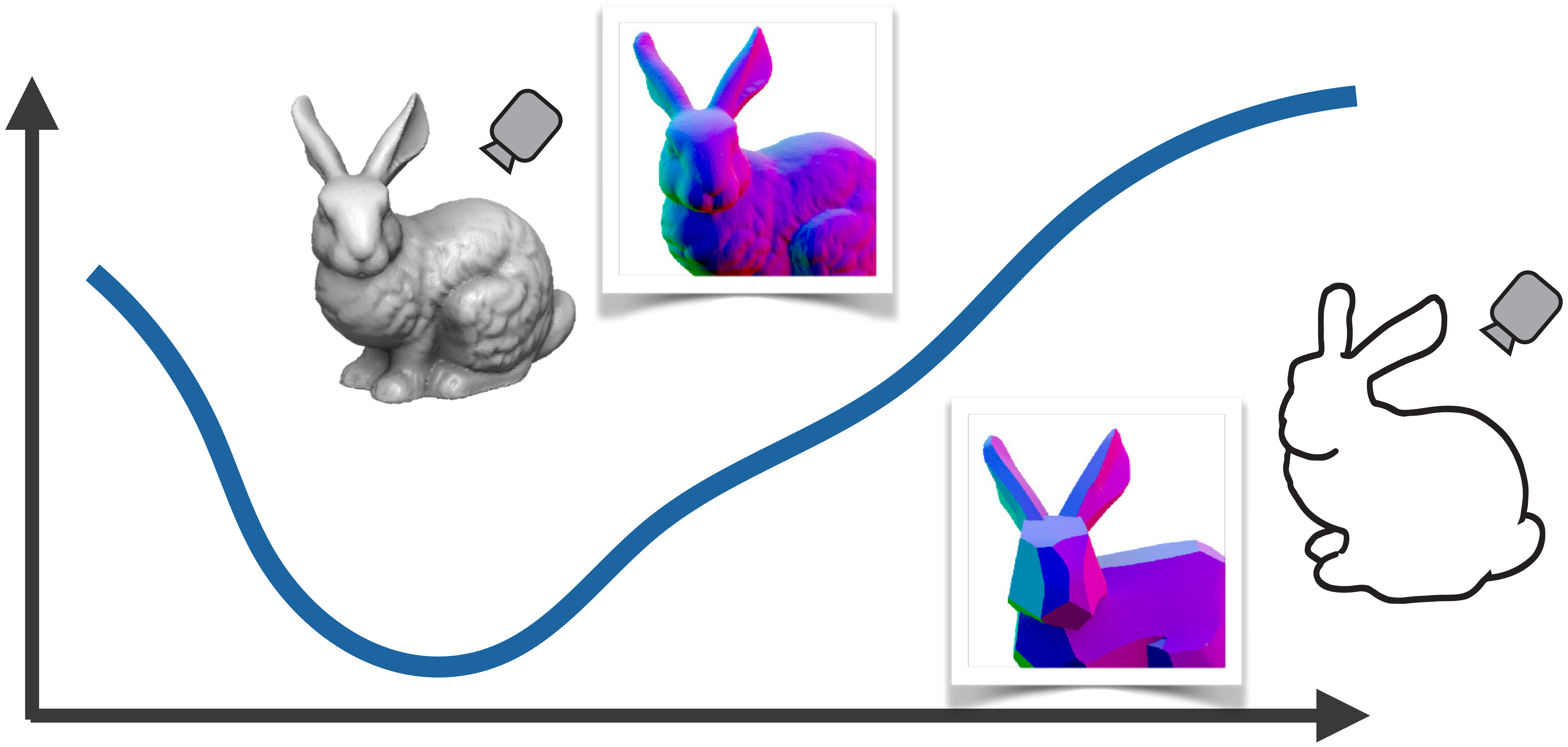
Paparazzi Shape Optimization

$$V^{\star} \leftarrow \arg\min_{V} E\big(R(V)\big)$$

optimized shape

image energy

rendering

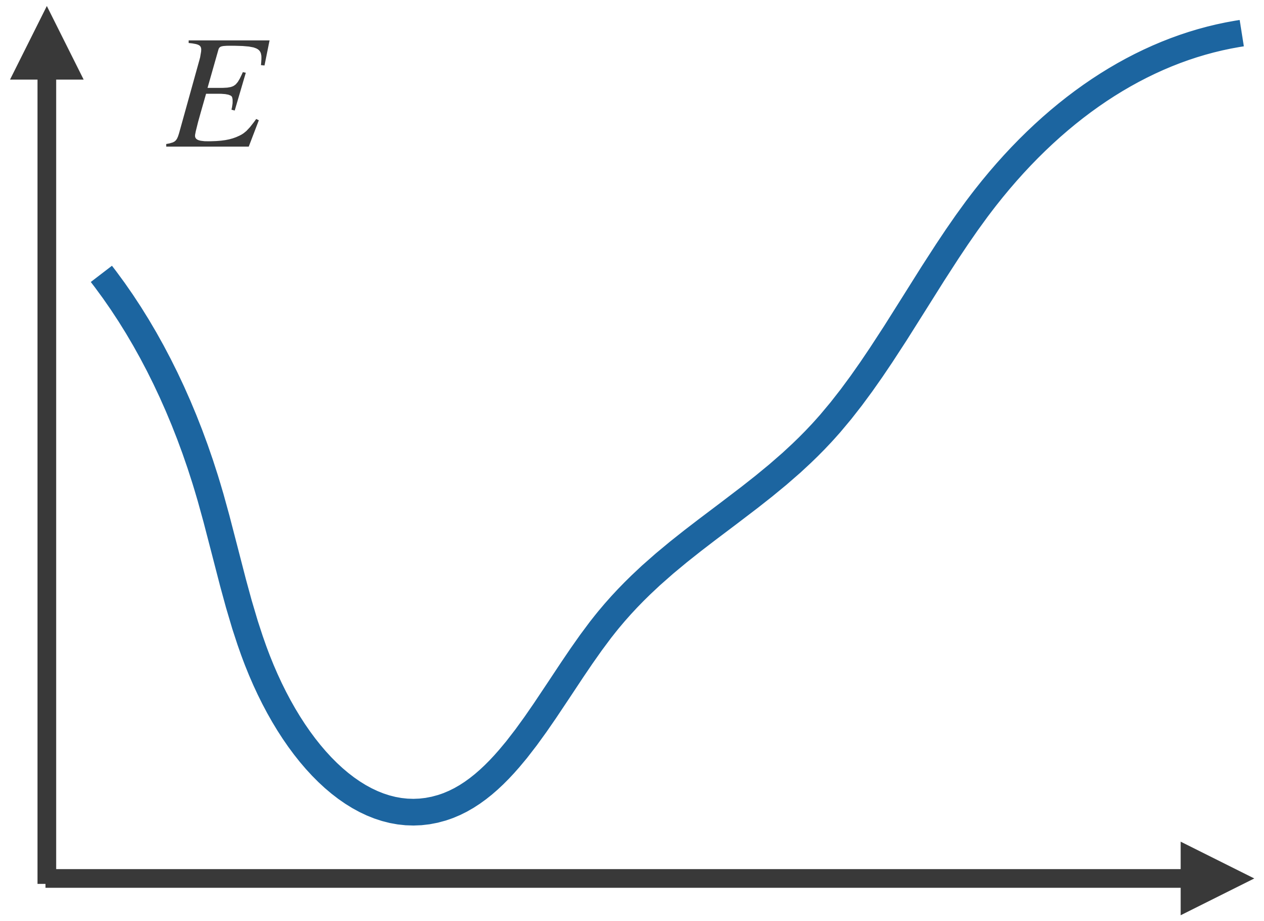


Paparazzi Shape Optimization

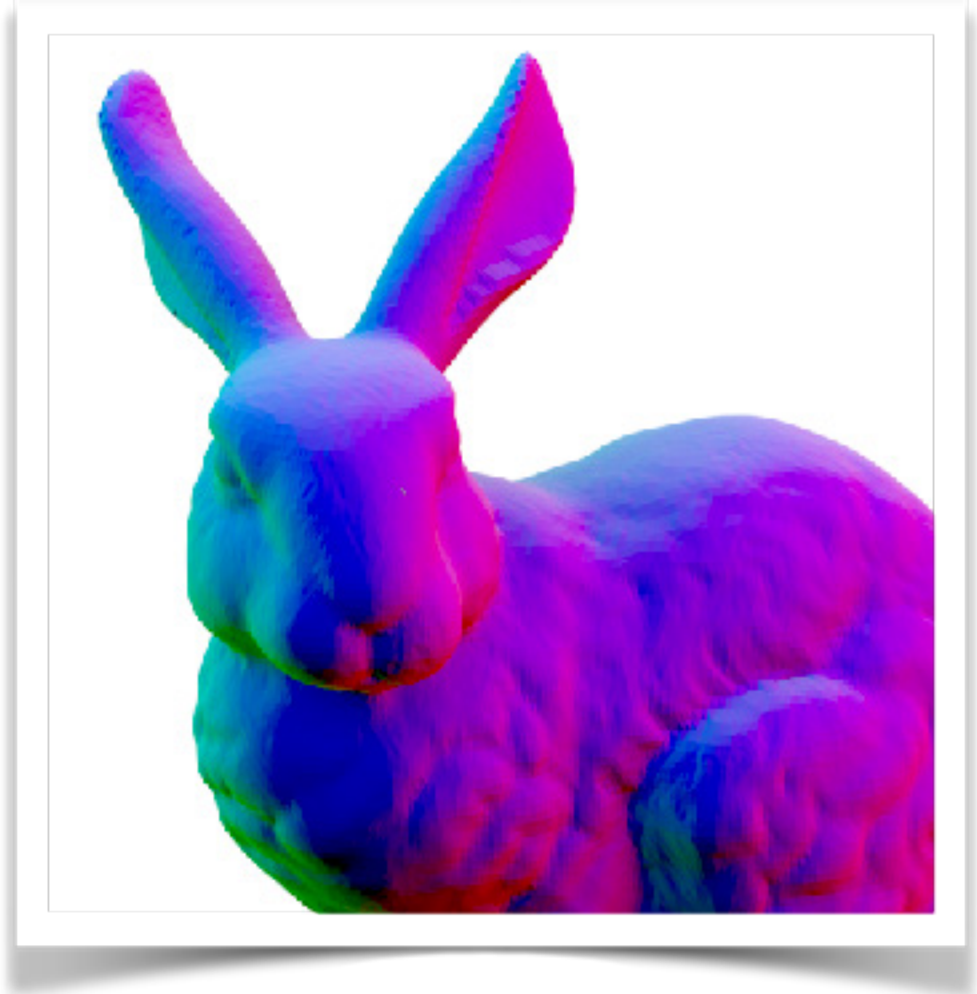
$$V^\star \leftarrow \arg\min_V E\big(R(V)\big)$$

Gradient descent method

$$V \leftarrow V - \gamma \frac{\partial E}{\partial R}\frac{\partial R}{\partial V}$$

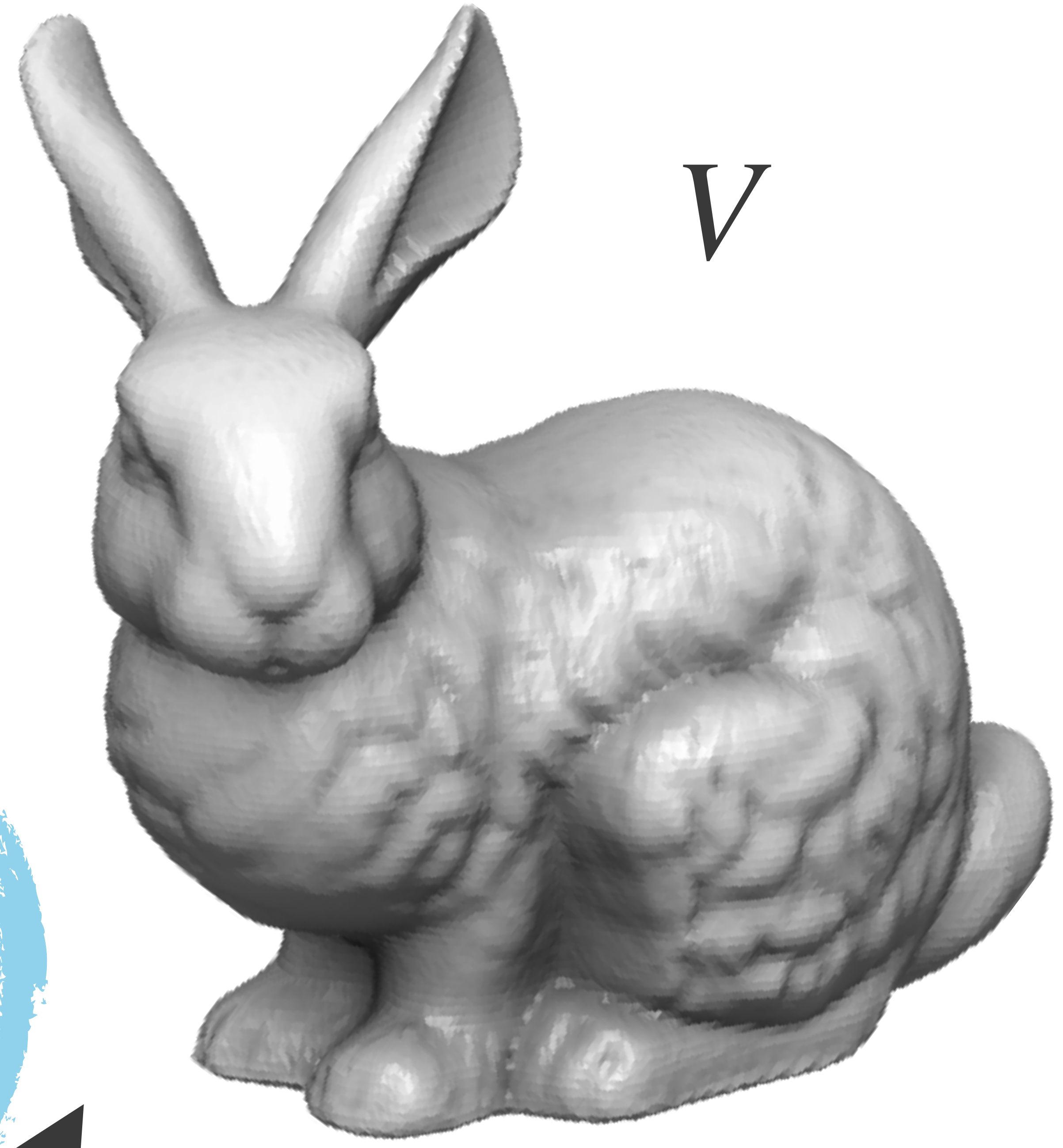


$$\frac{\partial E}{\partial R}$$



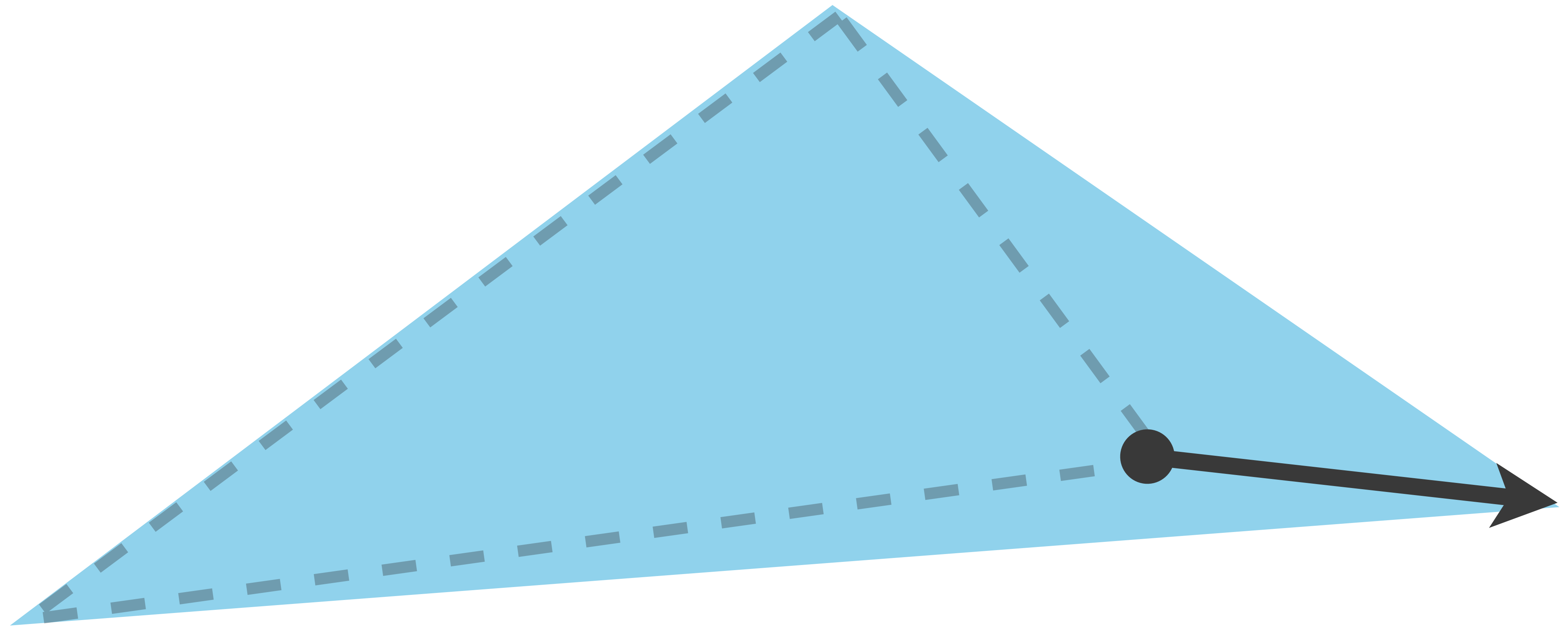
$R(V)$

$$\frac{\partial R}{\partial V}$$

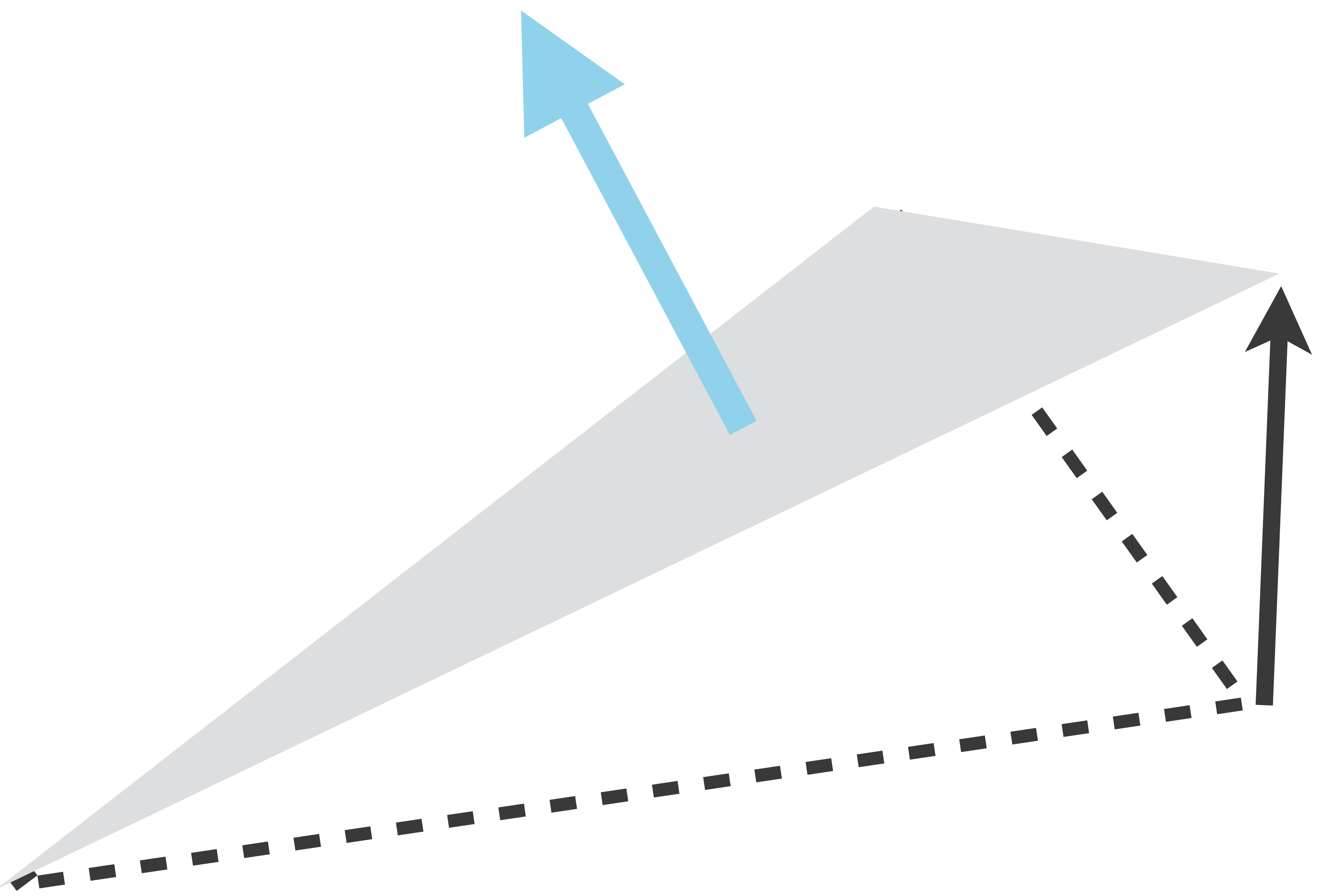


Rendering Differentiable?

Rendering a Geometry

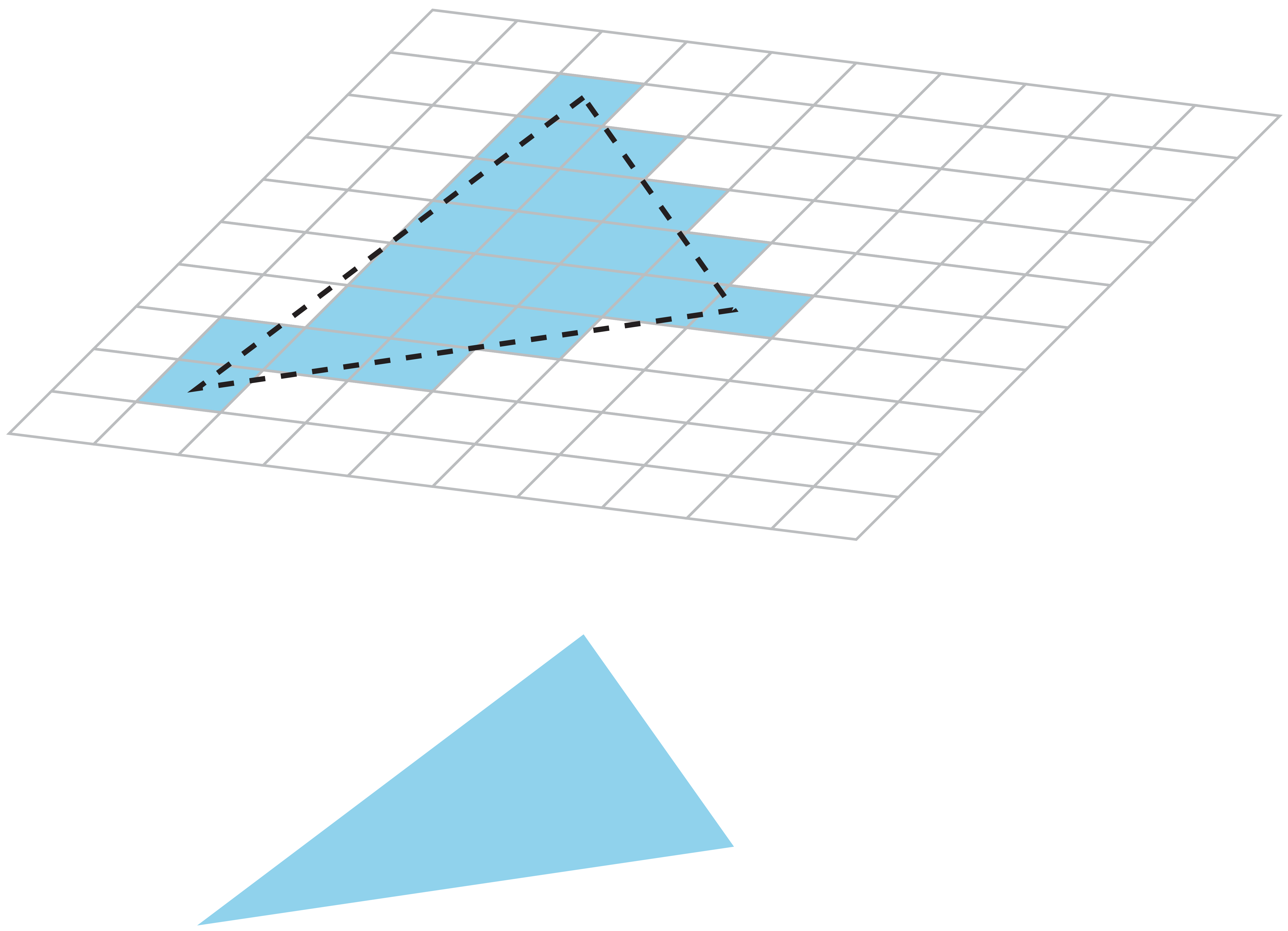


Visibility

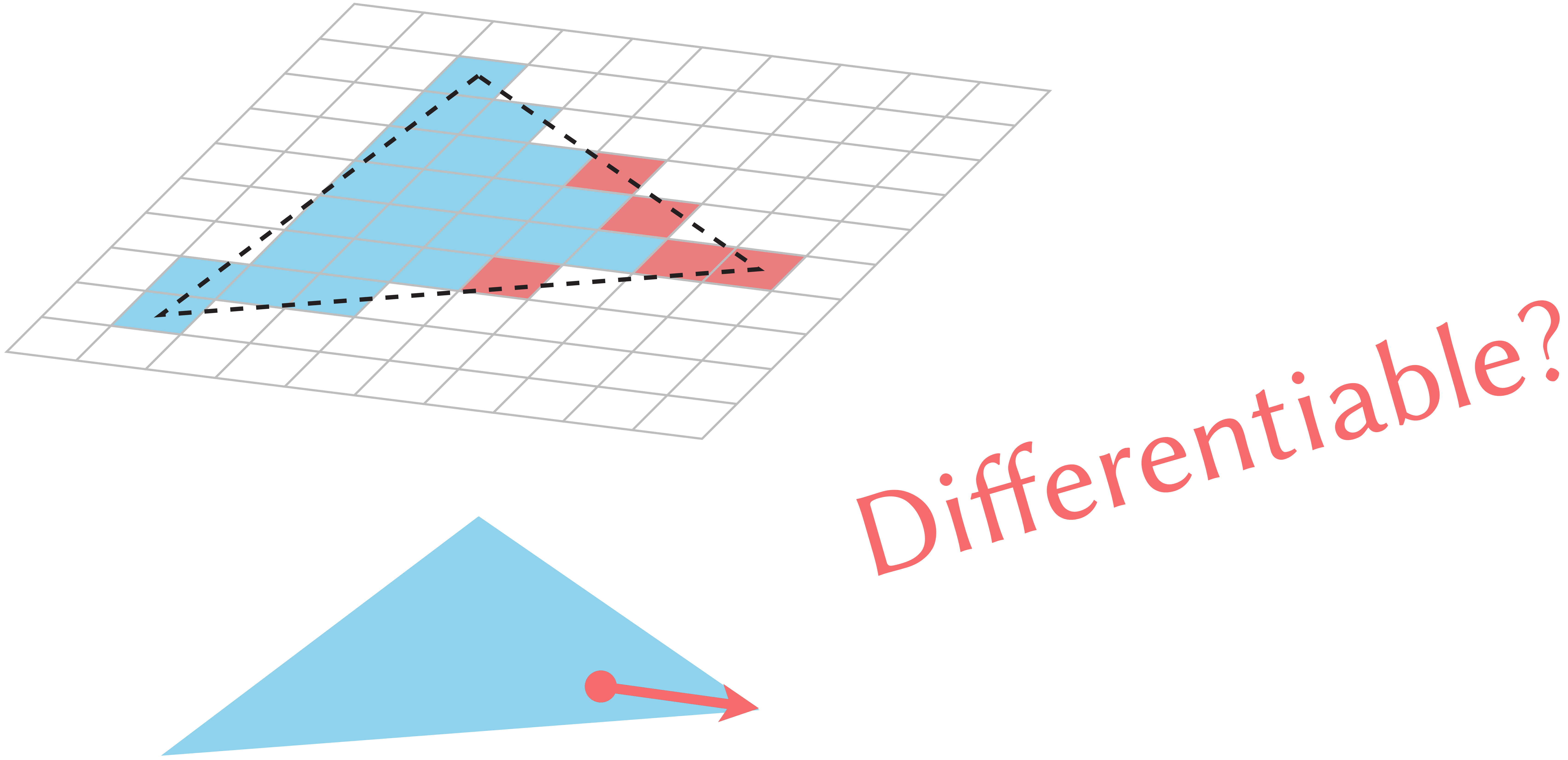


Orientation

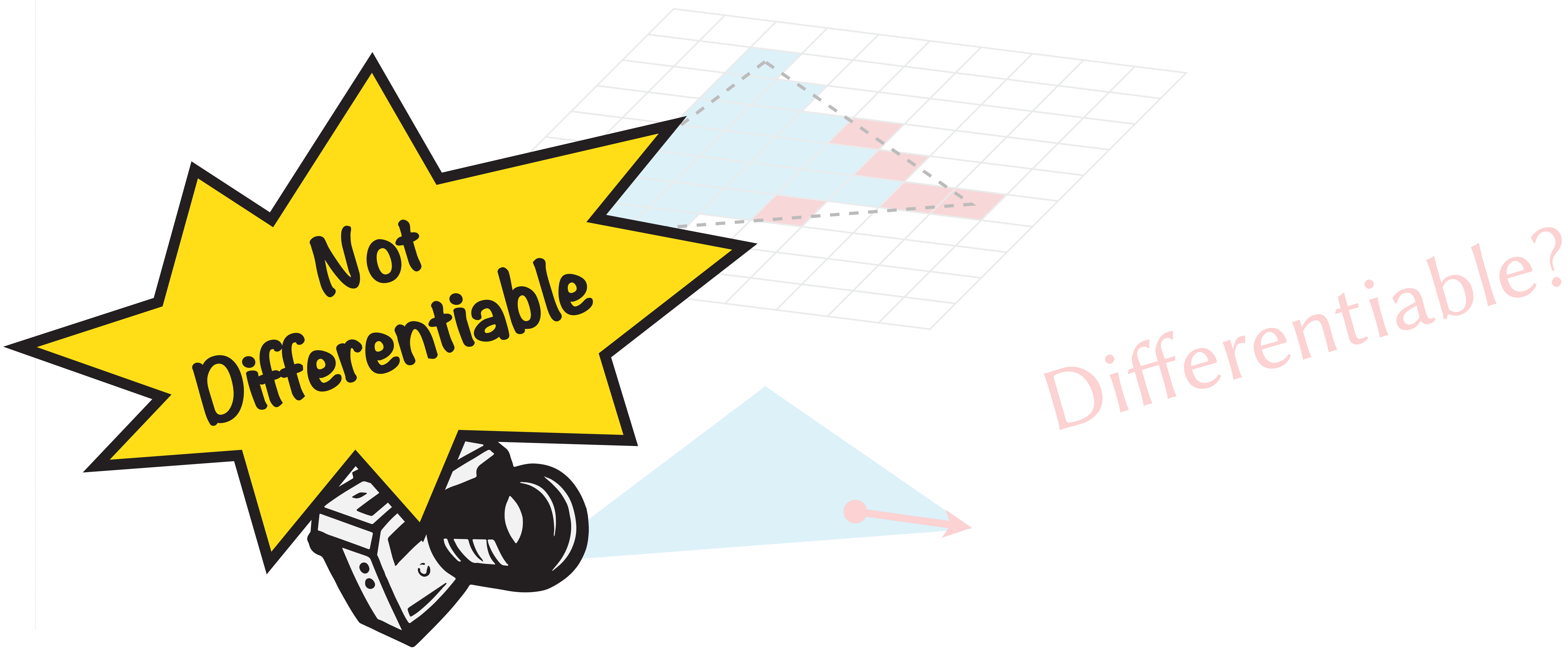
Visibility Component



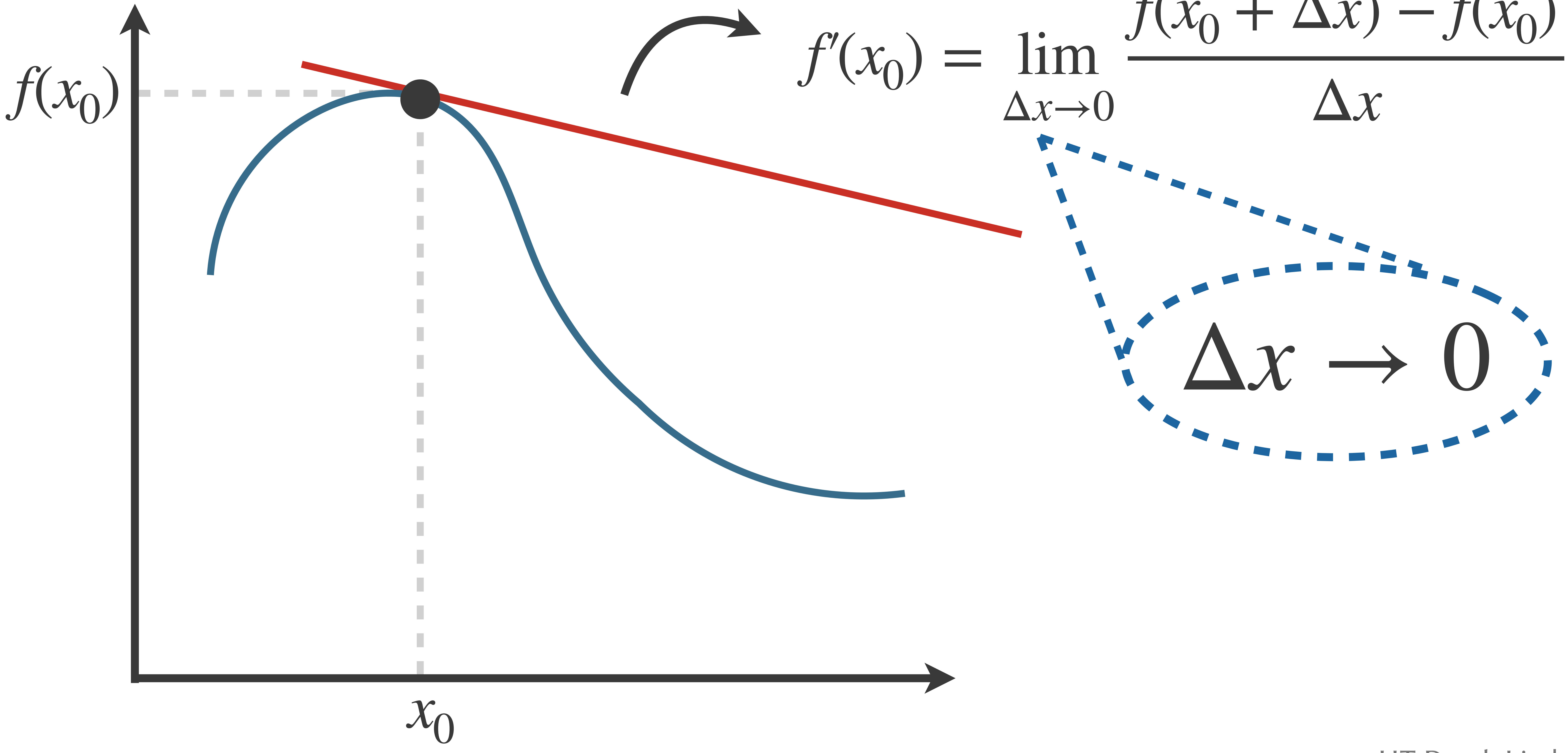
Visibility Component



Visibility Component

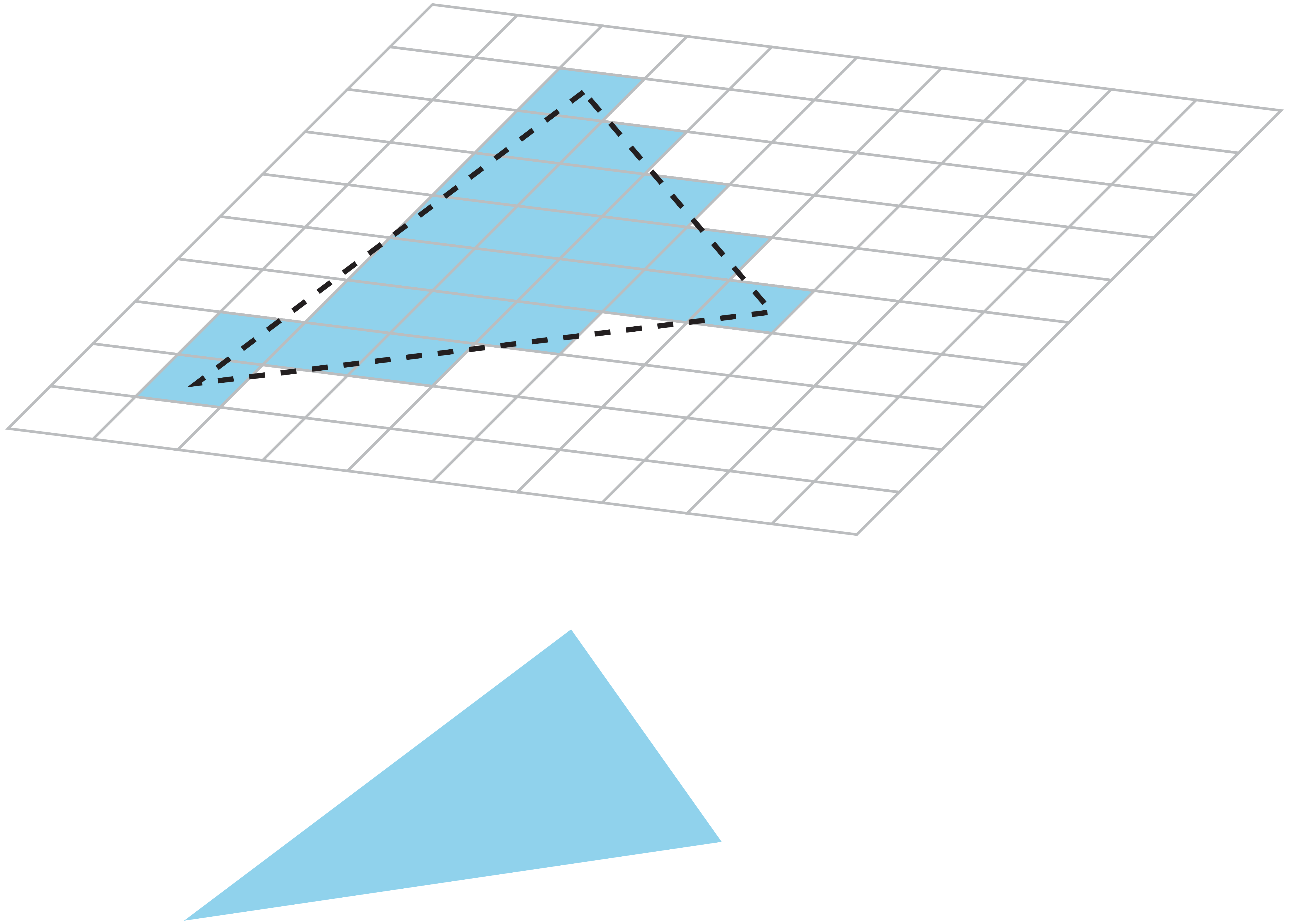


Analytical Derivative

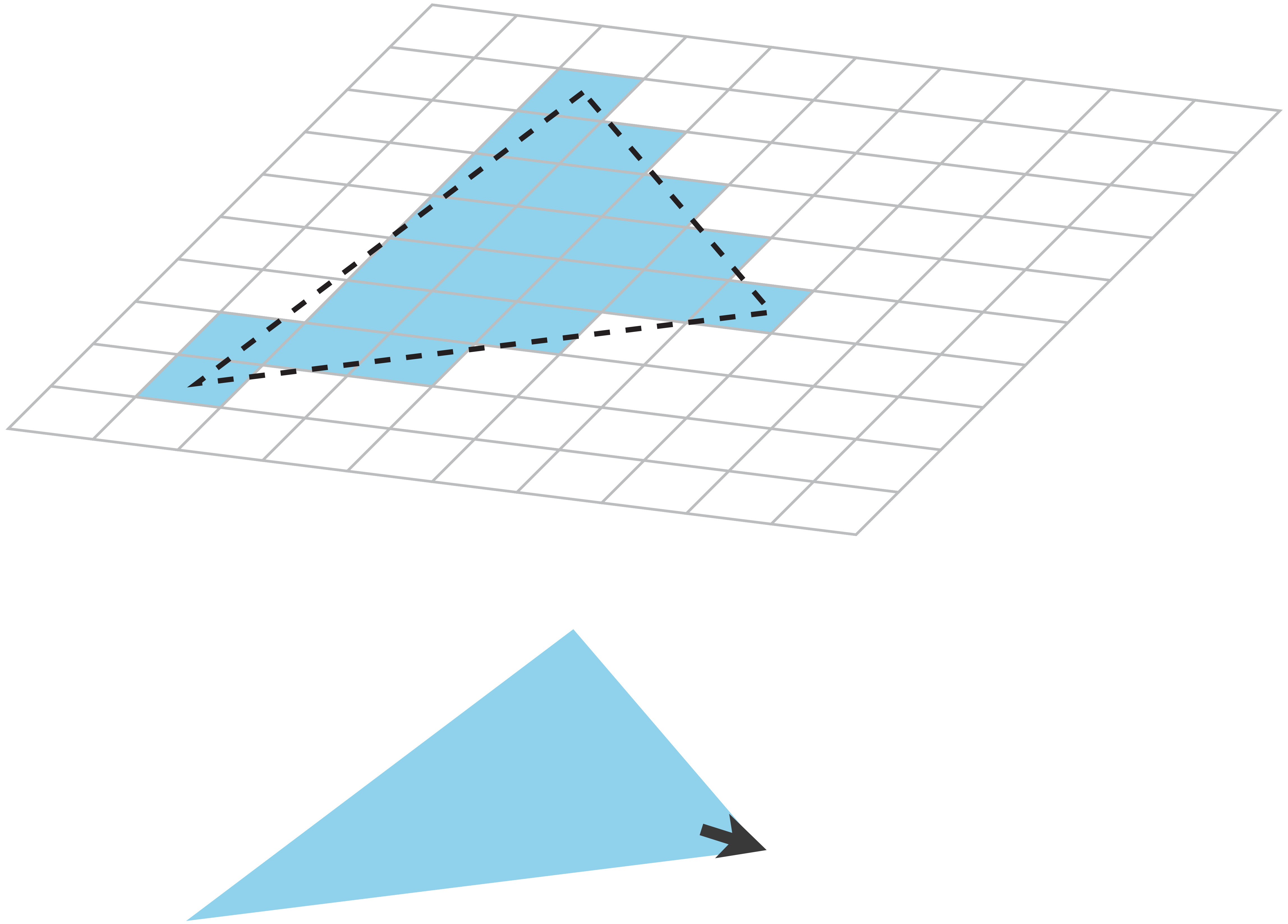


$$f'(x_0) = \lim_{\Delta x \to 0} \frac{f(x_0 + \Delta x) - f(x_0)}{\Delta x}$$

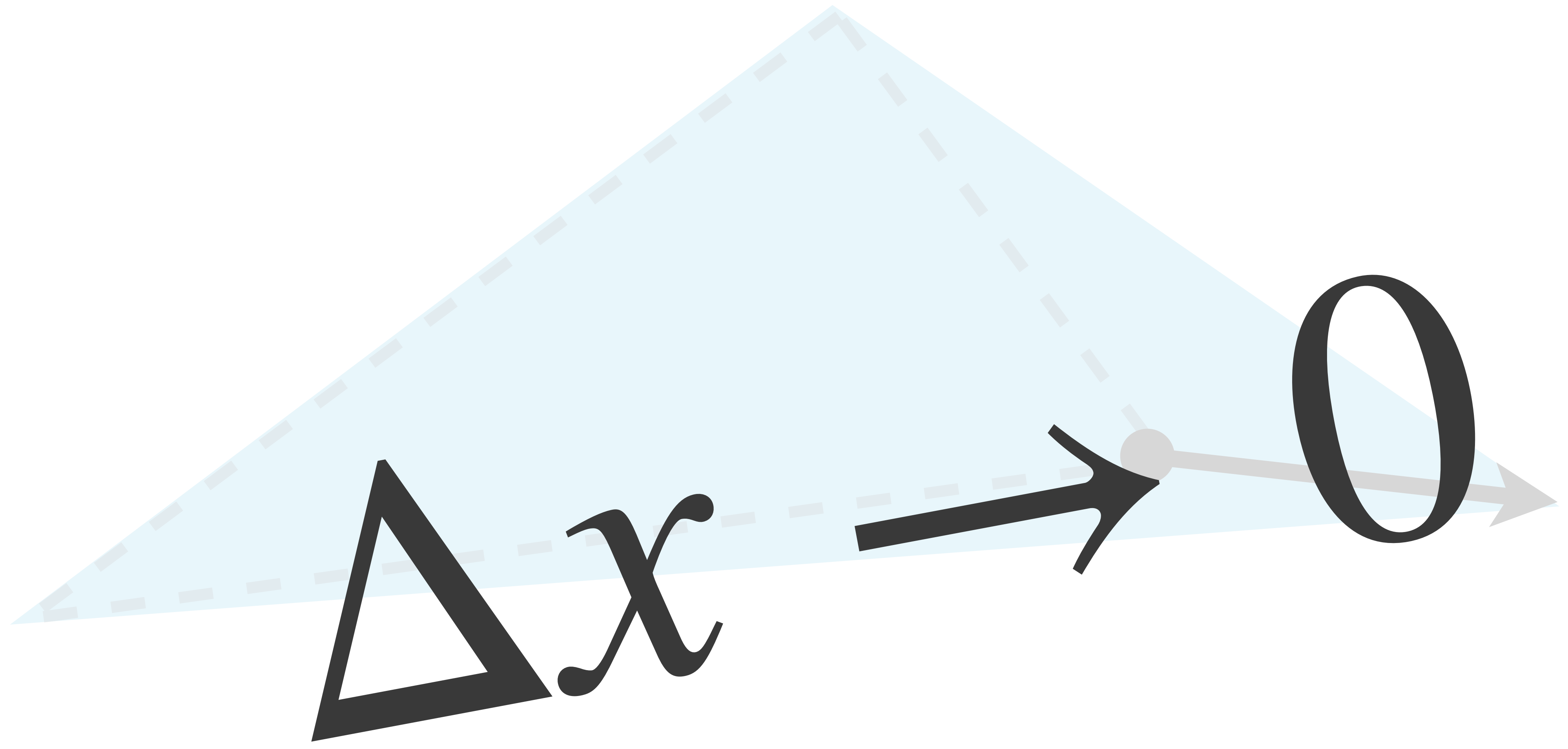
Visibility Component $\Delta x \to 0$



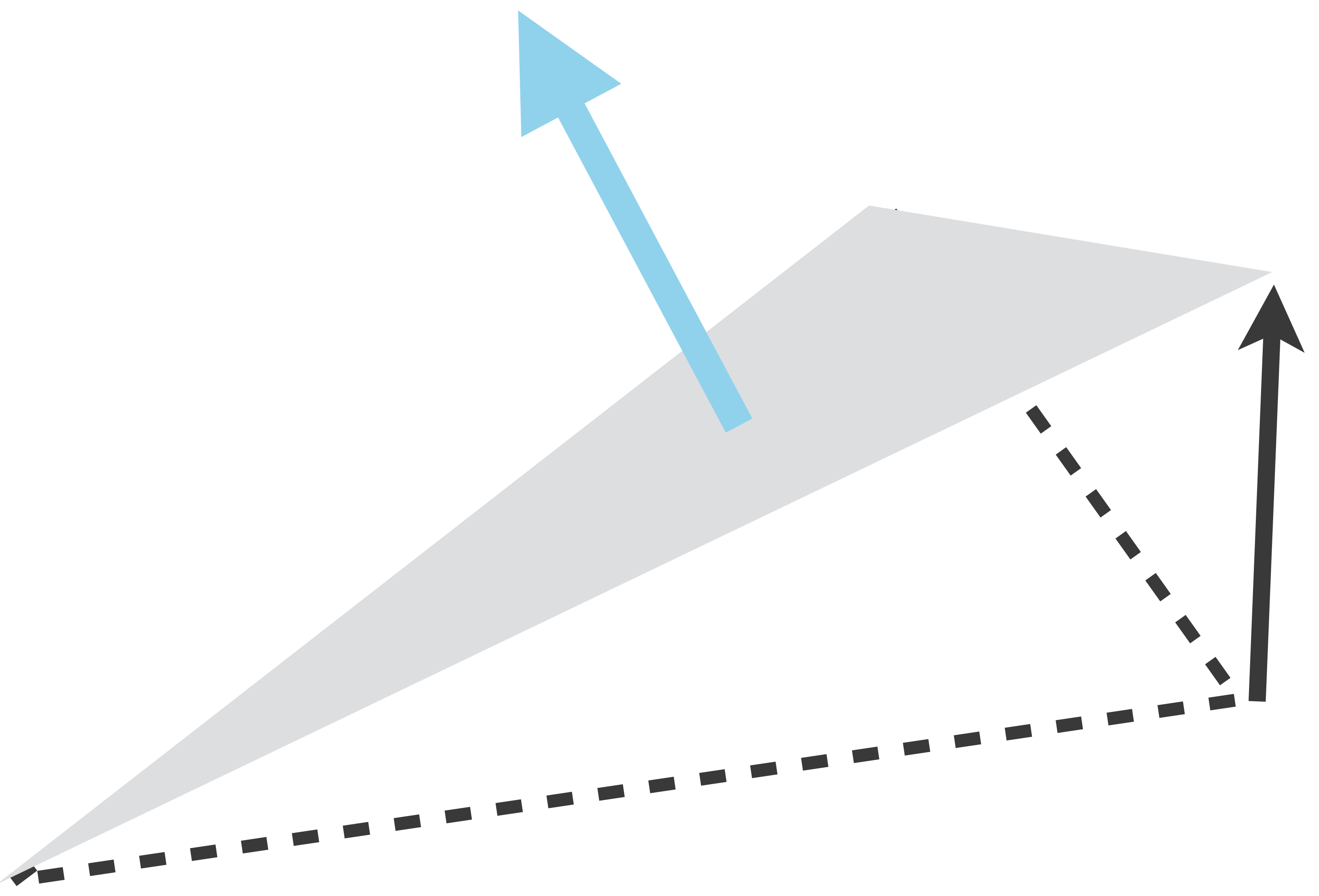
Visibility Component $\Delta x \to 0$



Rendering a Geometry

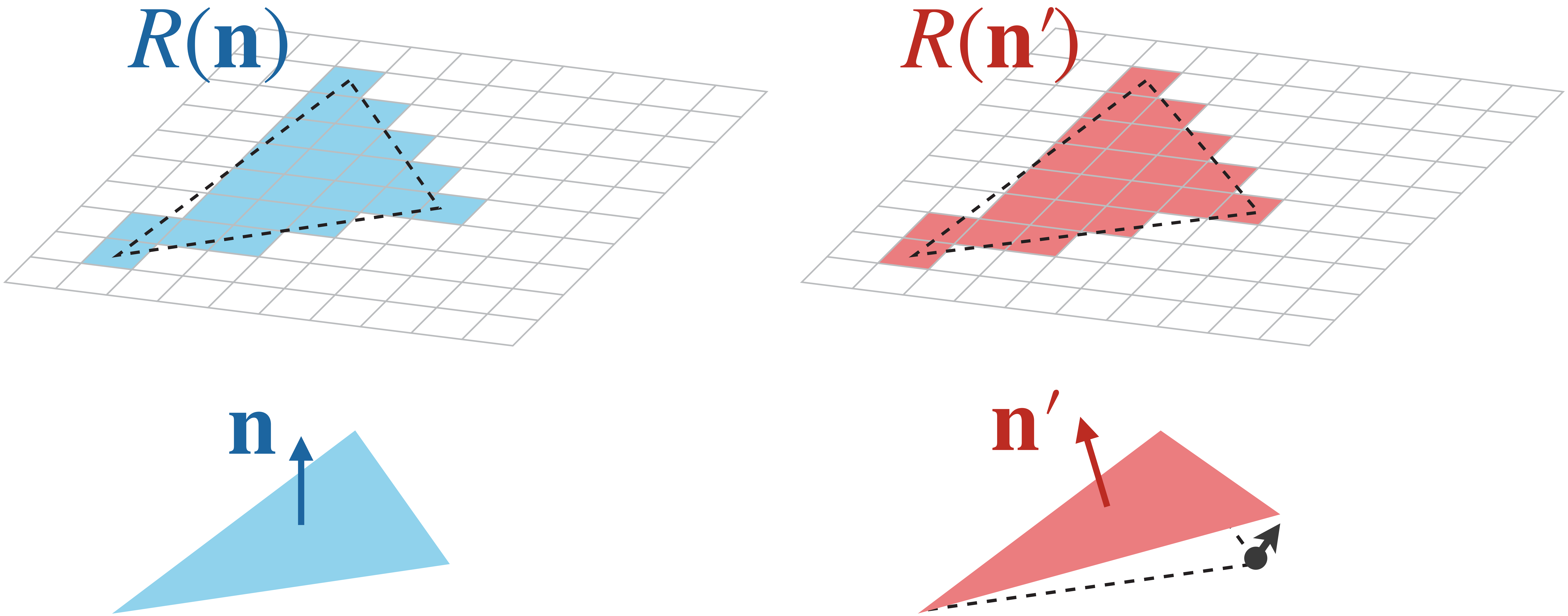


Visibility

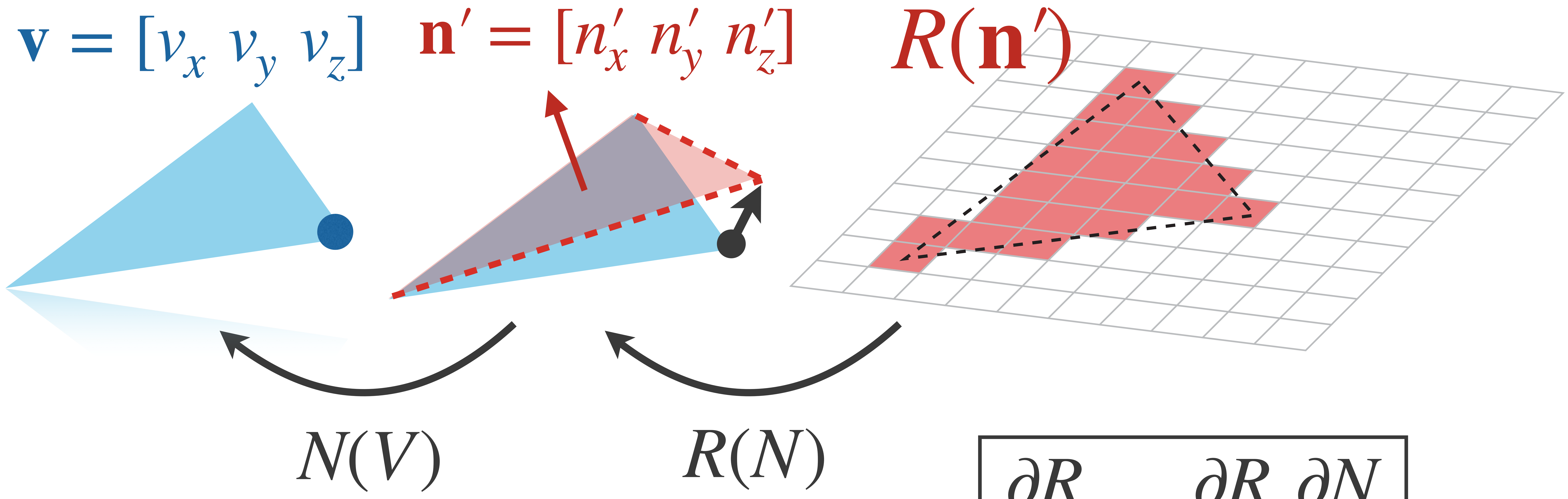


Orientation

Orientation Component

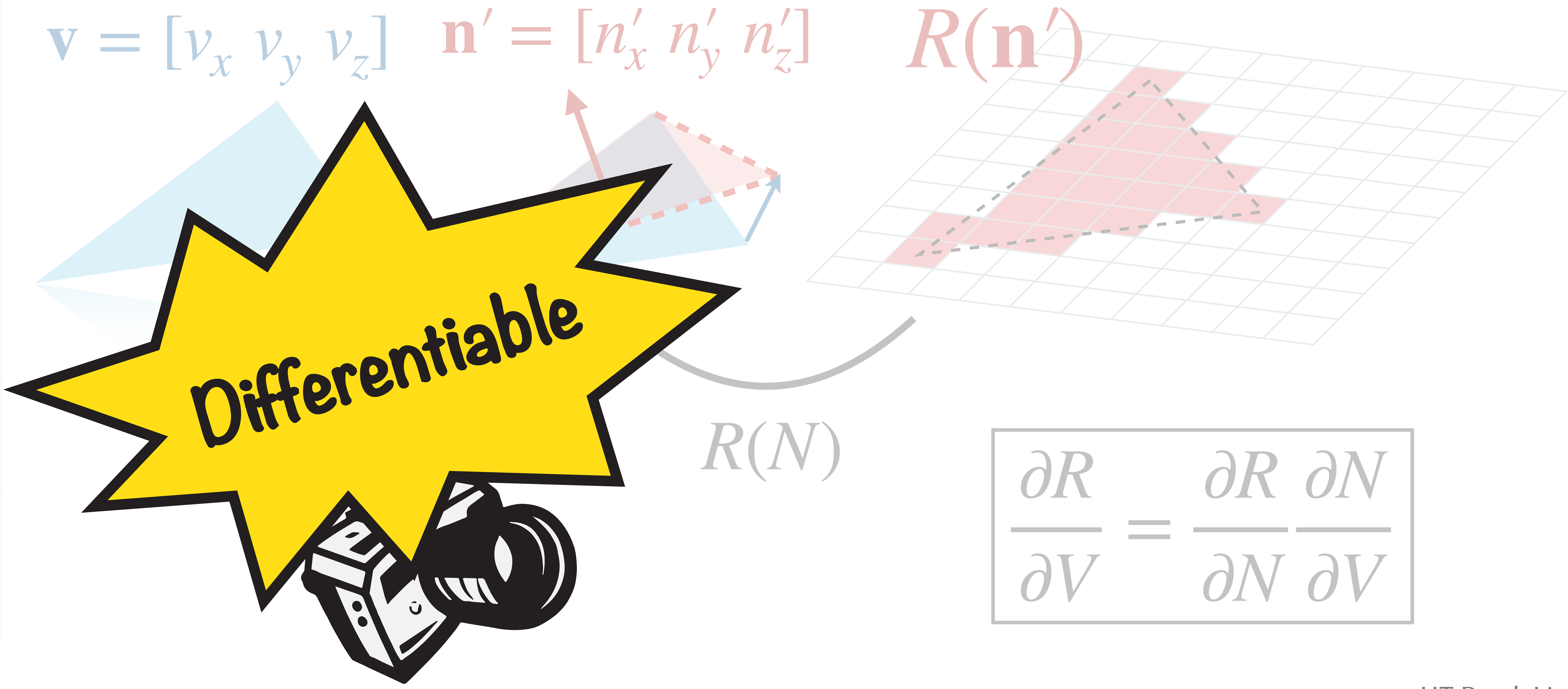


Orientation Component

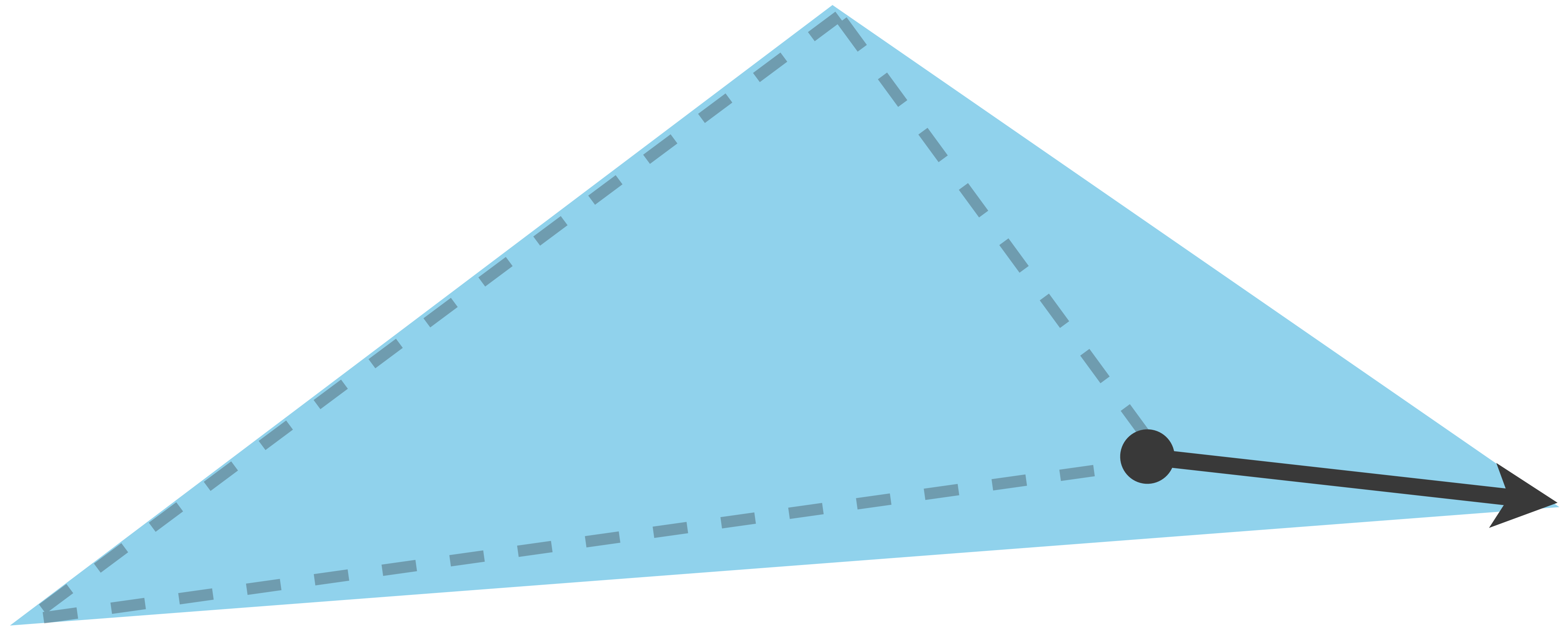


$$\frac{\partial R}{\partial V} = \frac{\partial R}{\partial N}\frac{\partial N}{\partial V}$$

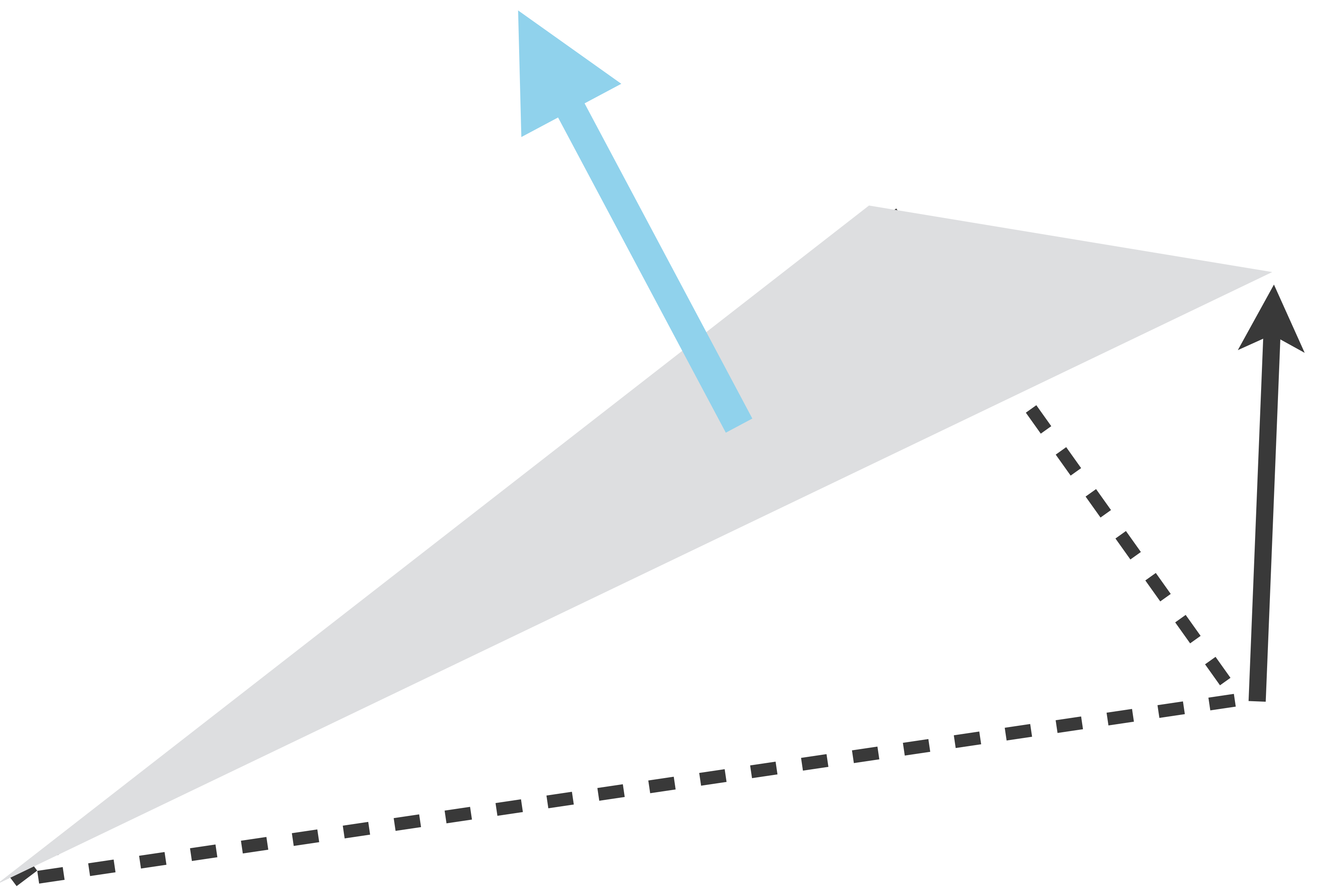
Orientation Component



Rendering a Geometry

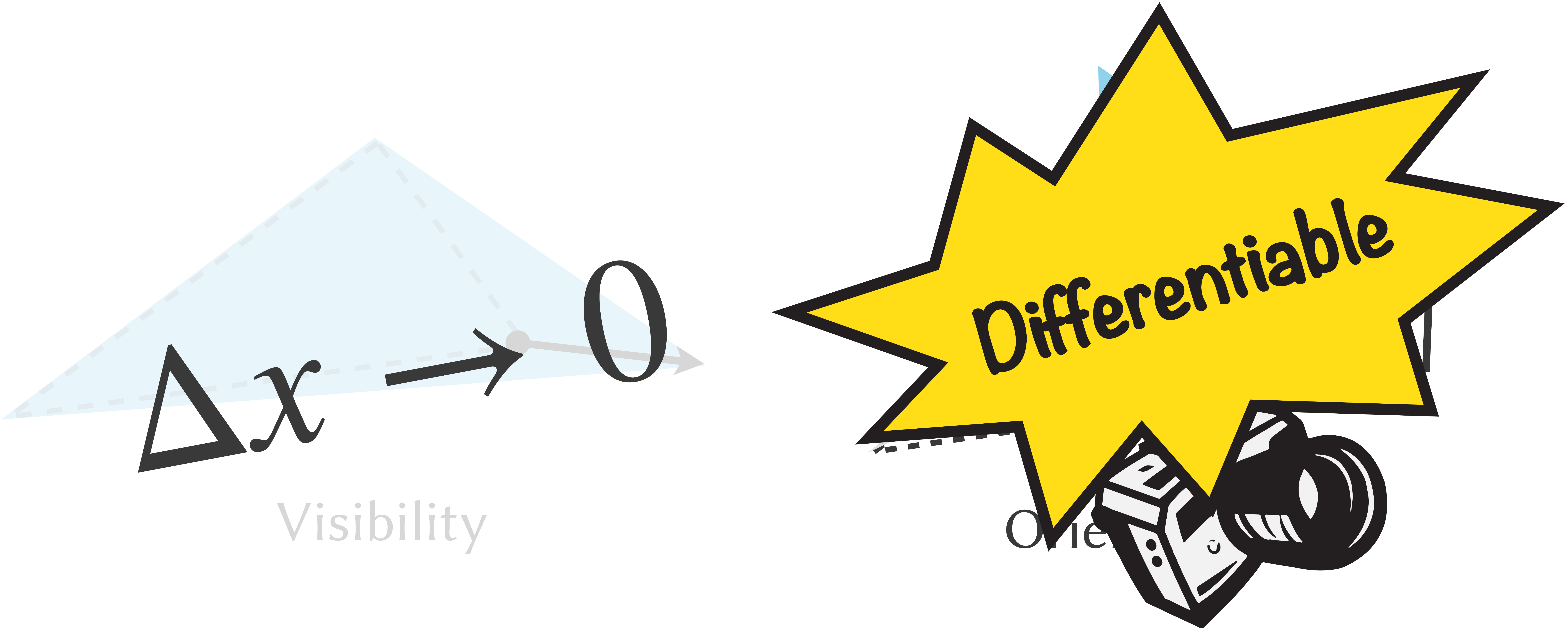


Visibility

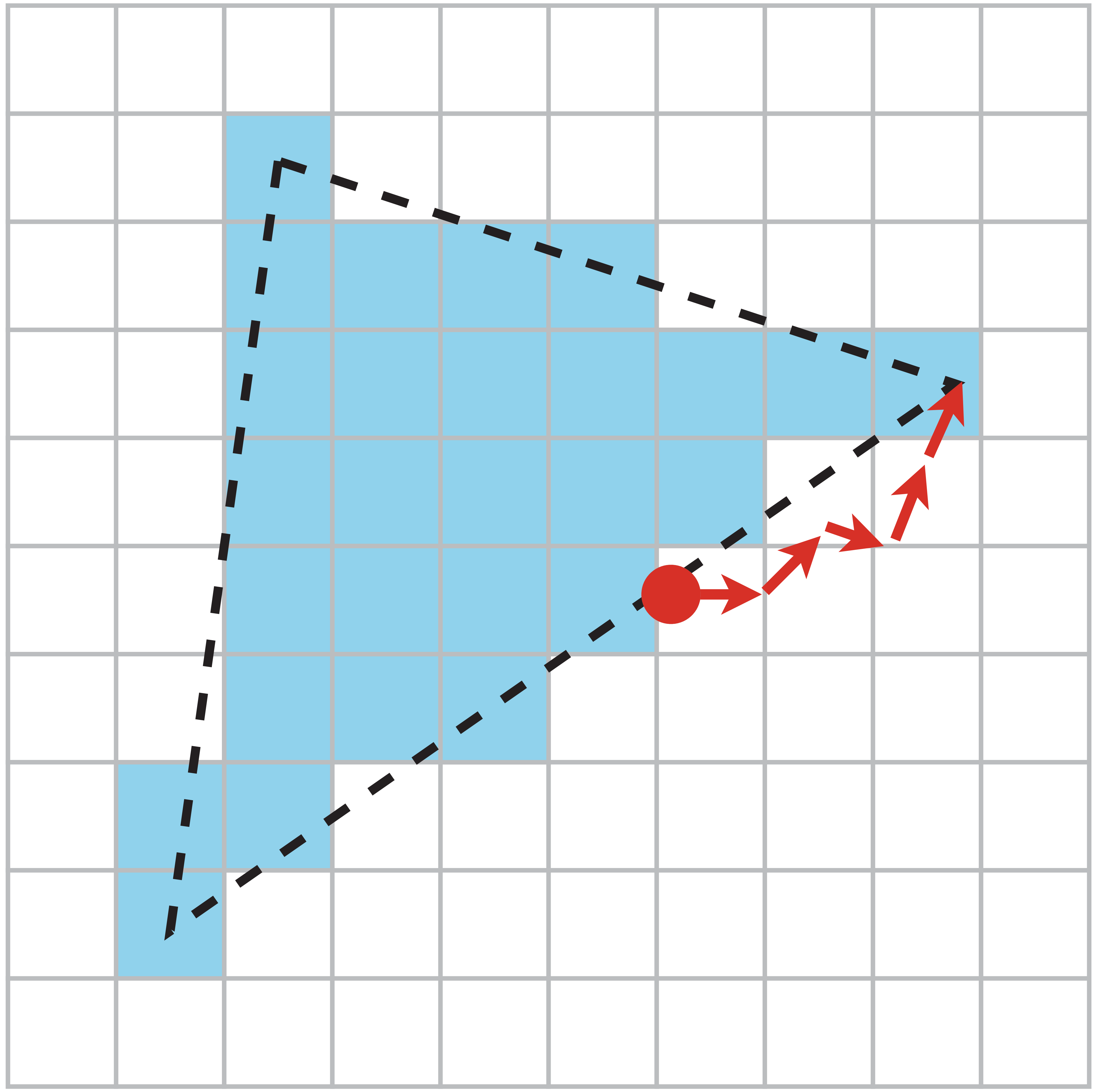


Orientation

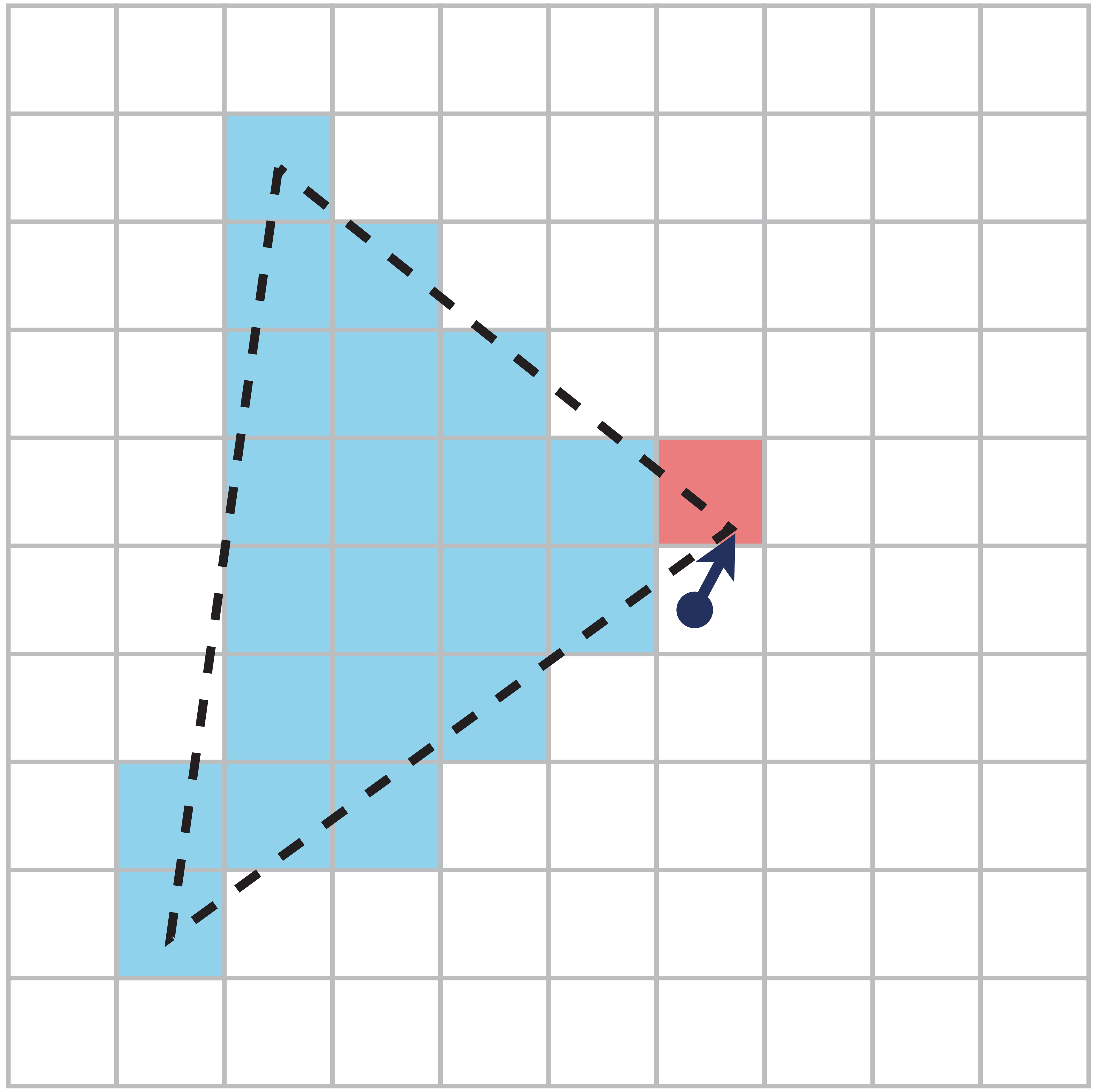
Rendering a Geometry



Visibility Change After Many Steps



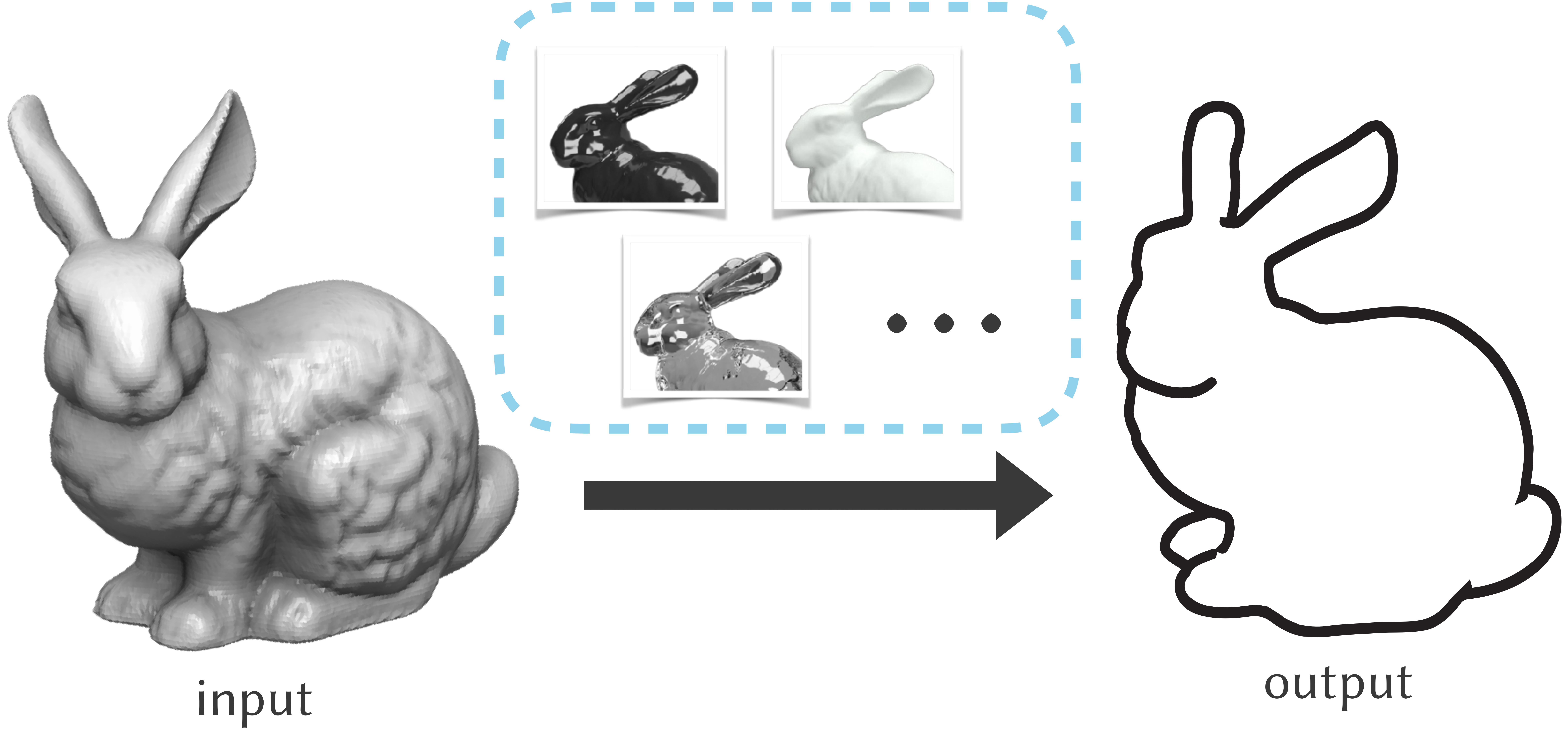
Update Visibility



$$\frac{\partial R}{\partial V} = \frac{\partial R}{\partial N}\frac{\partial N}{\partial V}$$

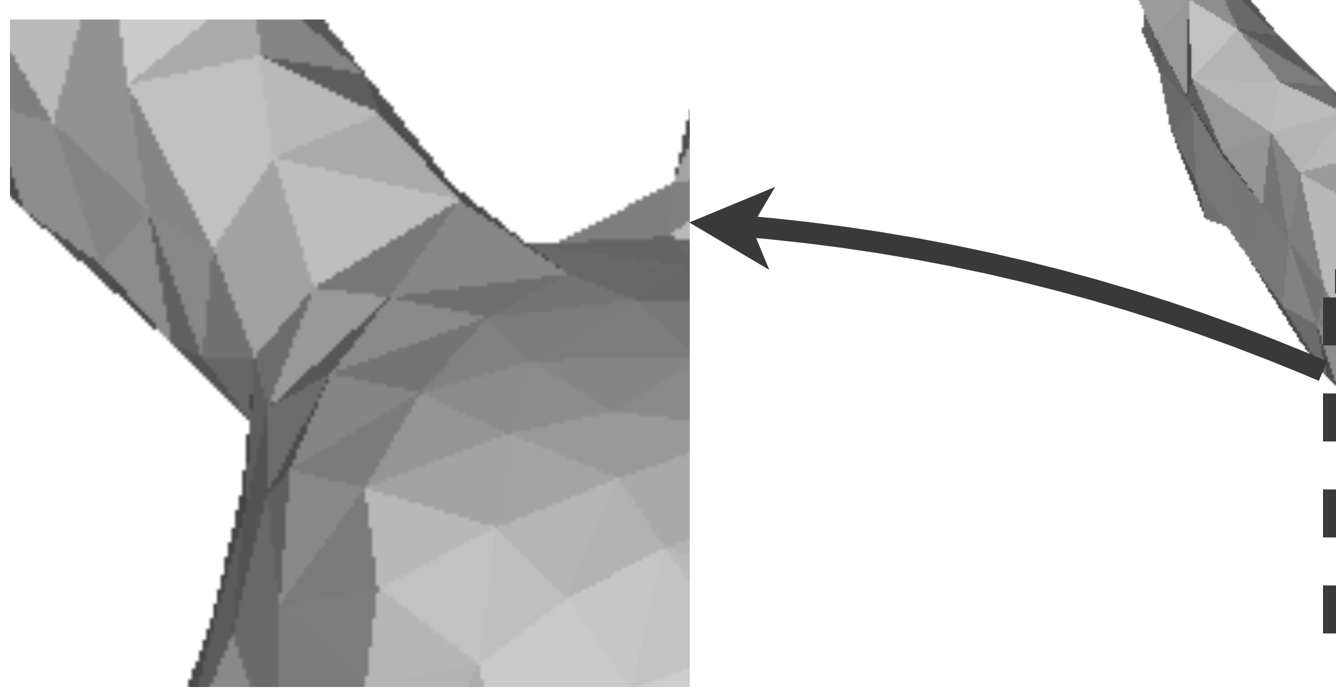
Paparazzi Differentiable Renderer

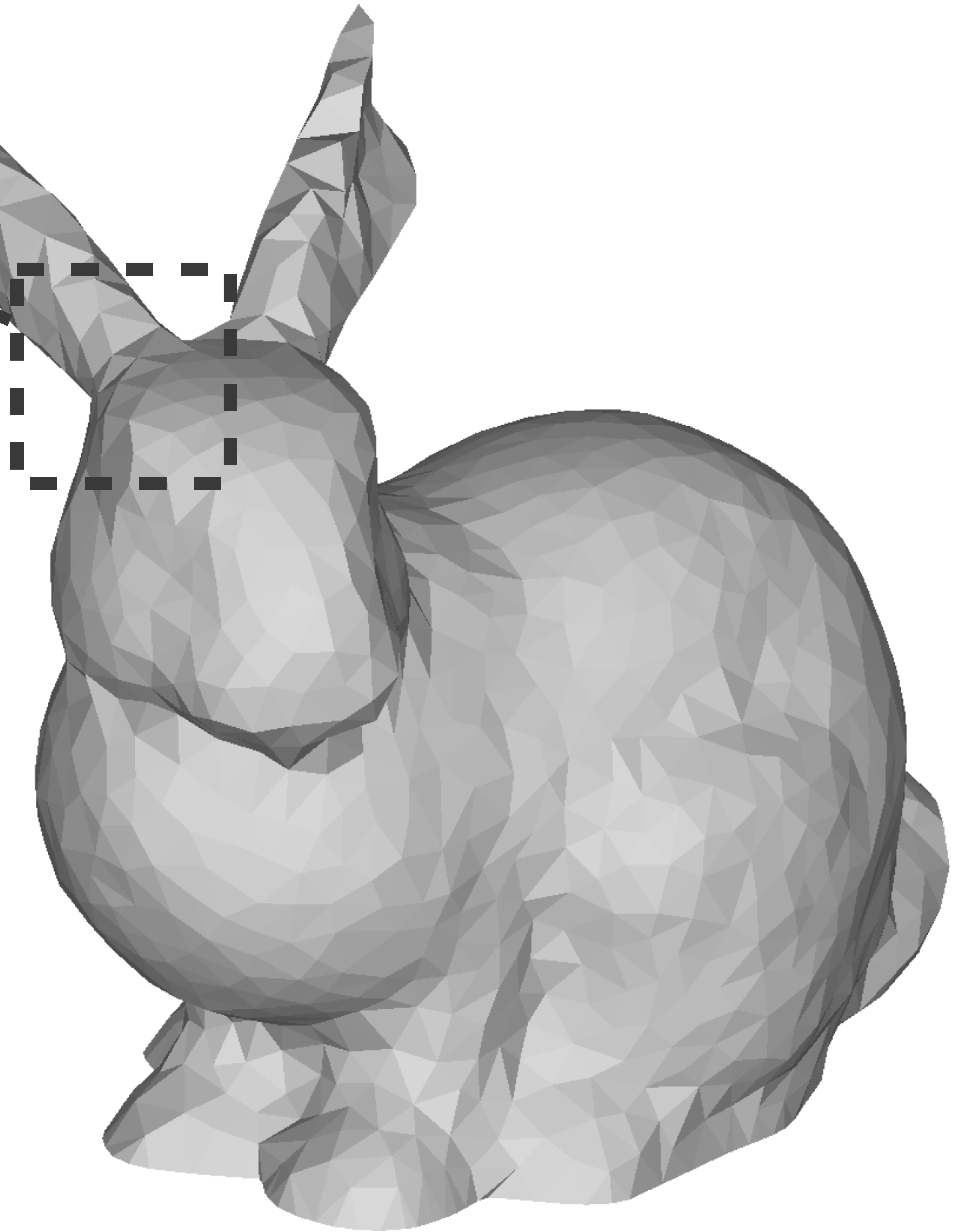
Rendering Quality Means To An End



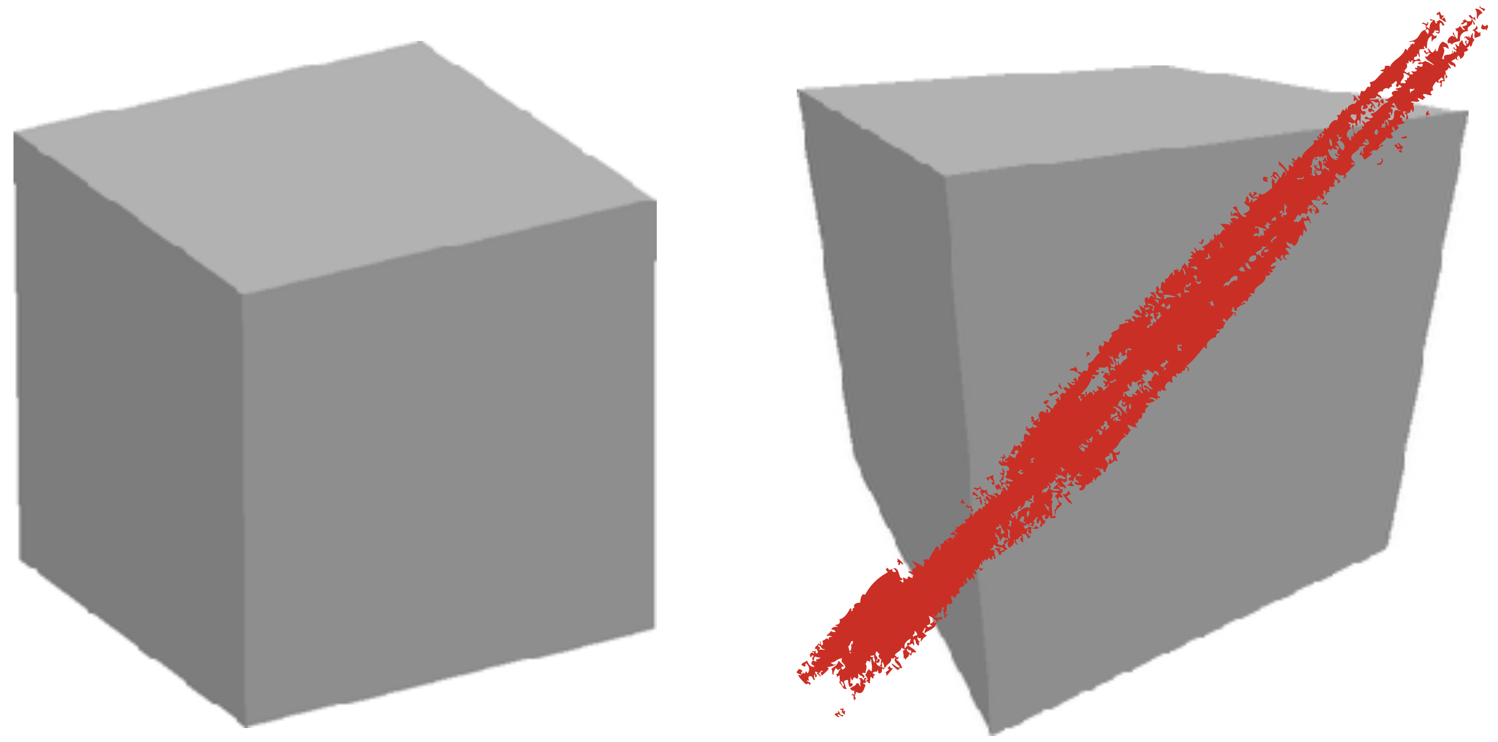
Paparazzi Renderer

Flat shading

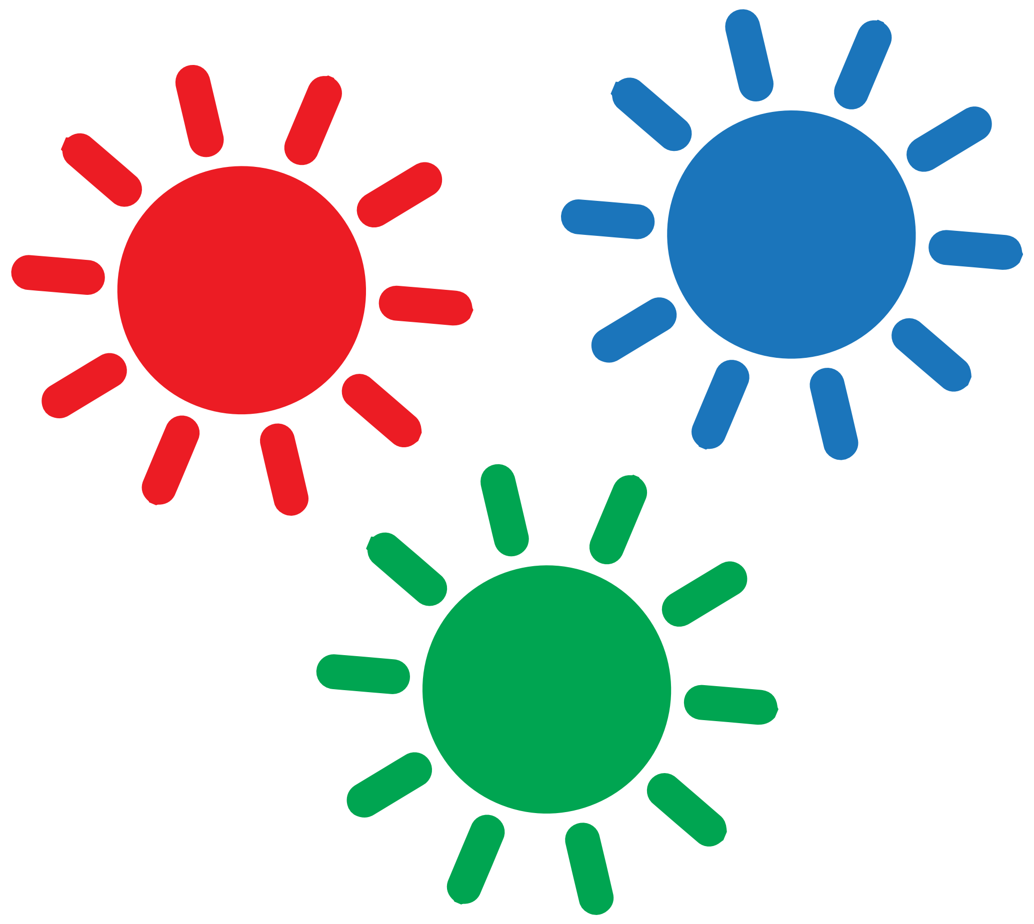




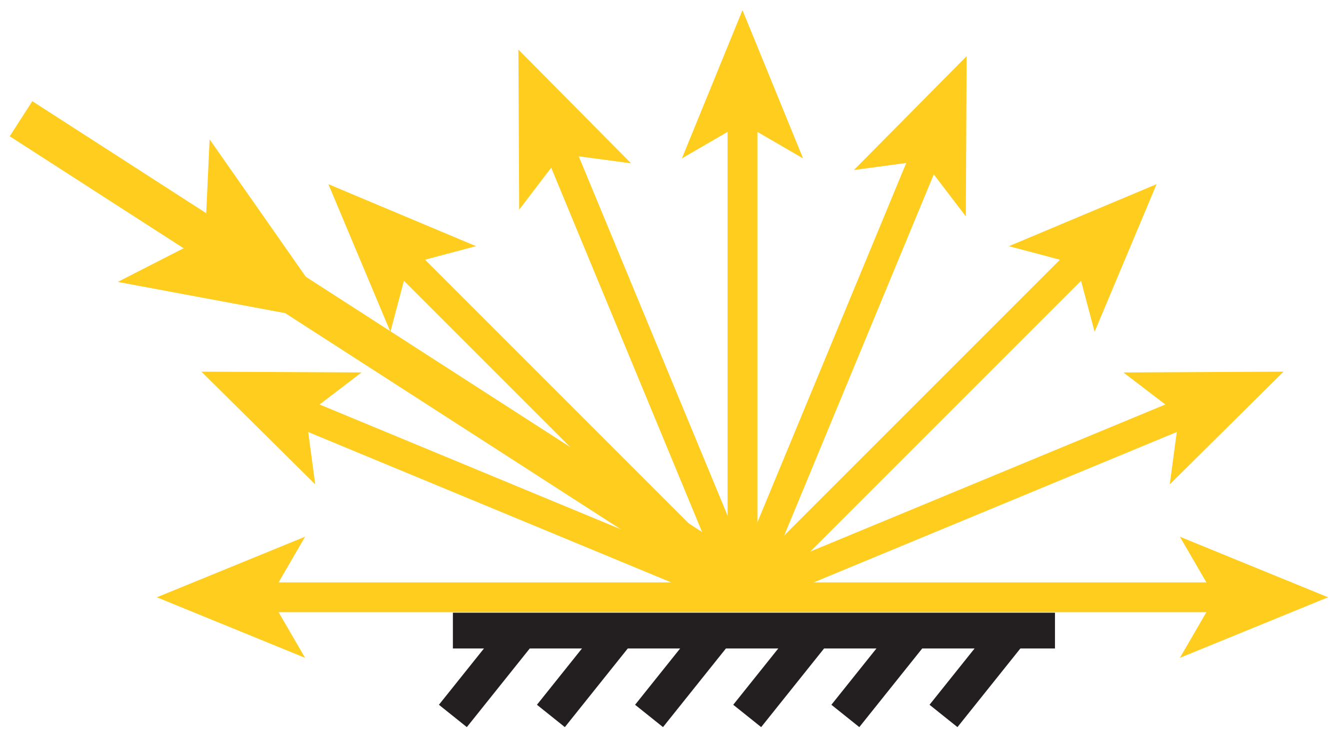
orthographic projection



directional lights

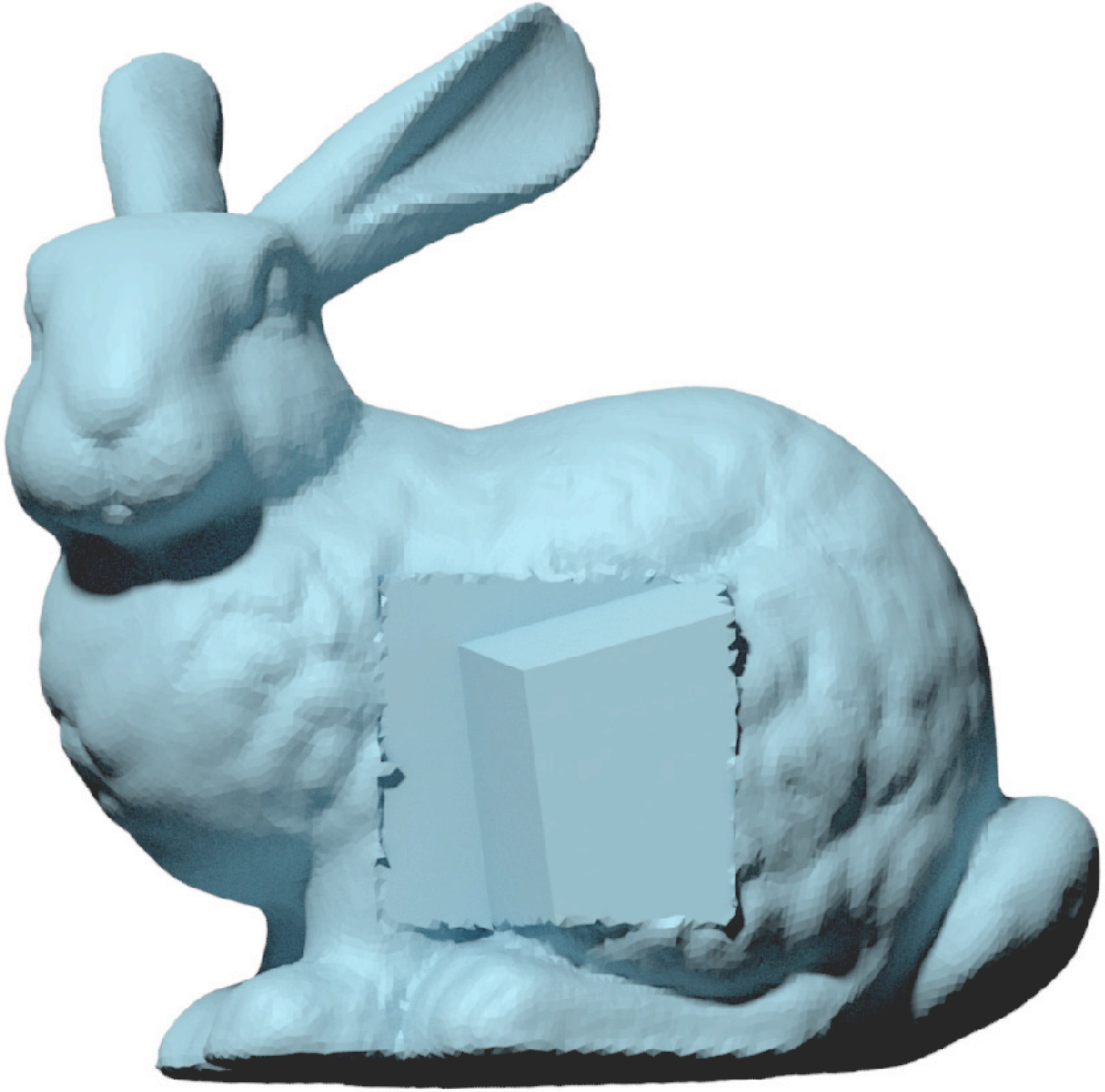


Lambertian material

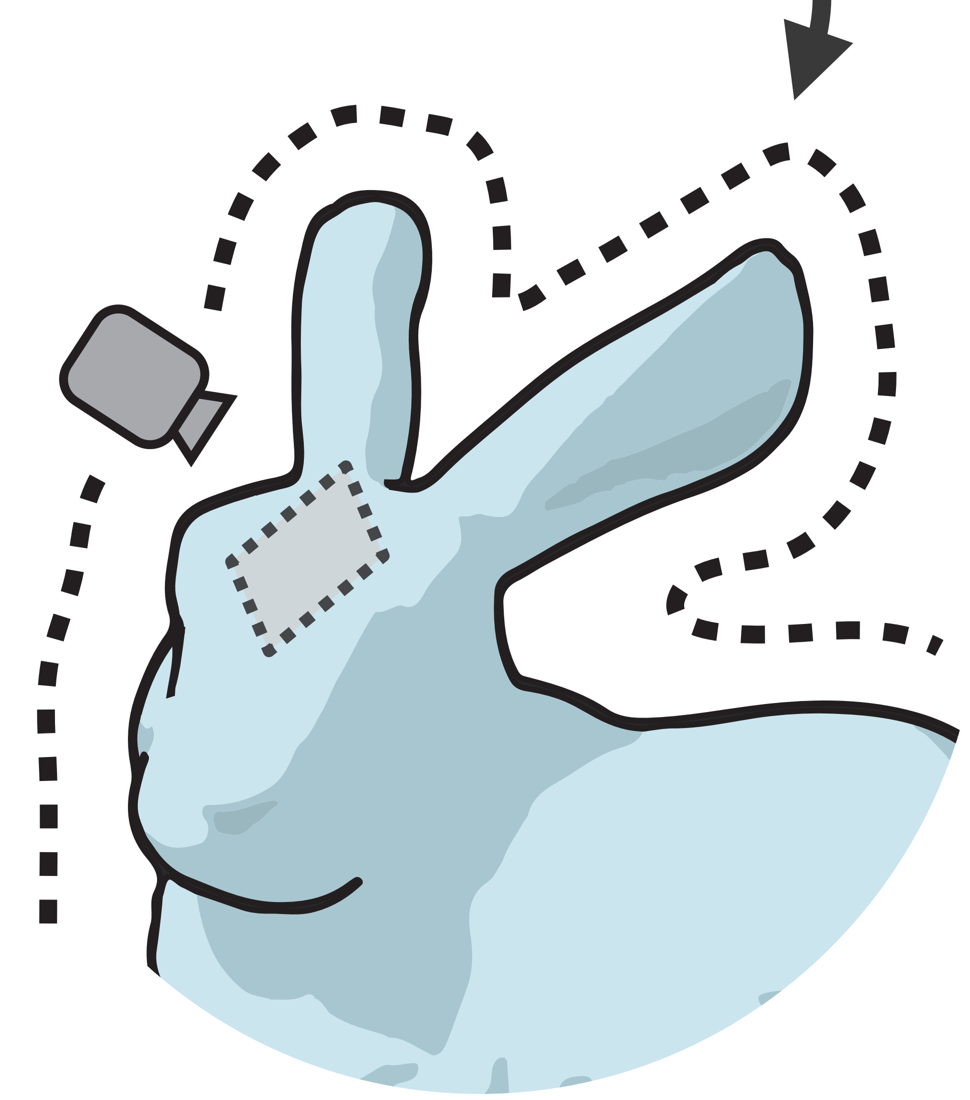


Paparazzi Renderer

Single-View



Multi-view Generalization



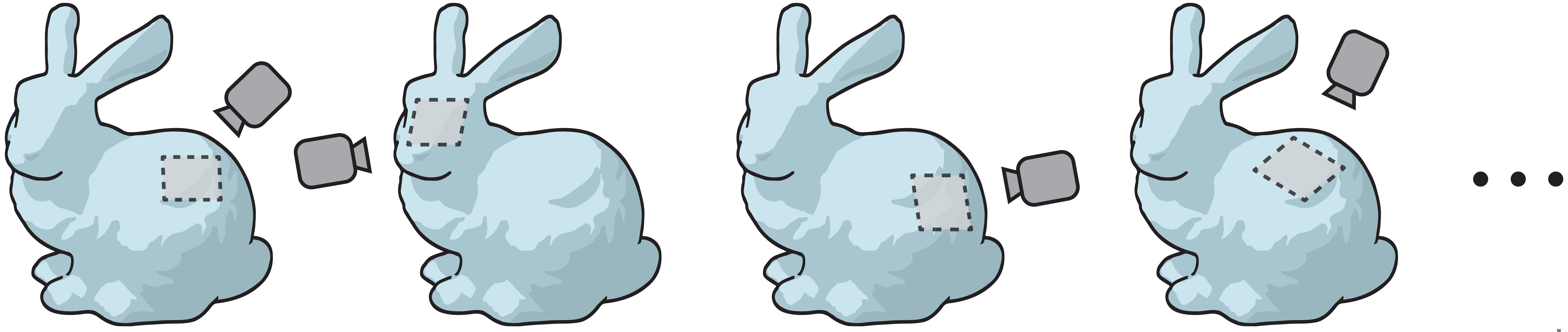
Multi-view energy:

$$V^{\star} \leftarrow \arg\min_{V} \int_{\text{cam}} E\left(R_{\text{cam}}(V)\right)$$

Gradient descent optimization:

$$V \leftarrow V - \gamma \int_{\text{cam}} \frac{\partial E}{\partial R_{\text{cam}}} \frac{\partial R_{\text{cam}}}{\partial V}$$

Stochastic gradient descent



From Energy to Filter

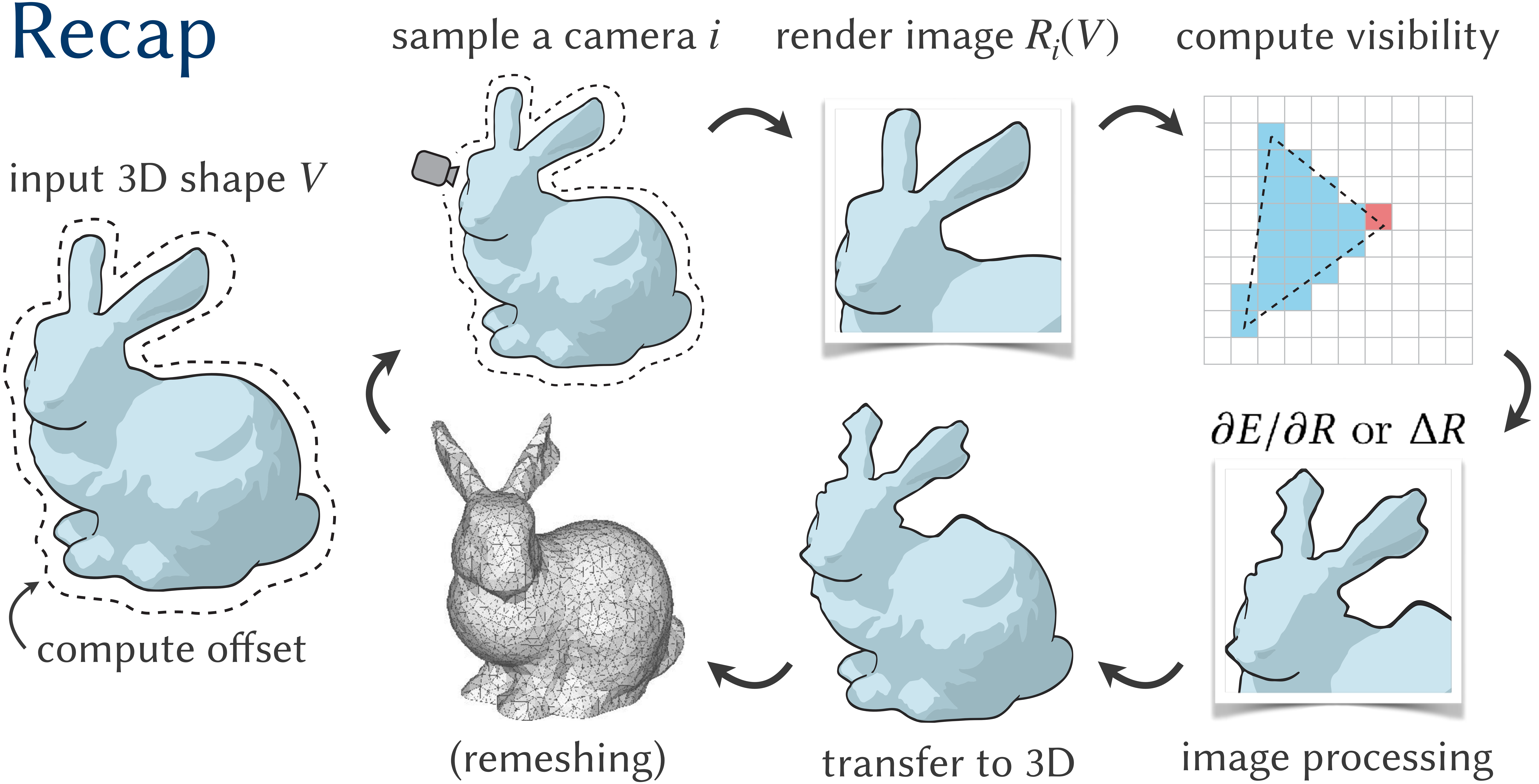
$$V \leftarrow V - \gamma \int \cancel{\frac{\partial E}{\partial R}} \frac{\partial R}{\partial V}$$

$$\Rightarrow V \leftarrow V - \gamma \int \Delta R \frac{\partial R}{\partial V}$$

$\Delta R =$  $-$ 

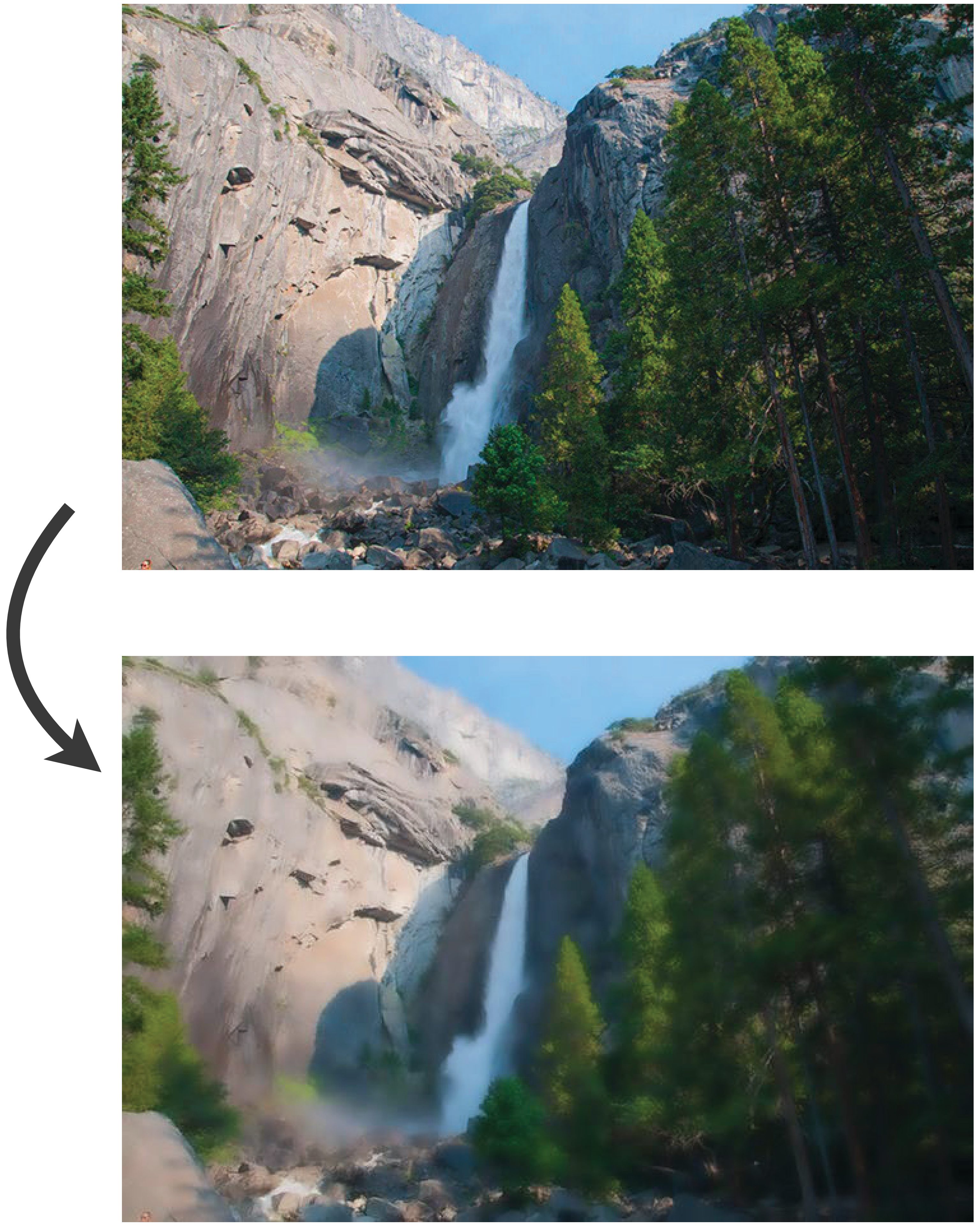
filtered image original image

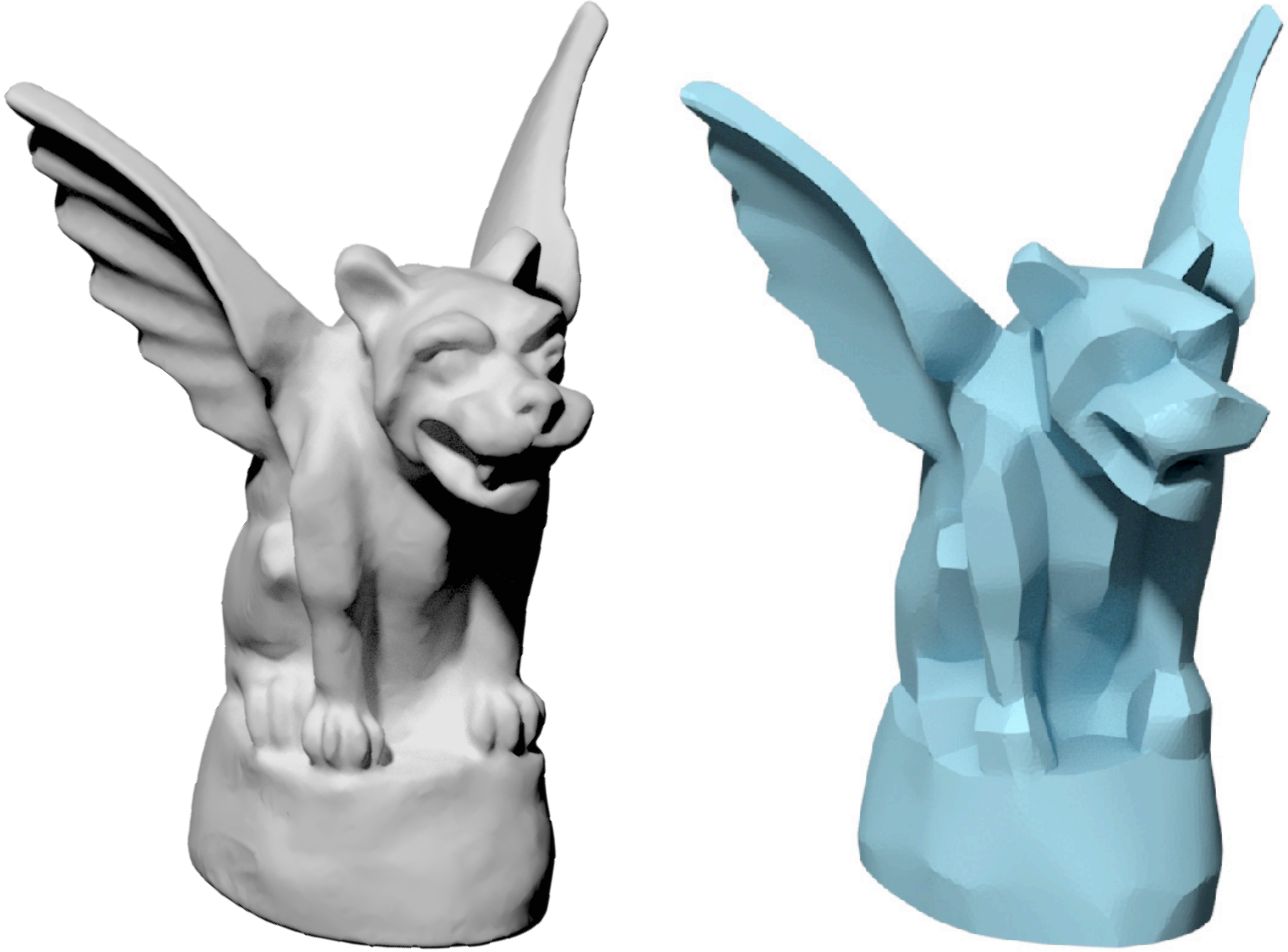
Recap


sample a camera i
render image $R_i(V)$
compute visibility
input 3D shape V
$\partial E/\partial R$ or ΔR
compute offset
(remeshing)
transfer to 3D
image processing

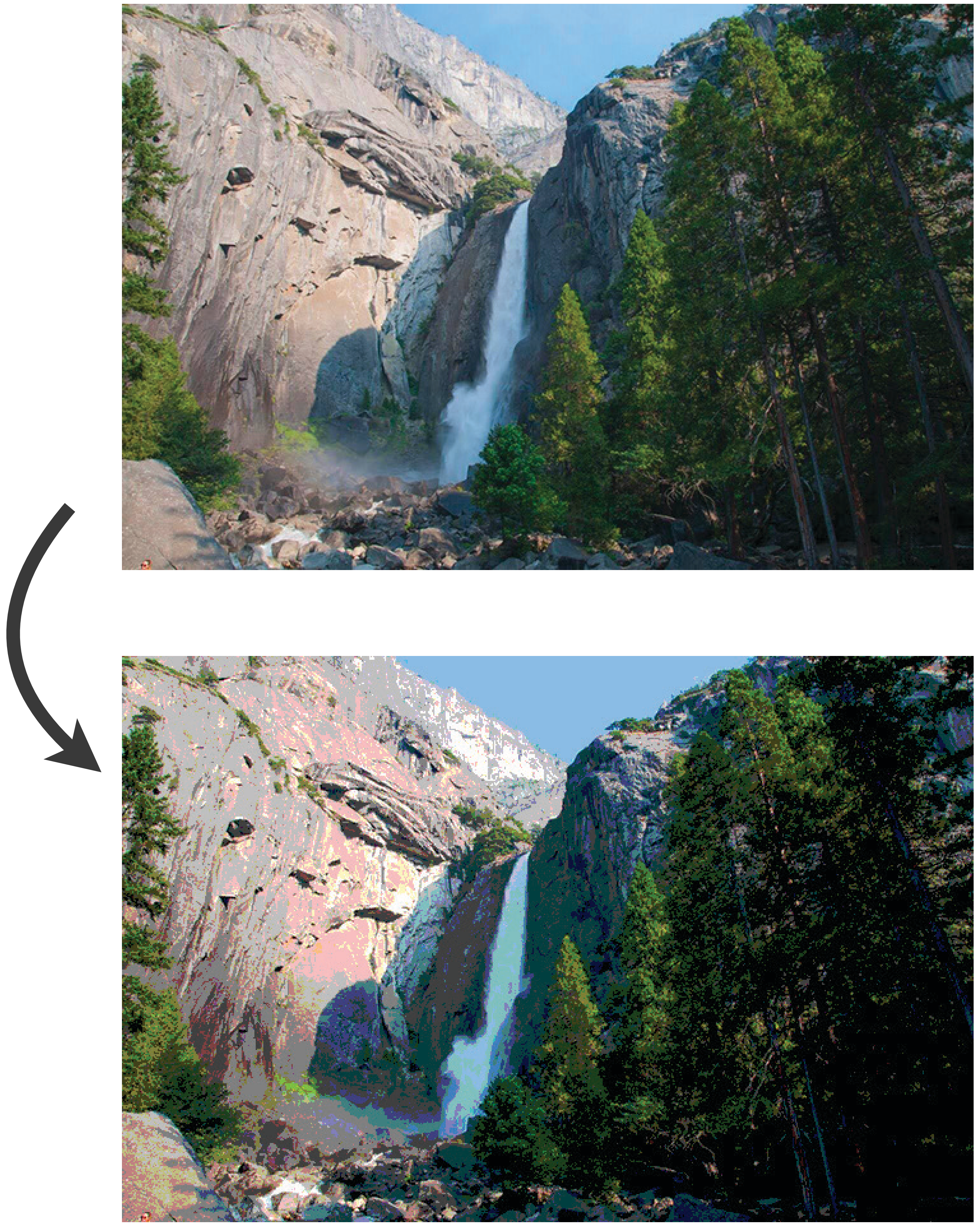
Results

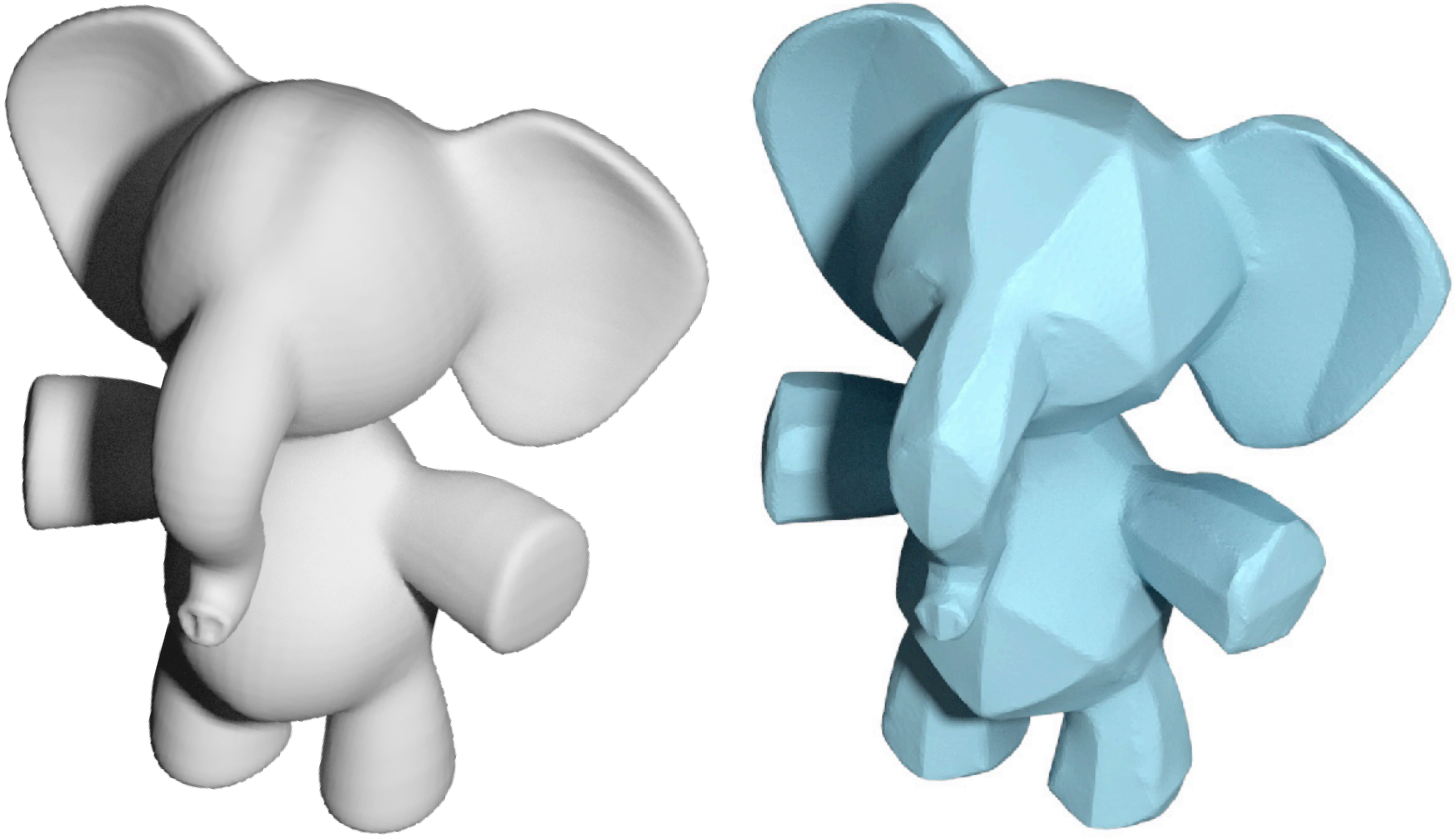
Fast Guided Filter [He and Sun 2015]



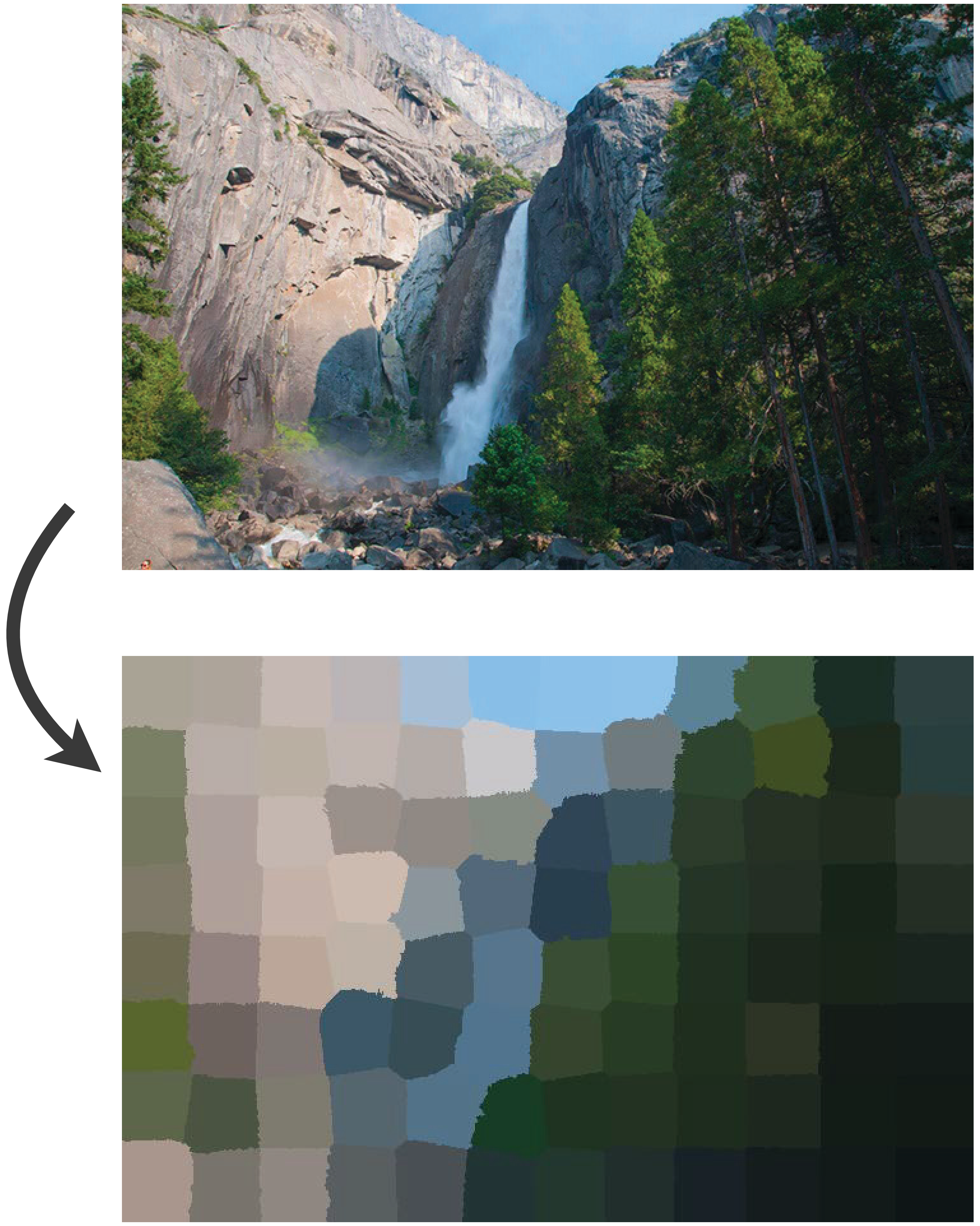


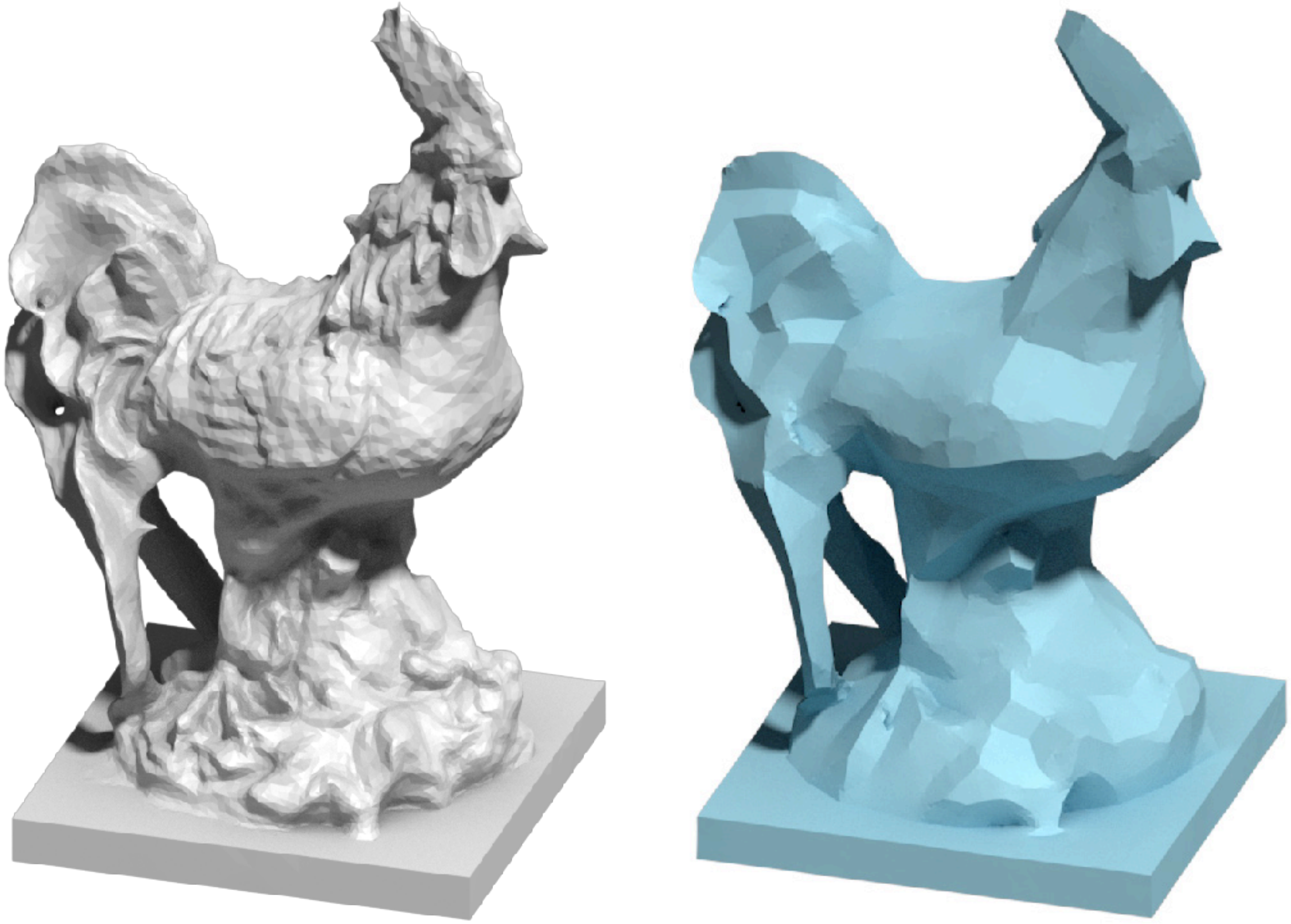
Quantization [Ozturk et al. 2014]



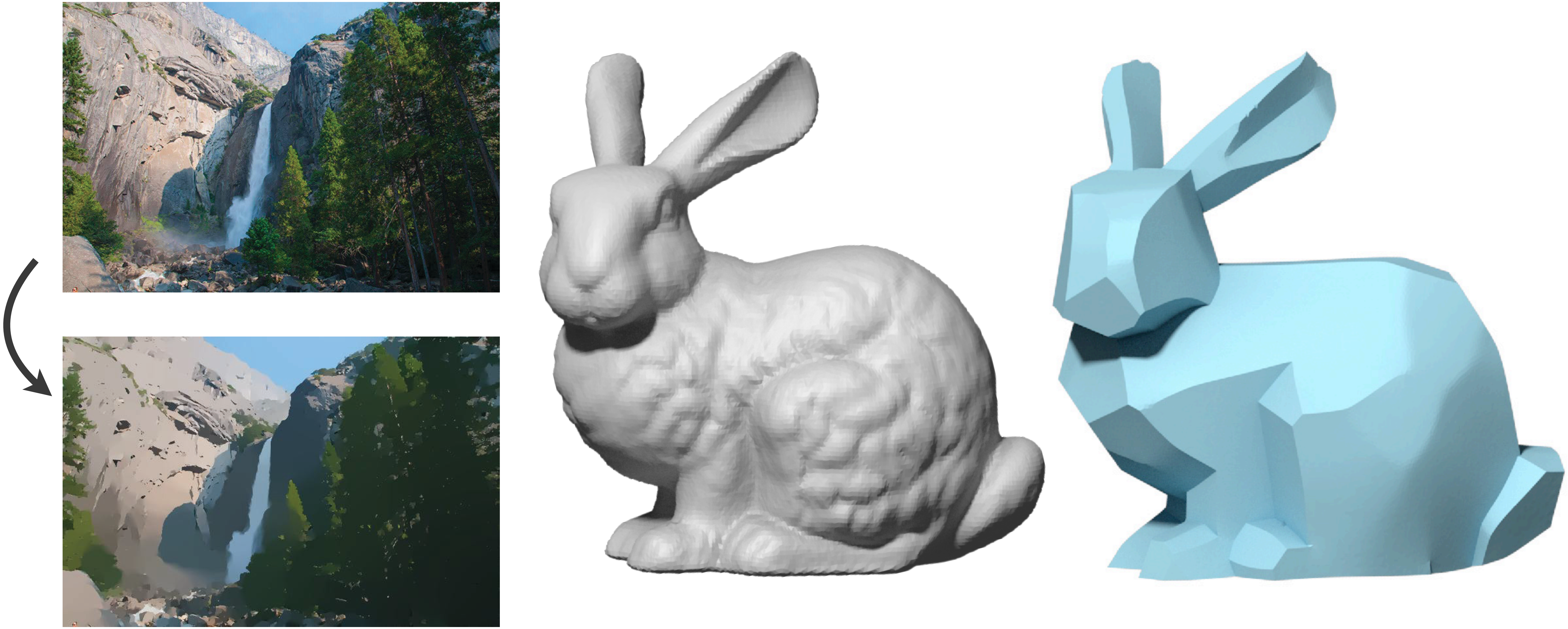


SLIC Superpixel [Achanta et al. 2012]

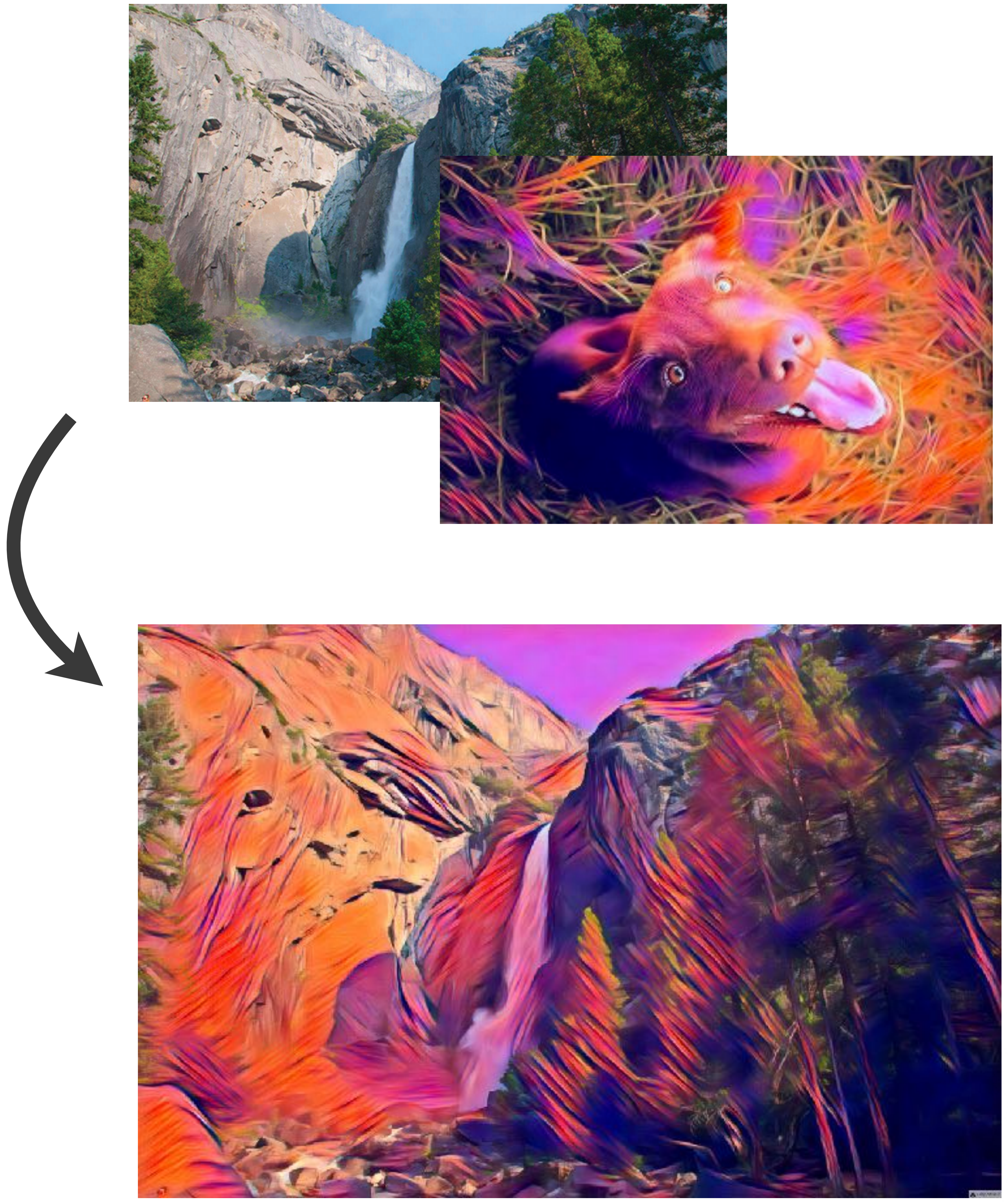




L0 Gradient Regularization [Xu et al. 2011]



Neural Style Transfer [Gatys et al. 2016]



Neural Style Transfer [Gatys et al. 2016]

Limitations & Future Work

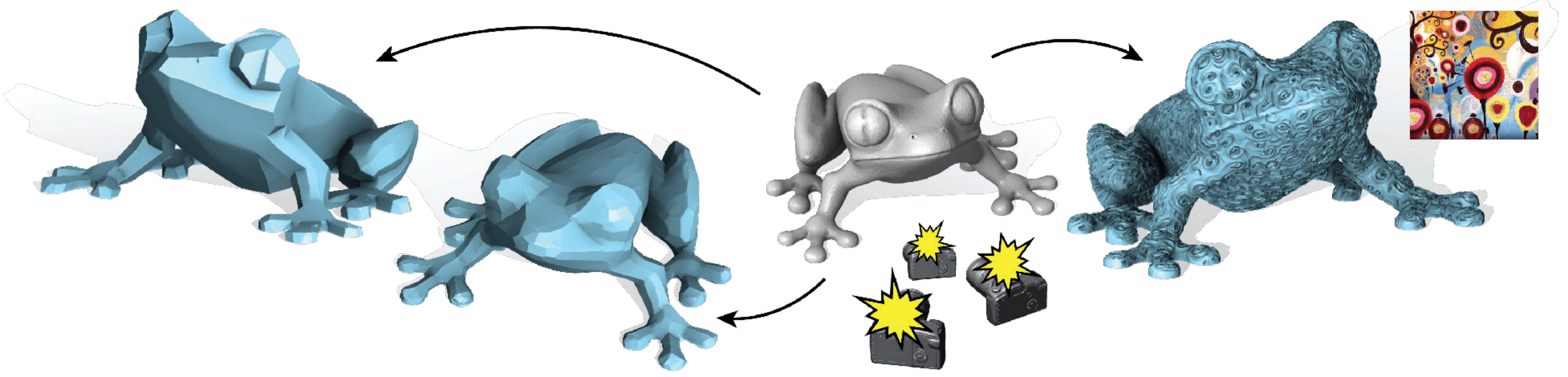
Surface editing using image processing
- accelerate (batch gradient descent)
- large deformations
- combine 3D and 2D editing

Analytically differentiable renderer
- applications in computer vision & machine learning
- incorporate real-time rendering techniques

3D adversarial examples

street sign
98%

mailbox
83%



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