

# Computer Graphics

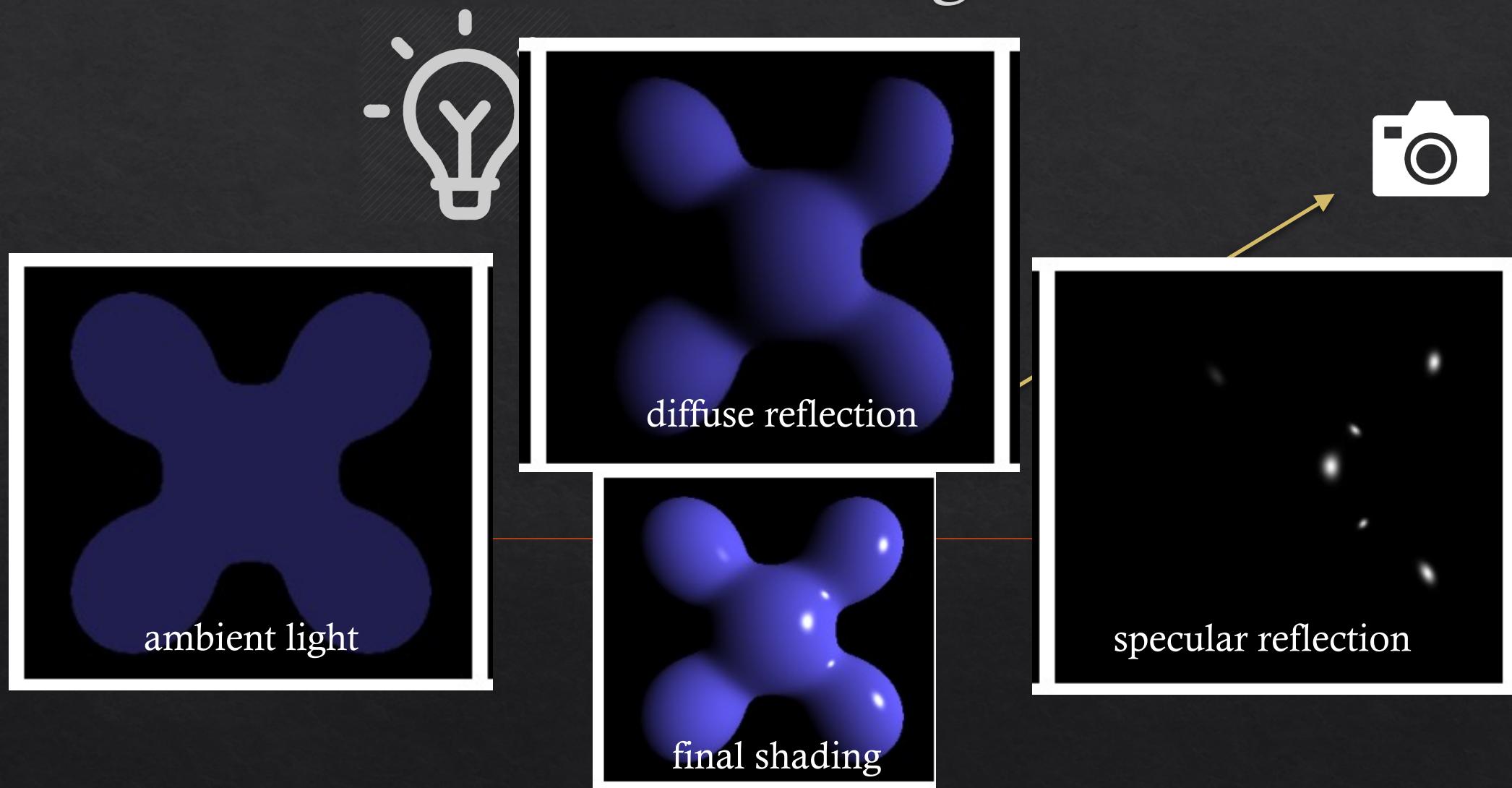
Lecture 7: Raytracing - advanced

Kartic Subr

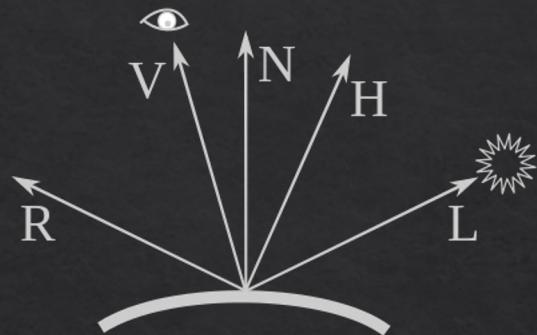
# Recap

for each pixel p  
trace ray  
shade hit point

# Shading

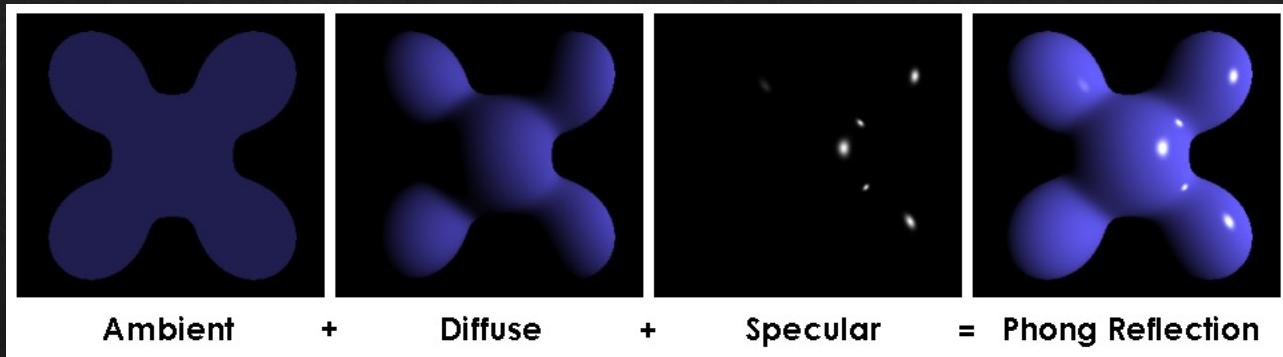


# Phong shading



$$I_p = k_a i_a + \sum_{m \in \text{lights}} (k_d (\hat{L}_m \cdot \hat{N}) i_{m,d} + k_s (\hat{R}_m \cdot \hat{V})^\alpha i_{m,s})$$

ambient                      diffuse                      specular



light property

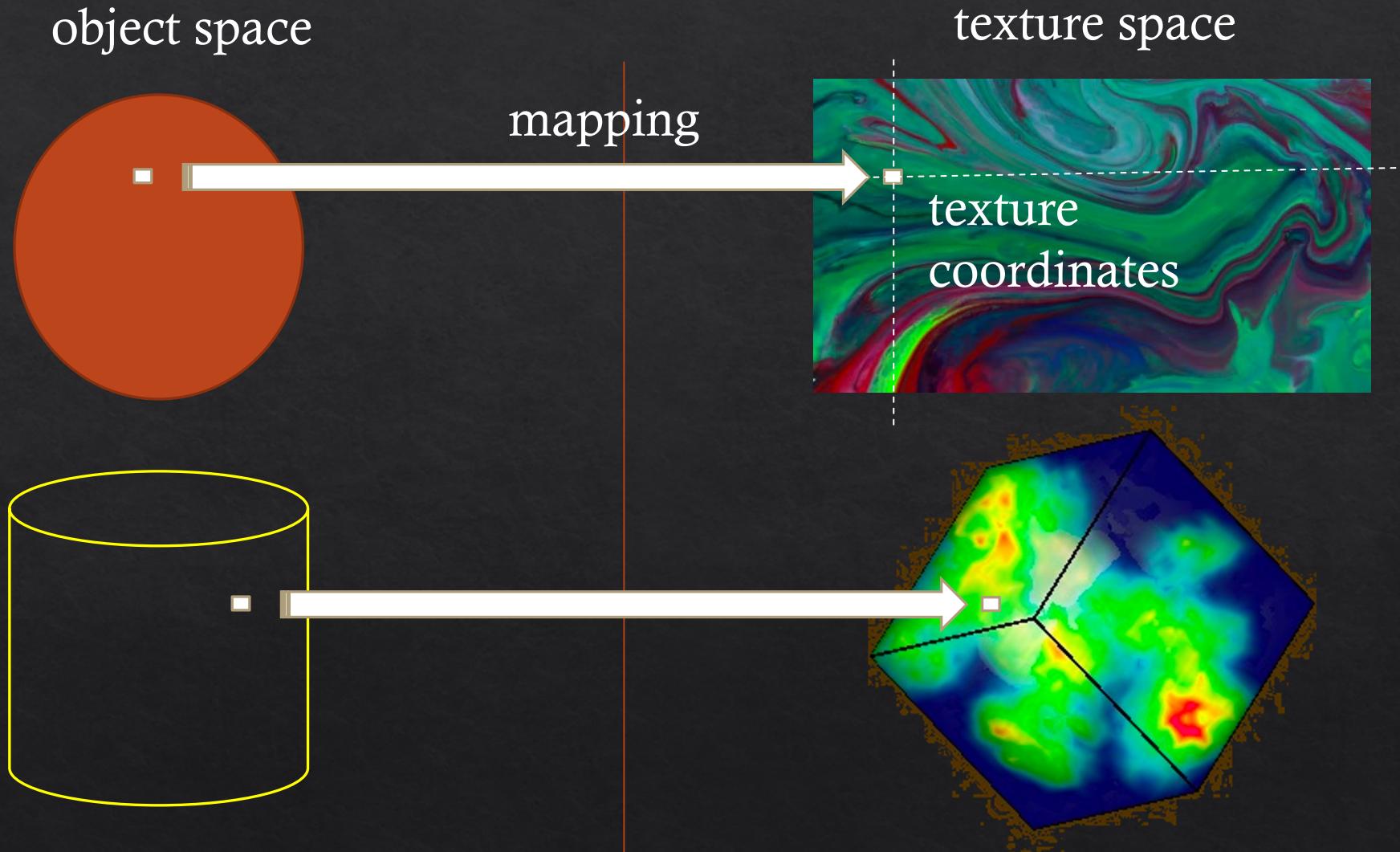
R is the mirror  
reflection direction

source:wikipedia

# How to deal with texture?



# How to deal with texture?



# Texture coordinates on a sphere

$$r = \sqrt{x^2 + y^2 + z^2}$$

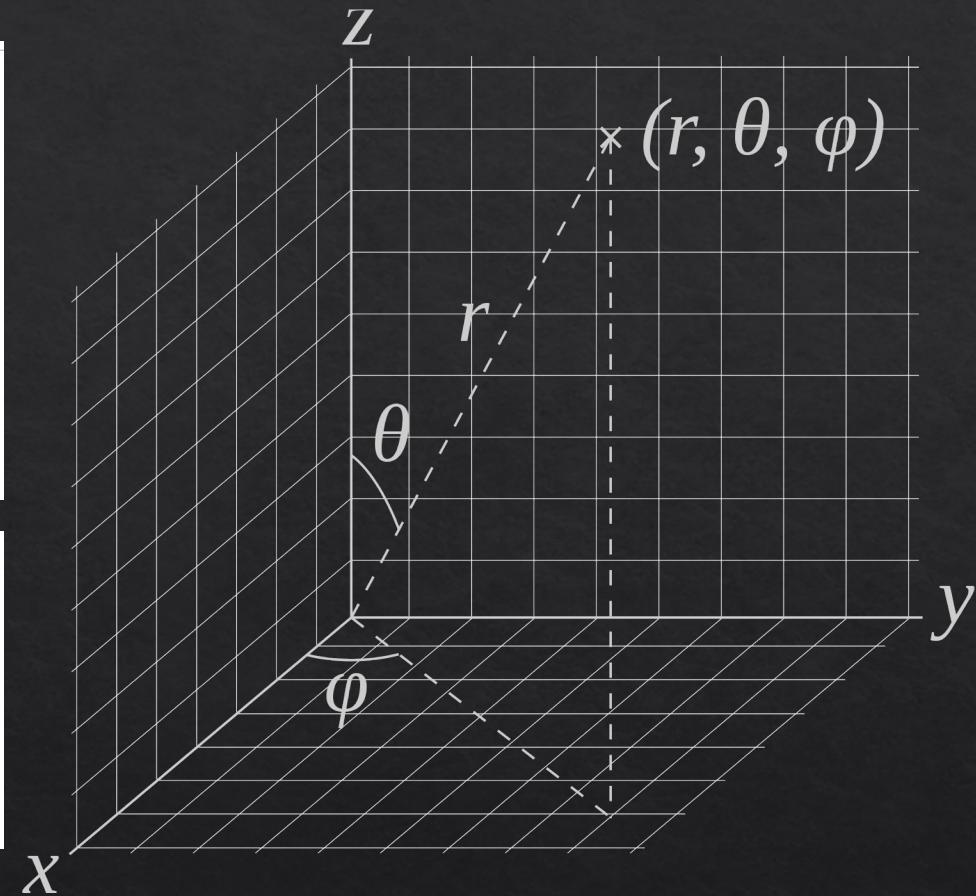
$$\varphi = \arctan \frac{y}{x}$$

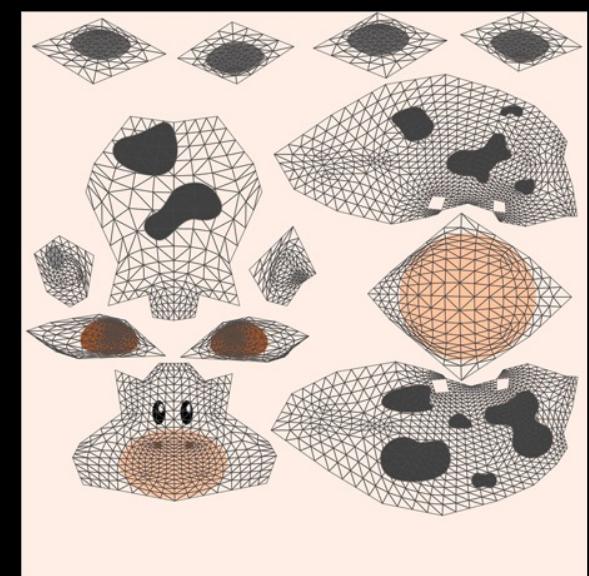
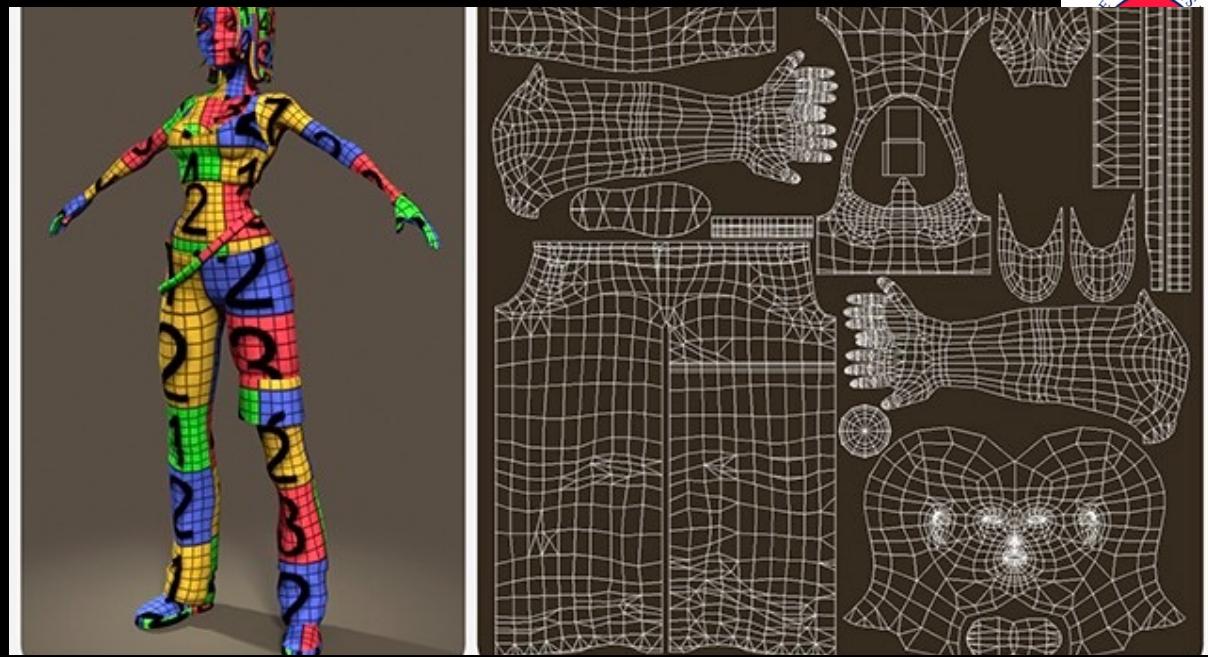
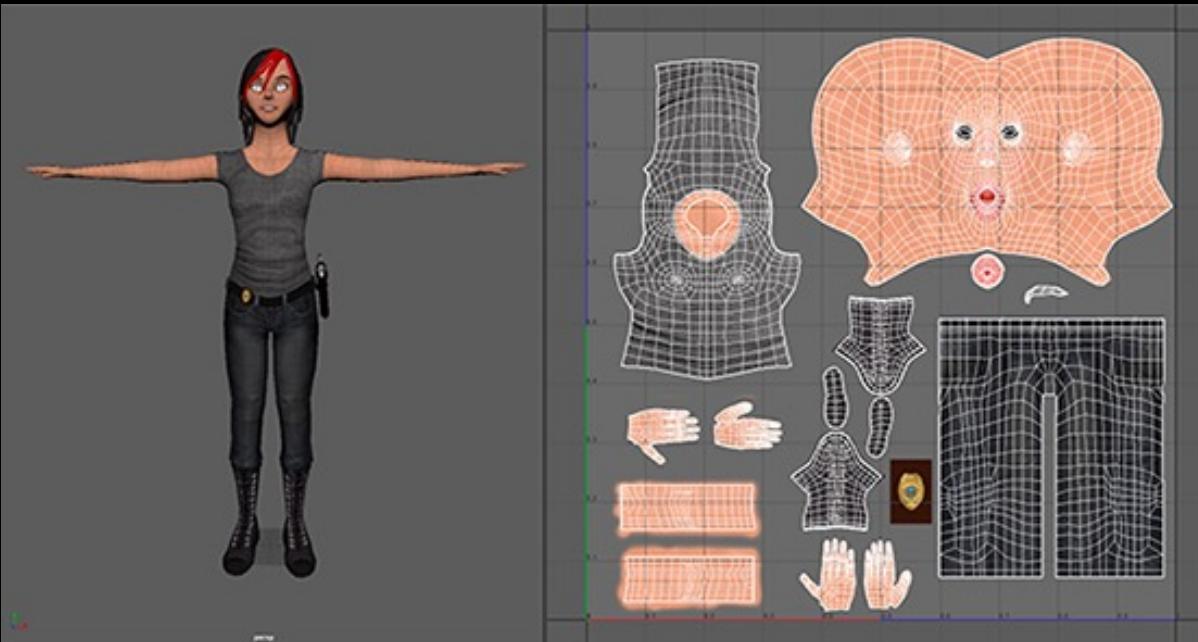
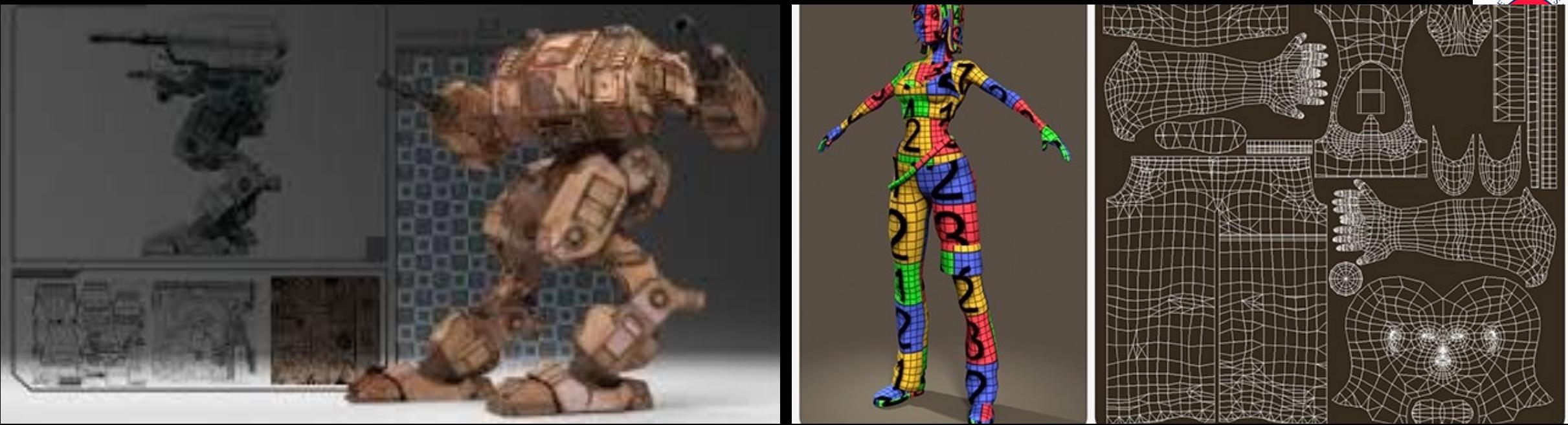
$$\theta = \arccos \frac{z}{\sqrt{x^2 + y^2 + z^2}} = \arccos \frac{z}{r}$$

$$x = r \sin \theta \cos \varphi$$

$$y = r \sin \theta \sin \varphi$$

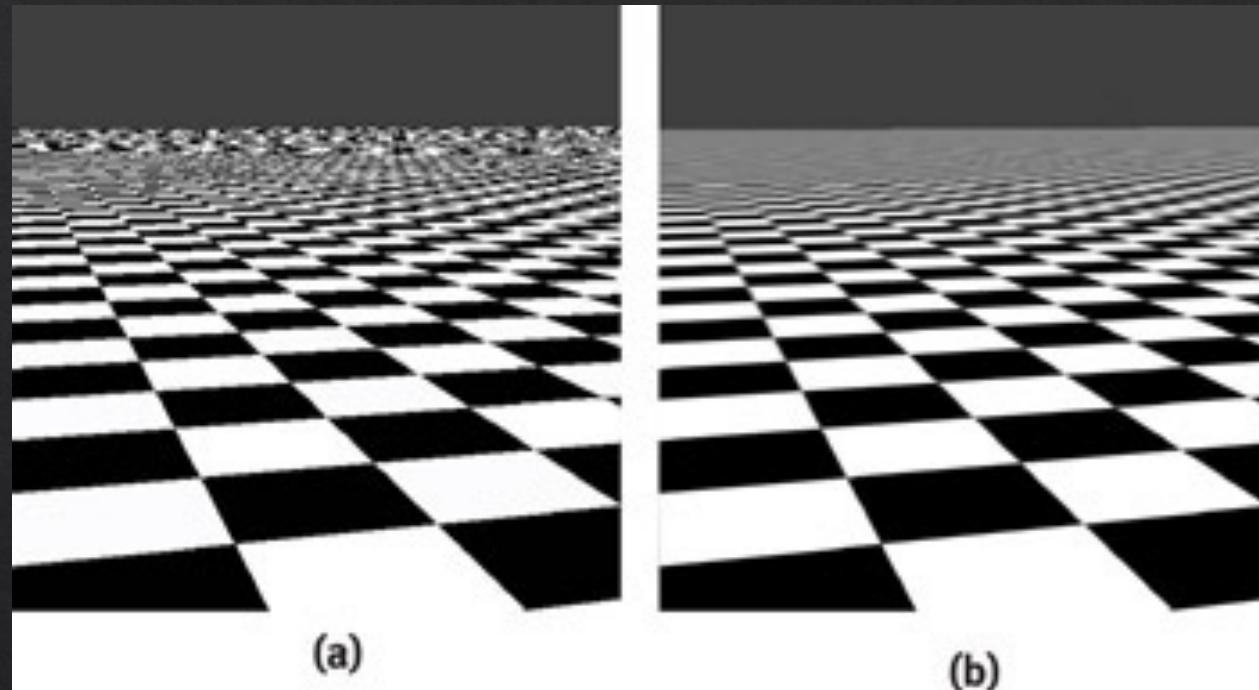
$$z = r \cos \theta$$





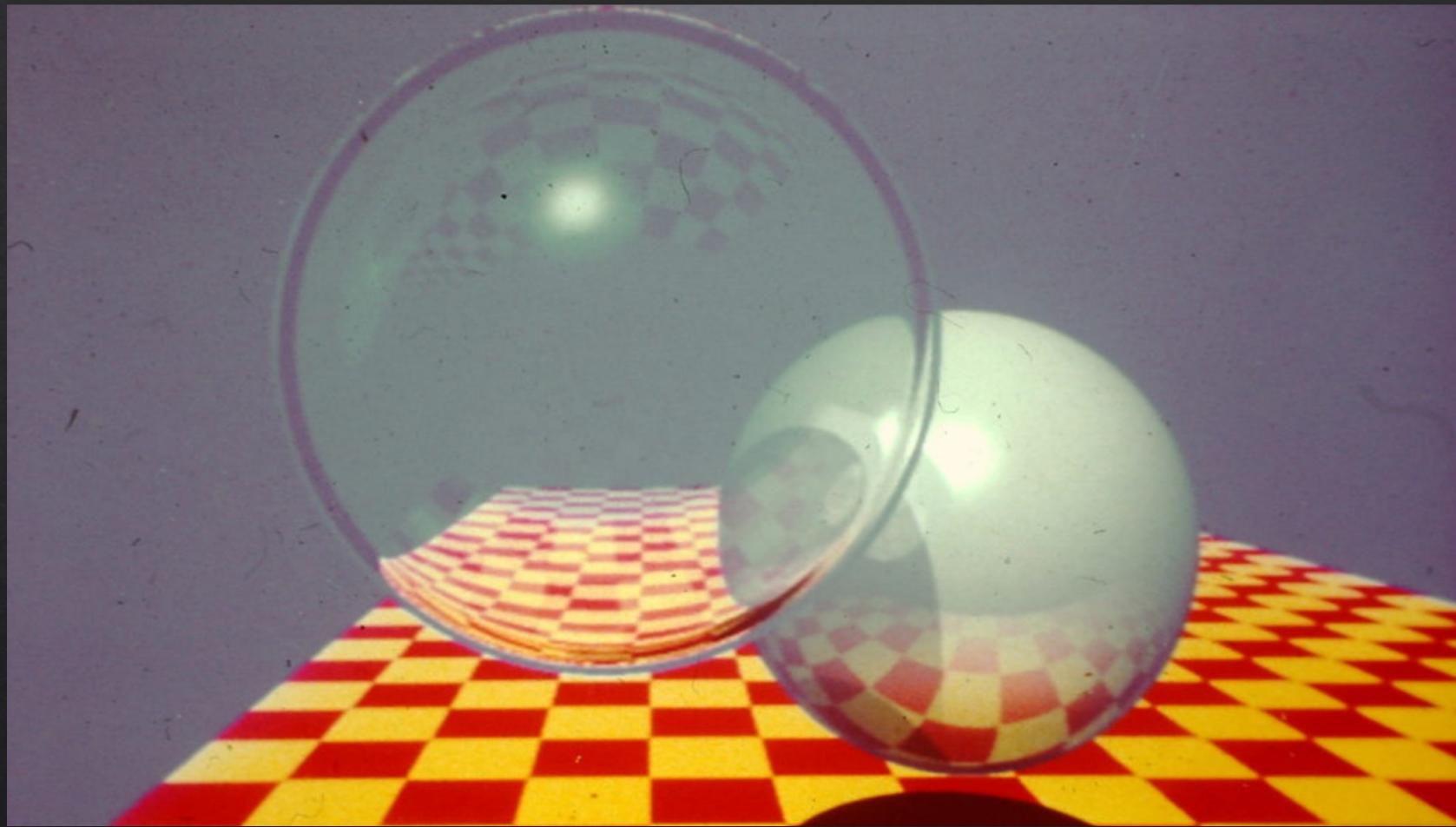
# Problems

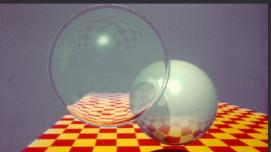
- How to generate maps?
- Finite resolution
- Artifacts
- More later!



[http://www.cemyuksel.com/courses/conferences/siggraph2017-rethinking\\_texture\\_mapping/rethinking\\_texture\\_mapping\\_course\\_notes.pdf](http://www.cemyuksel.com/courses/conferences/siggraph2017-rethinking_texture_mapping/rethinking_texture_mapping_course_notes.pdf)

# What's wrong with this image?



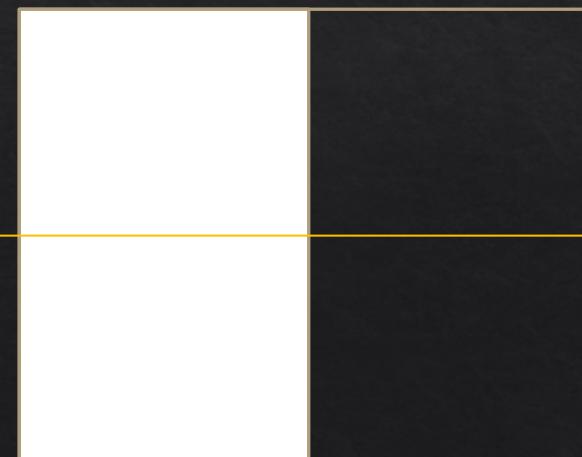
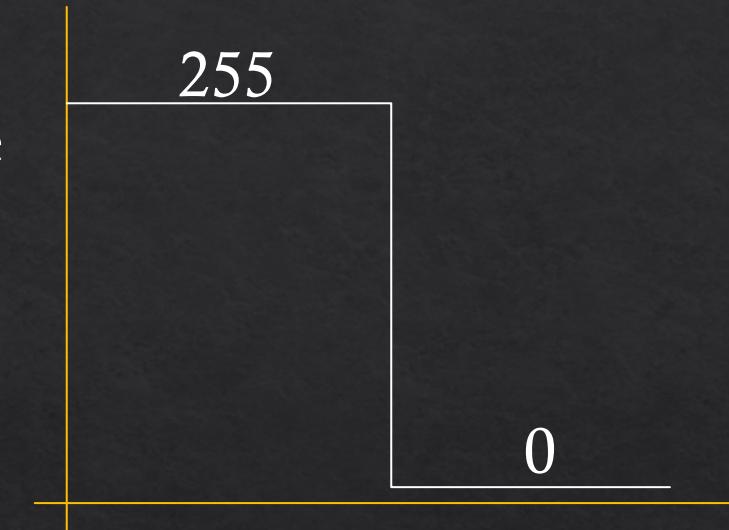


# Does not have any blur!



# What causes blur?

# A step function (edge)

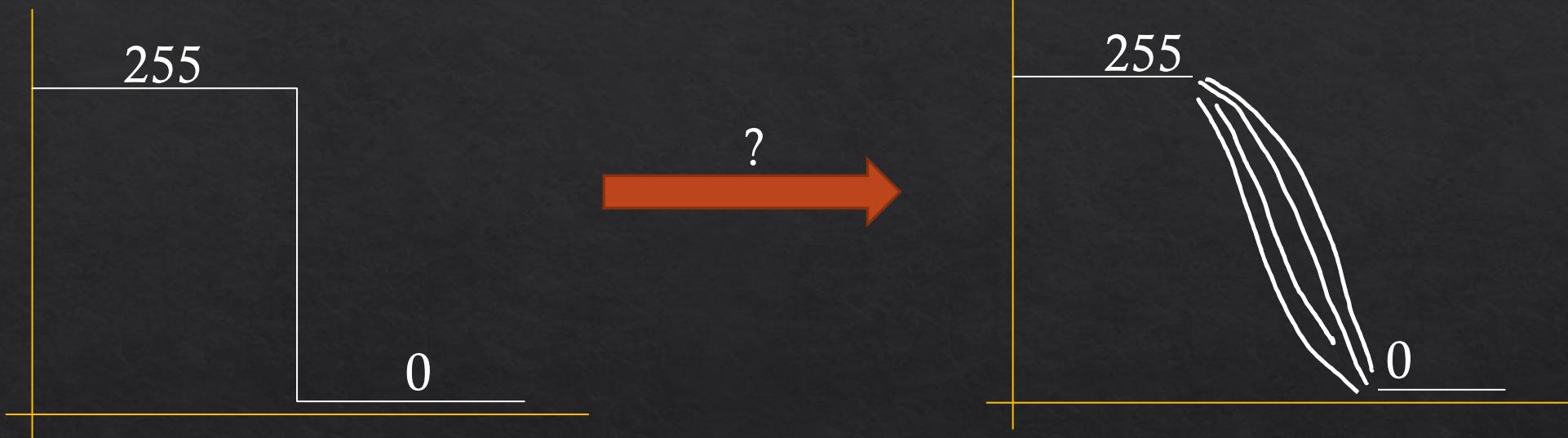


image

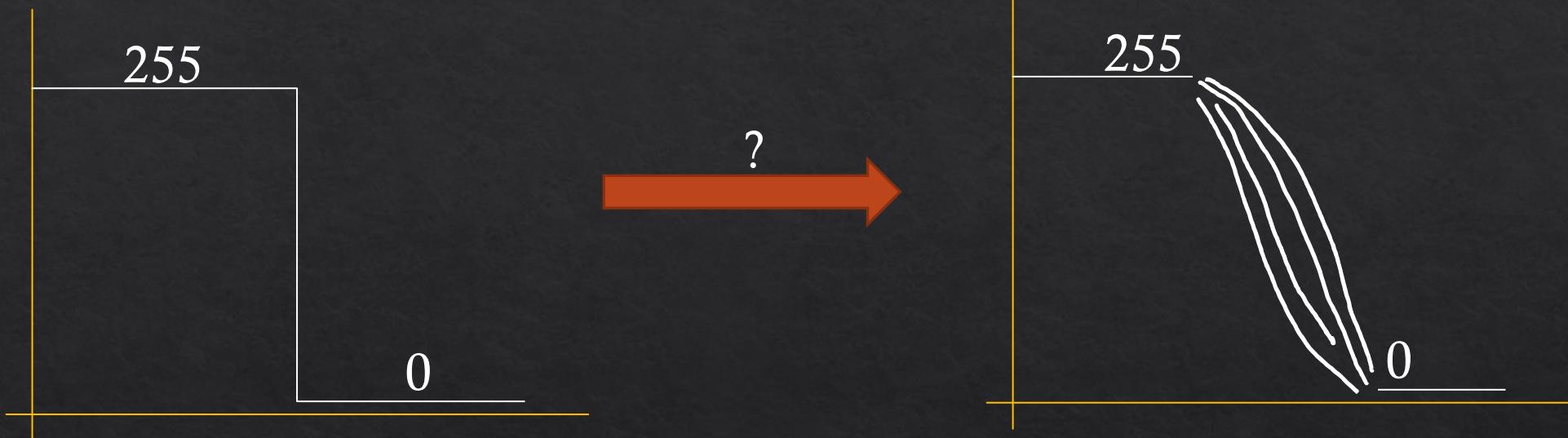
# A blurred step function



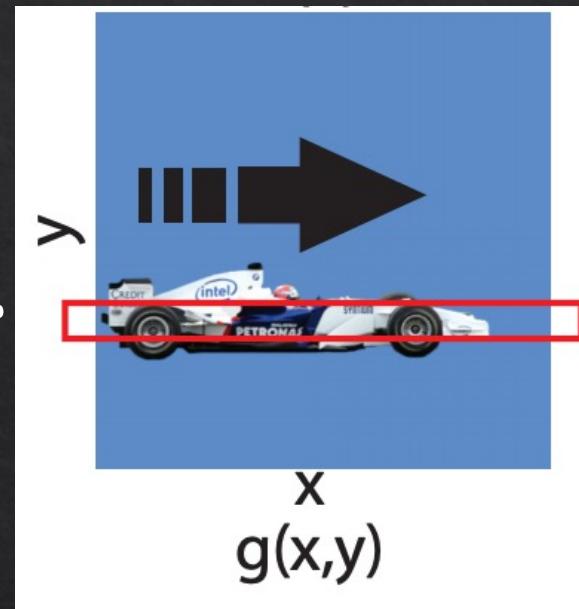
# Fundamental operation?



# Fundamental operation?



# Example: photo of a car



# Example: motion blur



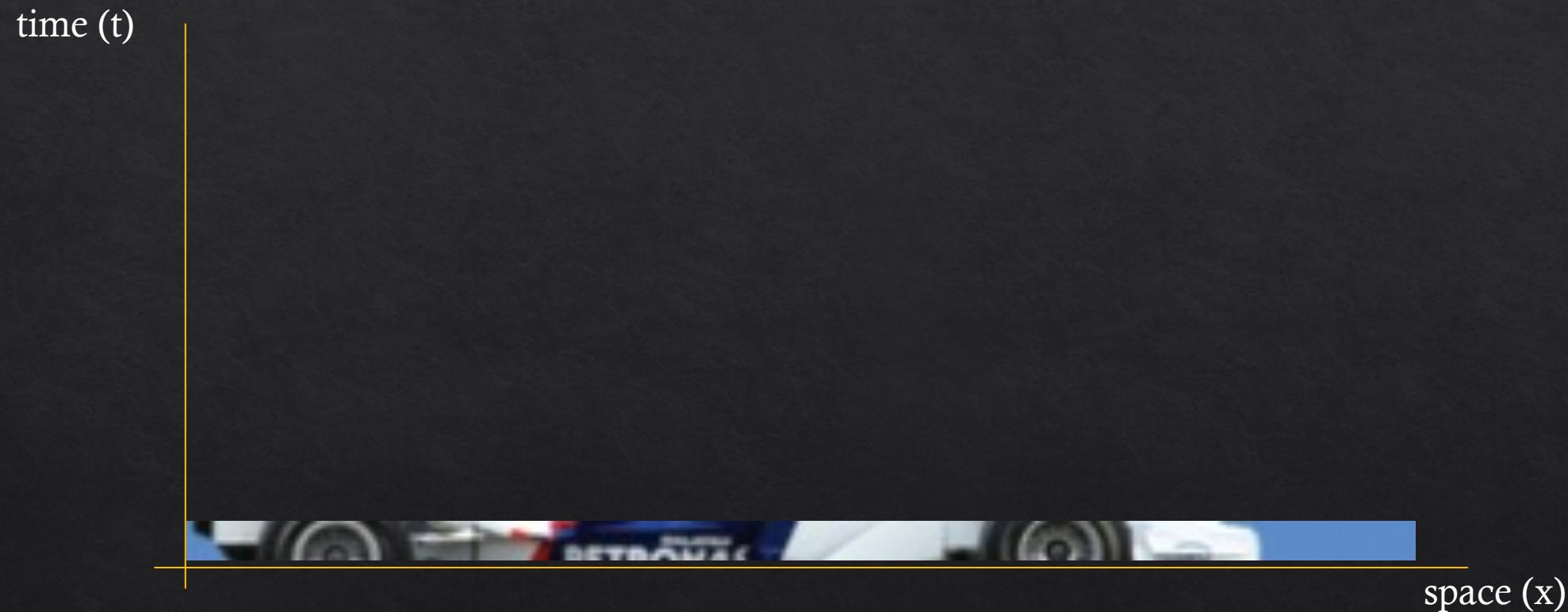
# Example: slice is a 1D function

$f(x)$

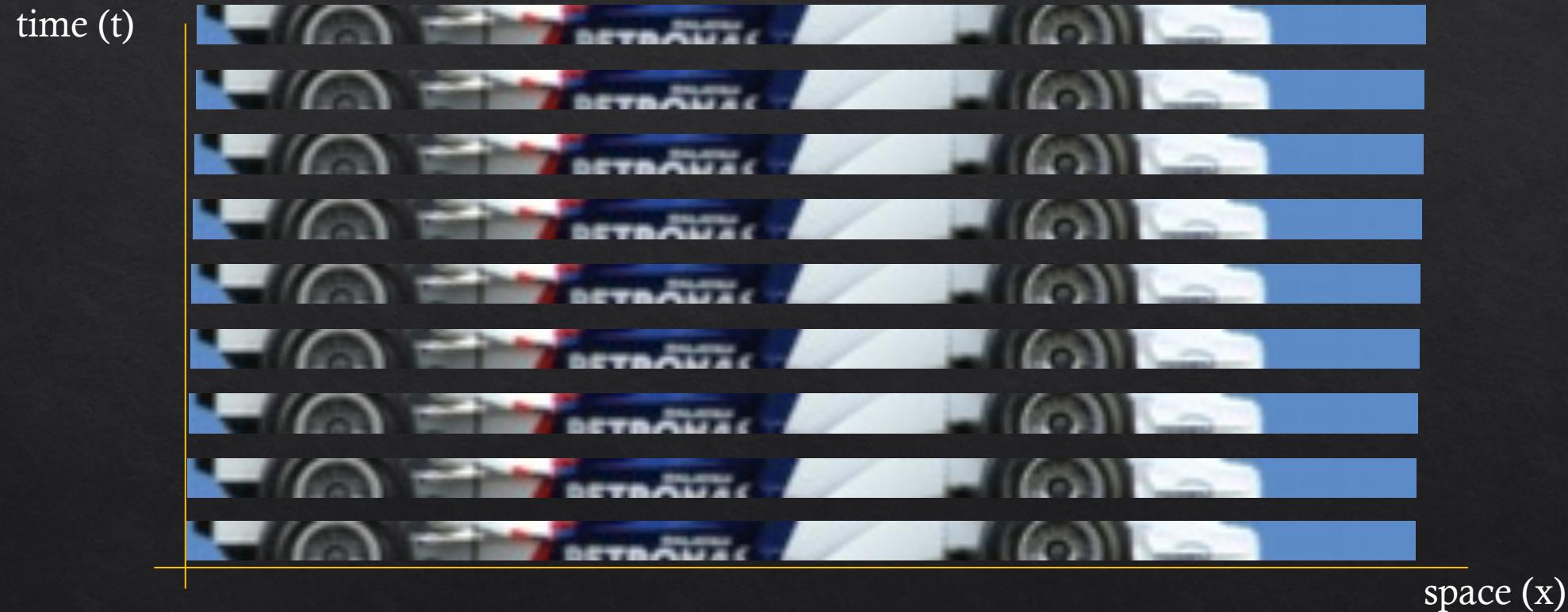


space ( $x$ )

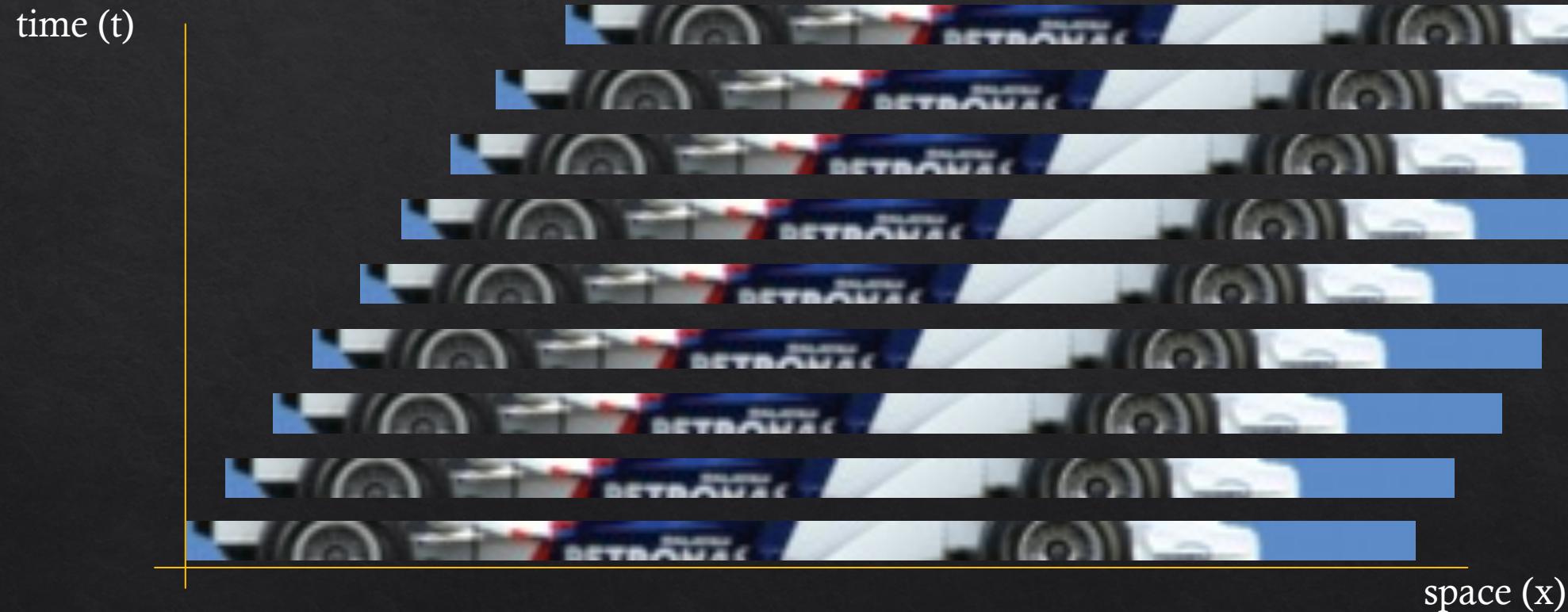
# Example: add time as second dimension



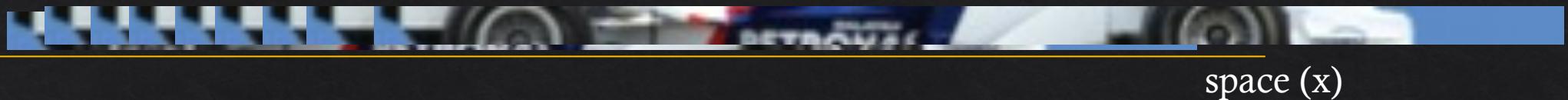
# Example: stationary car



# Example: car moving to the right



# Example: sum of shifted positions

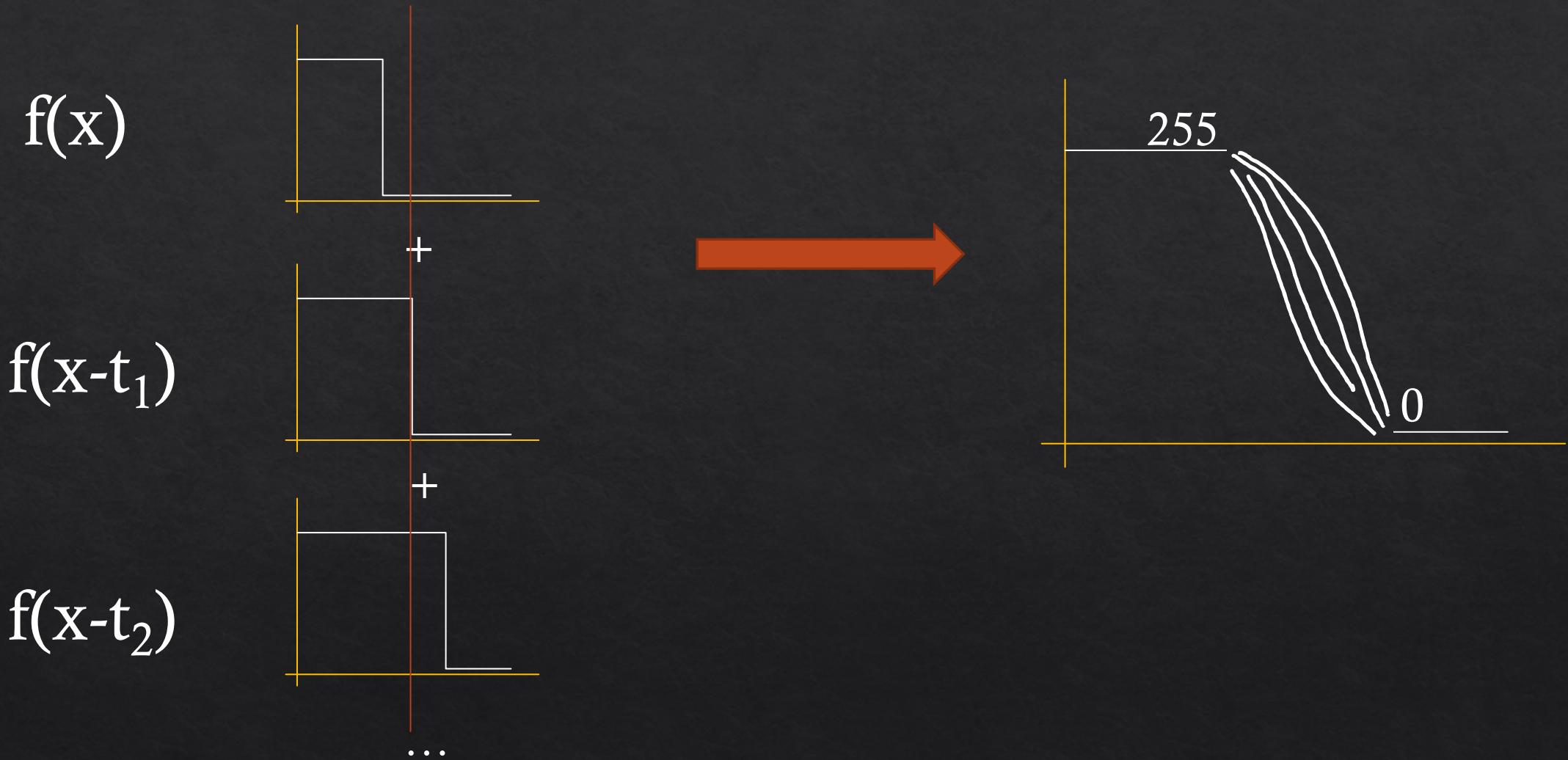


# Example: motion blur

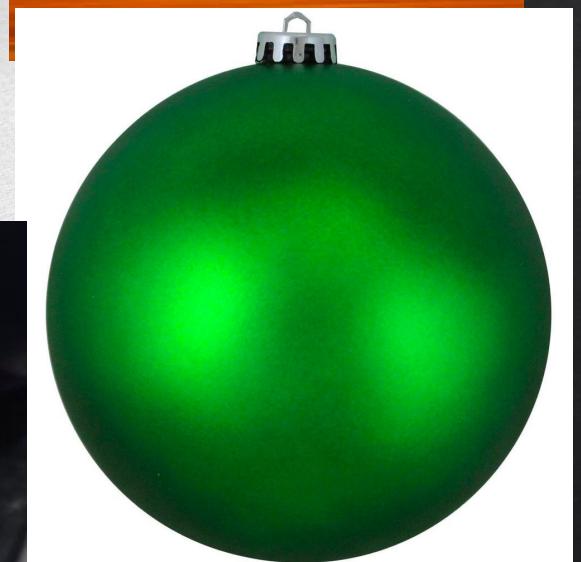
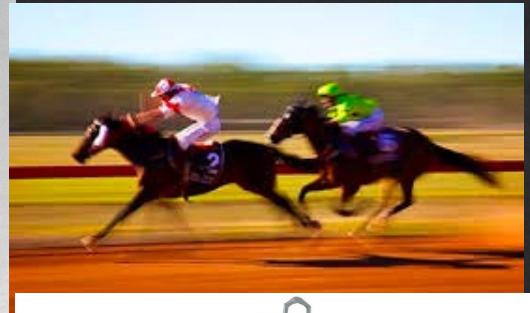


space (x)

# Sums of shifted functions!



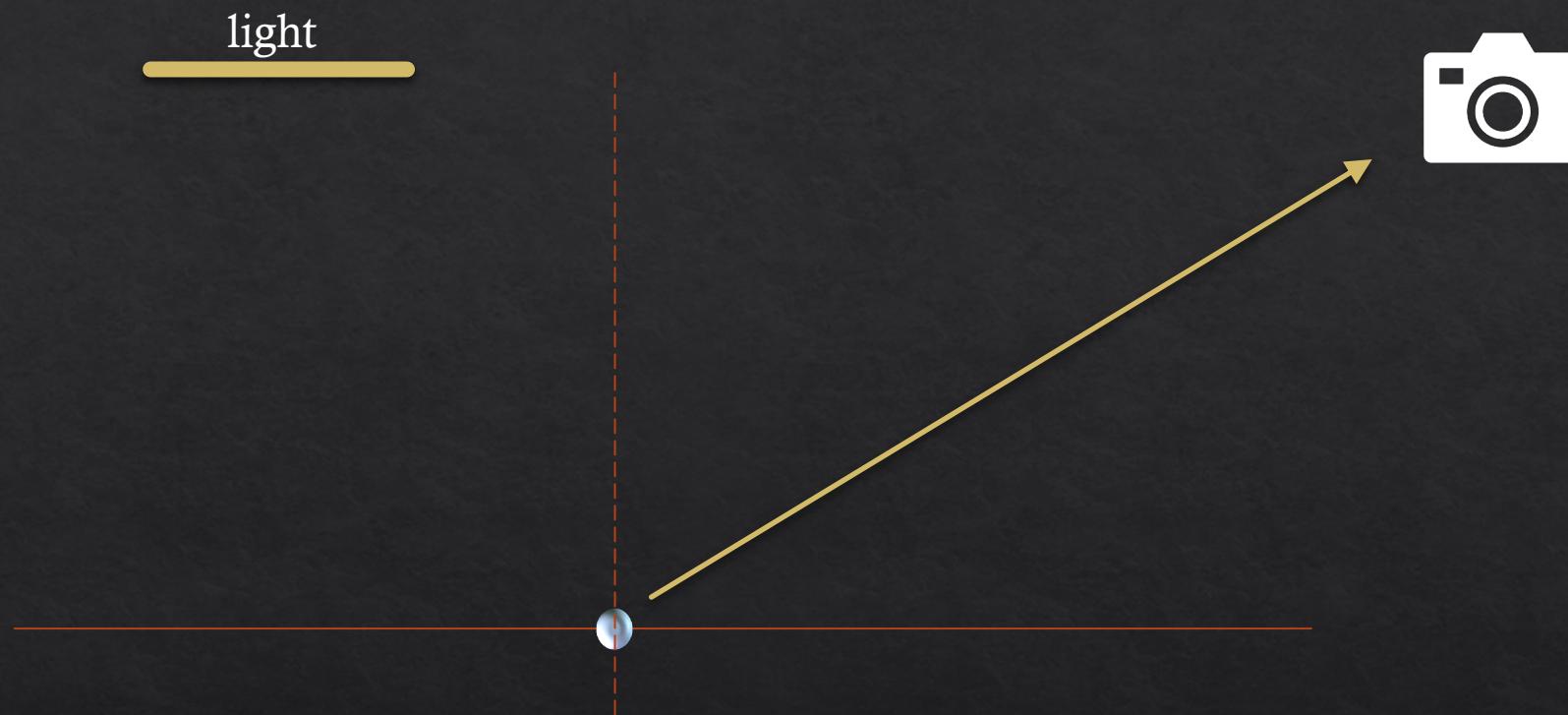
# Can you spot the “shifted sums” in each case?



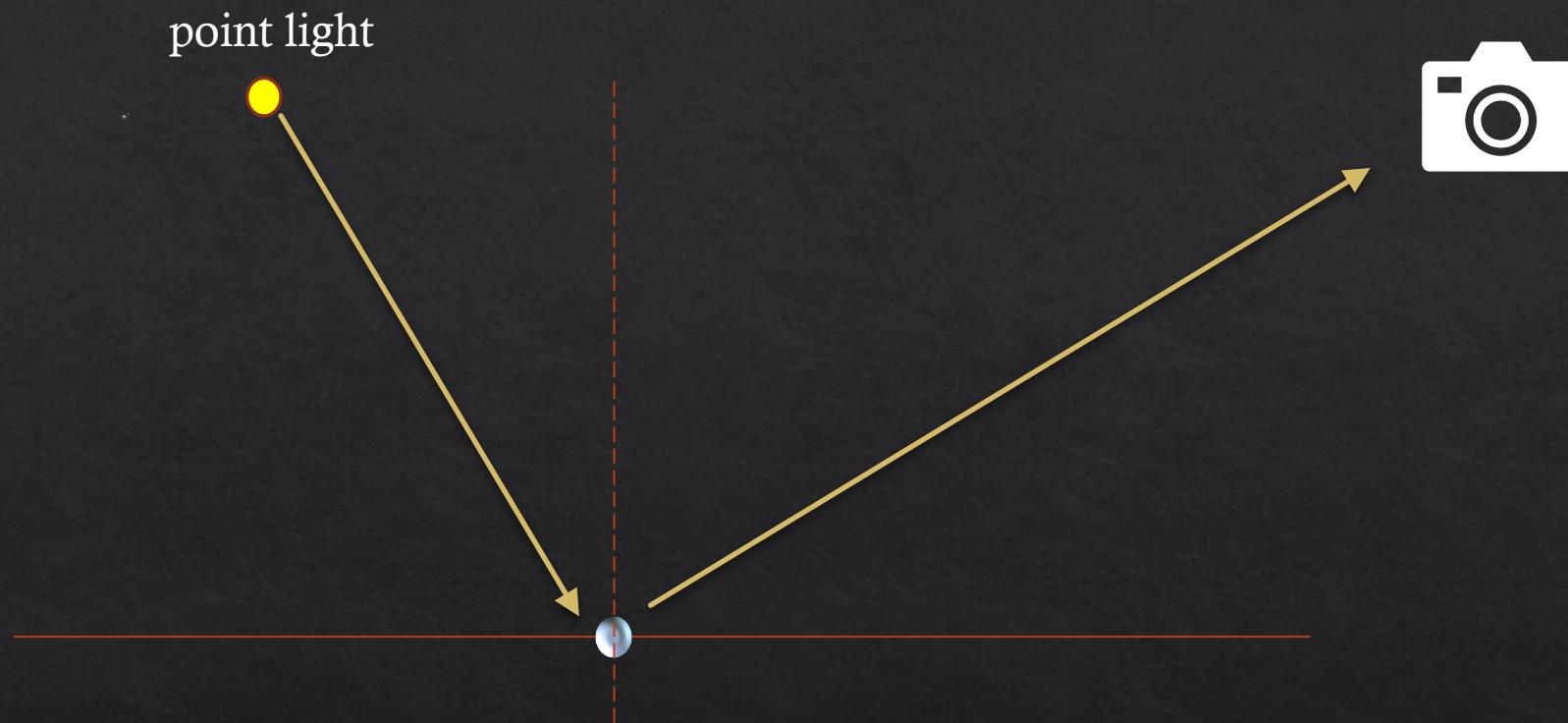
# Soft shadow due to area light



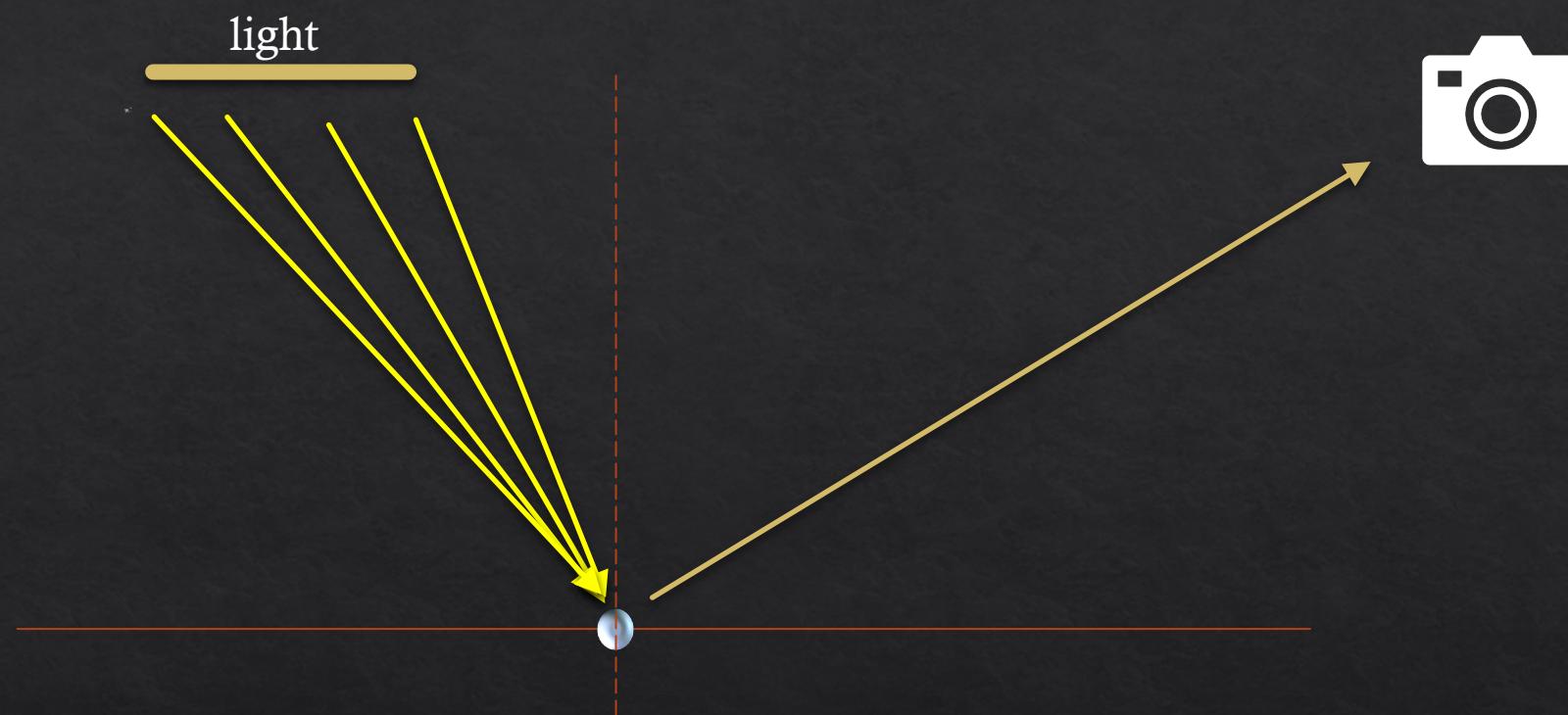
# Example: Area light



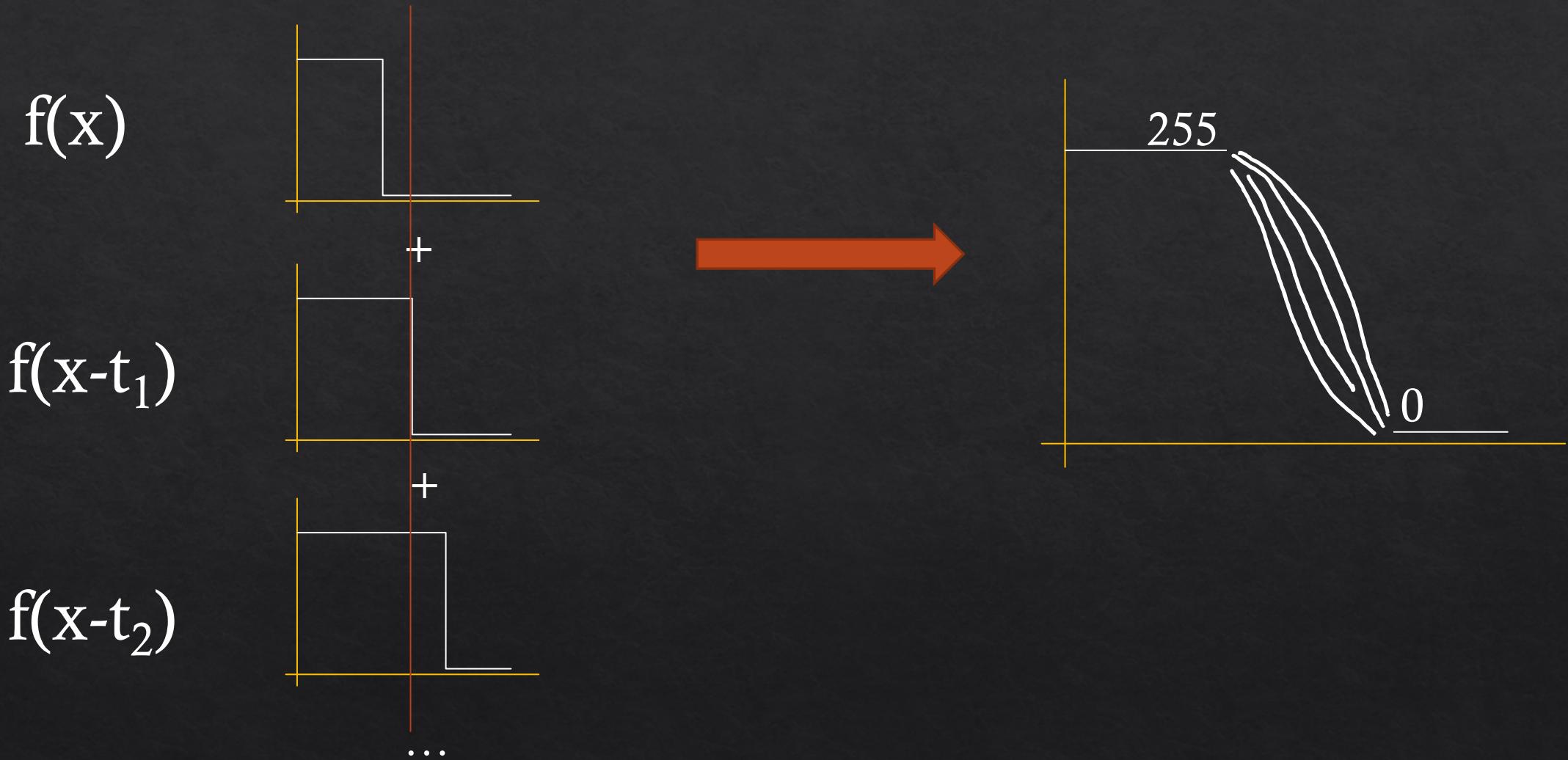
# Example: Area light



# Area light: integrate over angle



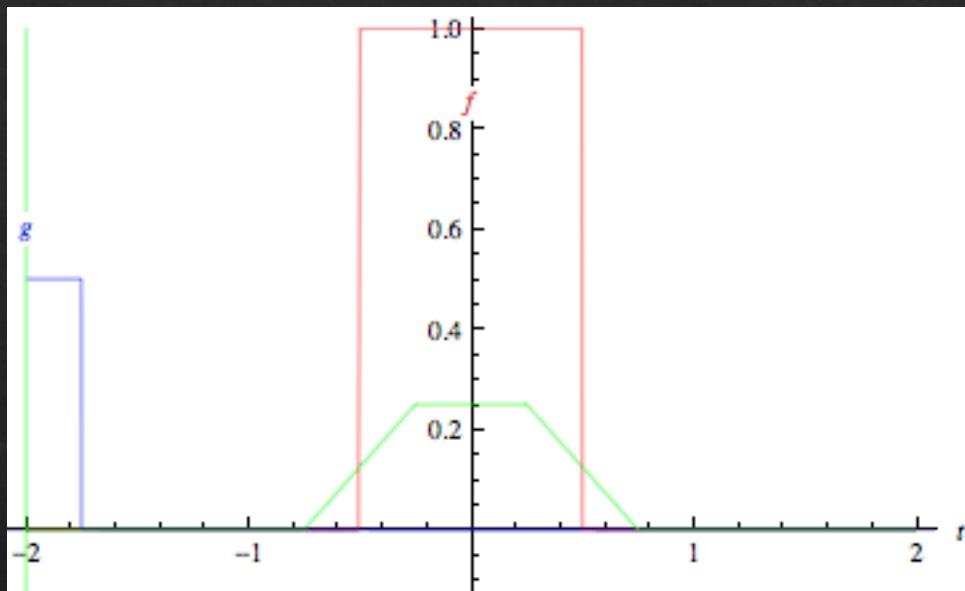
# Sums of shifted functions!



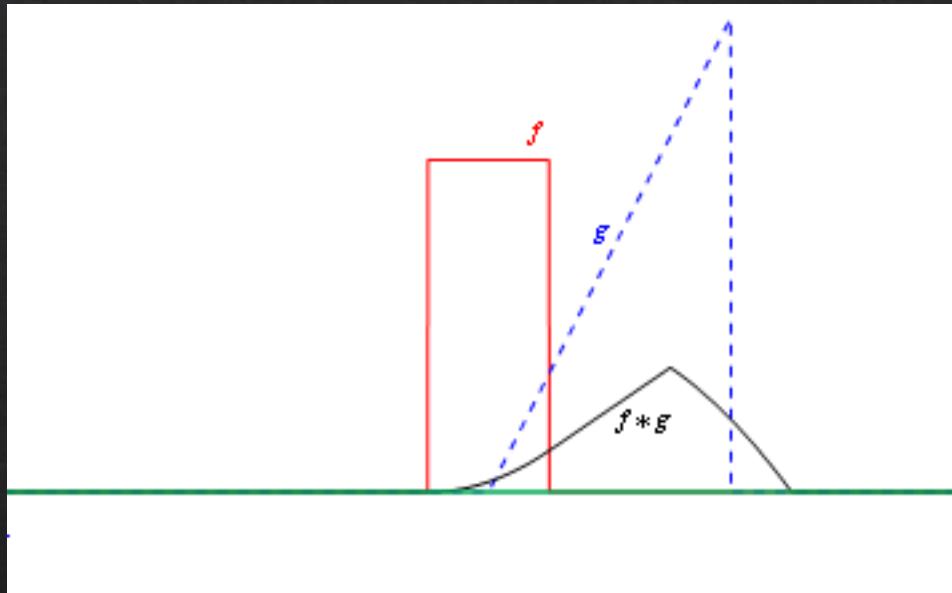
# Sums of shifted functions!

# Sums of weighted, shifted functions!

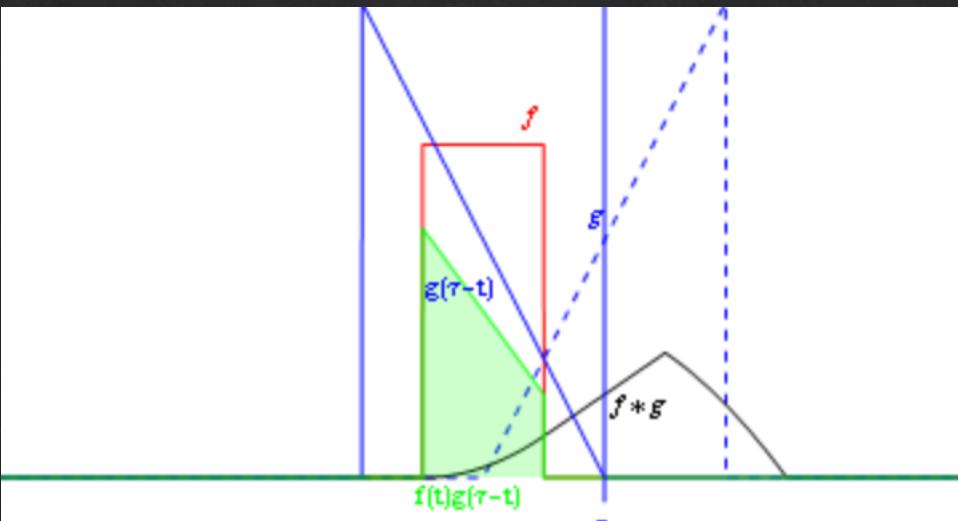
# Sums of weighted, shifted functions!



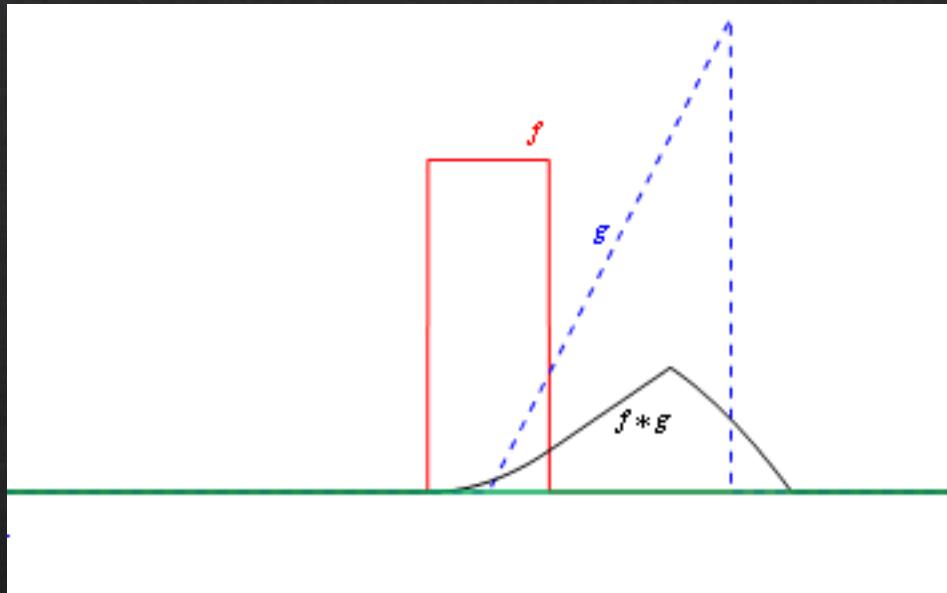
# Sums of weighted, shifted functions!



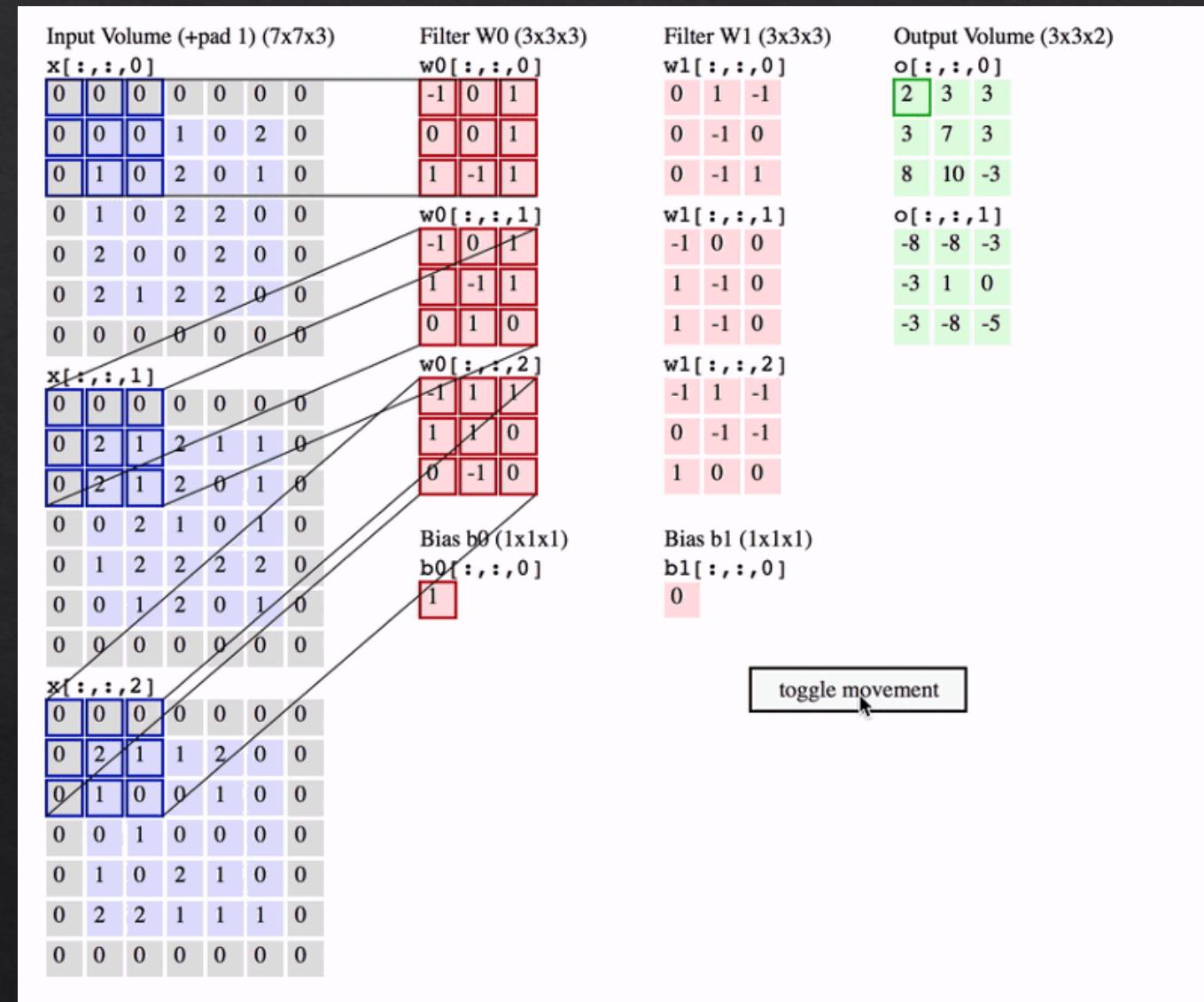
# 1D convolution



# Sums of weighted, shifted functions!



# 2D convolution



# Blurring due to integrals in rendering

- area lights
- camera lens
- camera shutter, exposure time
- wavelength (colour spectrum)
- gloss (reflectance)
- translucent objects