

Matting and Compositing

Digital Visual Effects, Spring 2007

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2007/5/1

*Traditional matting
and composting*

Photomontage



The Two Ways of Life, 1857, Oscar Gustav Rejlander
Printed from the original 32 wet collodion negatives.

Photographic compositions



Lang Ching-shan

Use of mattes for compositing



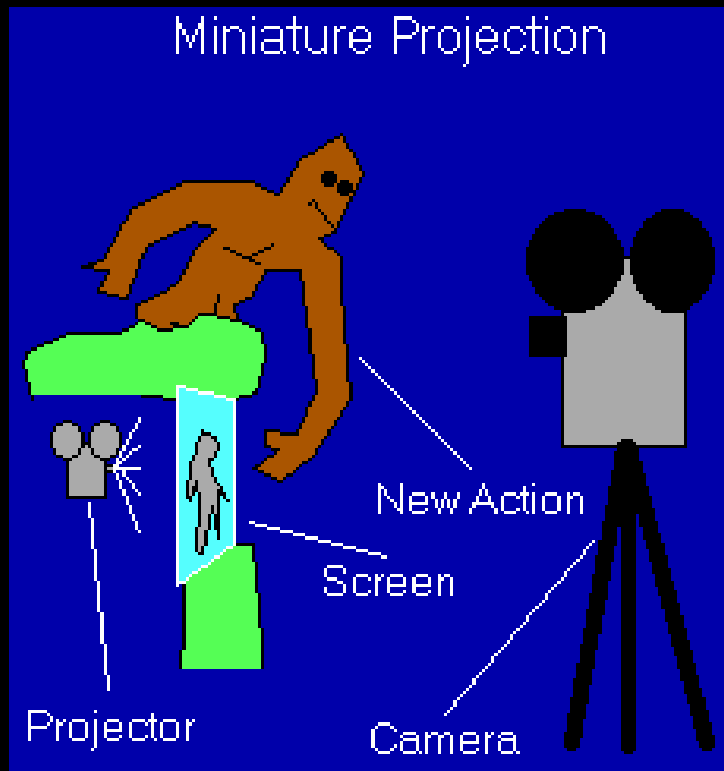
The Great Train Robbery (1903) matte shot

Use of mattes for compositing



The Great Train Robbery (1903) matte shot

Optical compositing



King Kong (1933) Stop-motion + optical compositing

Digital matting and compositing

The lost world (1925)



Miniature, stop-motion

The lost world (1997)



Computer-generated images

Digital matting and compositing

King Kong (1933)



Optical compositing

Jurassic Park III (2001)



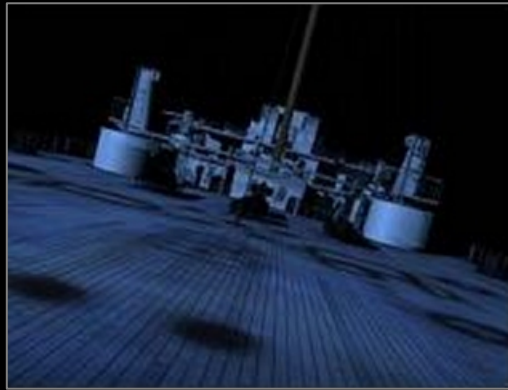
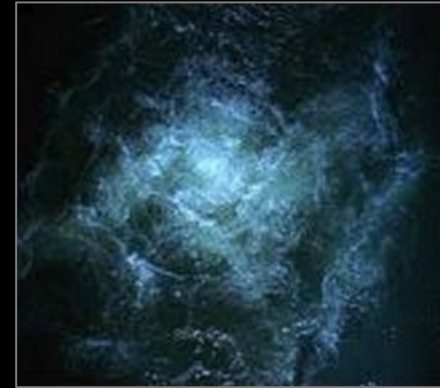
Blue-screen matting,
digital composition,
digital matte painting

Digital matting: bluescreen matting



Forrest Gump (1994)

- The most common approach for films.
- Expensive, studio setup.
- Not a simple one-step process.



Titanic

Matting and Compositing



background
replacement



background
editing



Matting and Compositing

Color difference method (Ultimate)

$$C = F + \bar{\alpha}B$$

F

$\bar{\alpha}$



Blue-screen
photograph

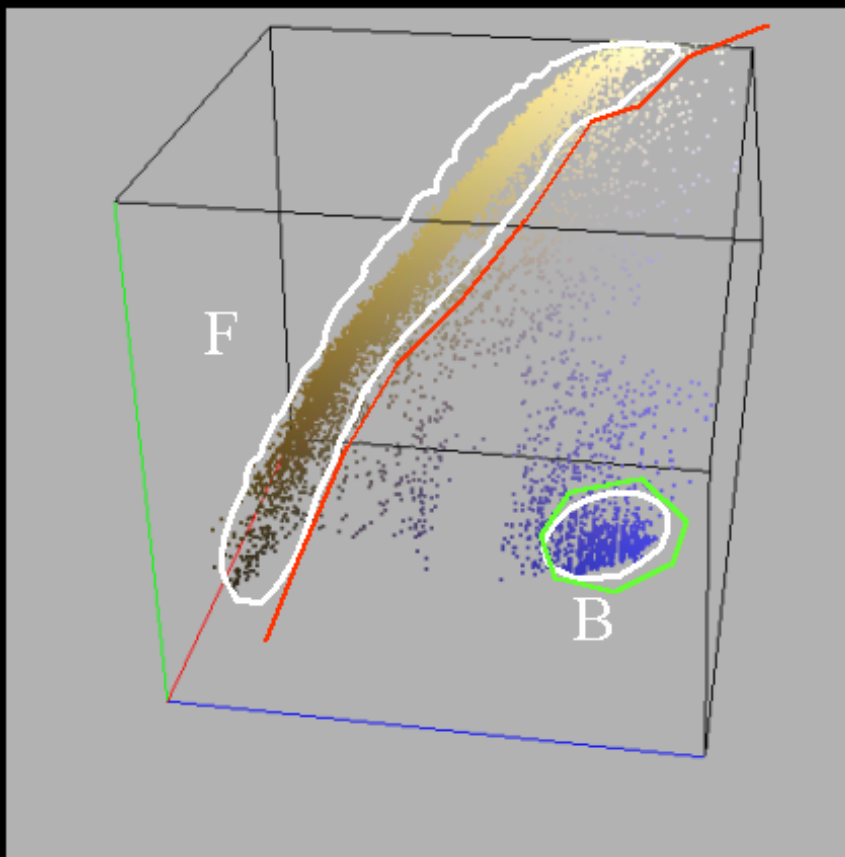


Spill suppression
if $B > G$ then $B = G$



Matte creation
 $\bar{\alpha} = B - \max(G, R)$

Chroma-keying (Primatte)





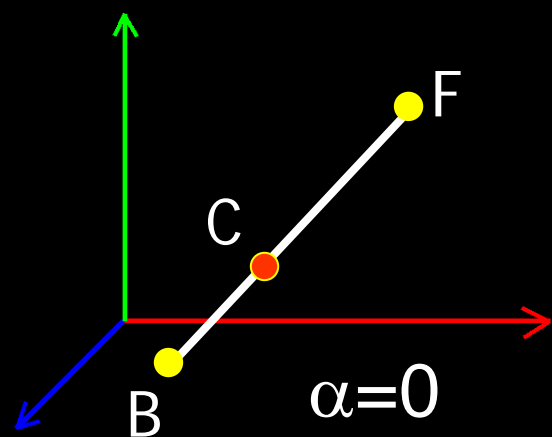
foreground color



alpha matte



background plate



$$C = \alpha F + (1 - \alpha)B$$

compositing
equation

Compositing

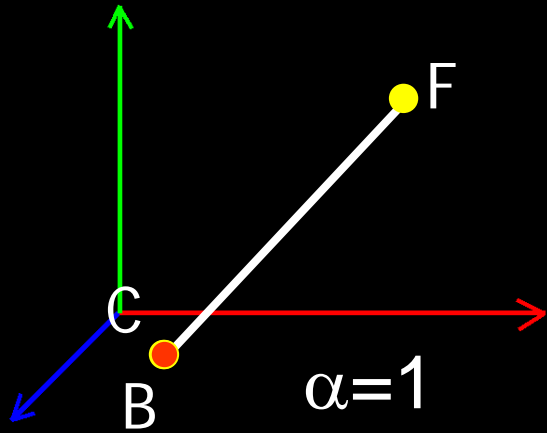
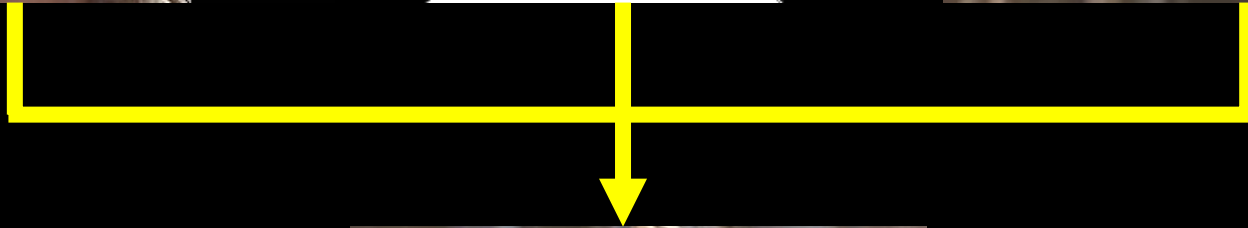
F



α



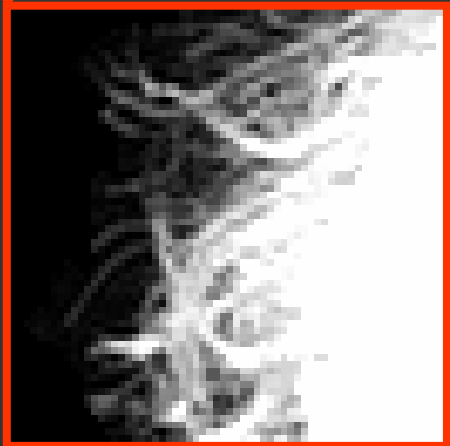
B



$$C = \alpha F + (1 - \alpha) B$$

compositing
equation

Compositing



F



α



B



observation

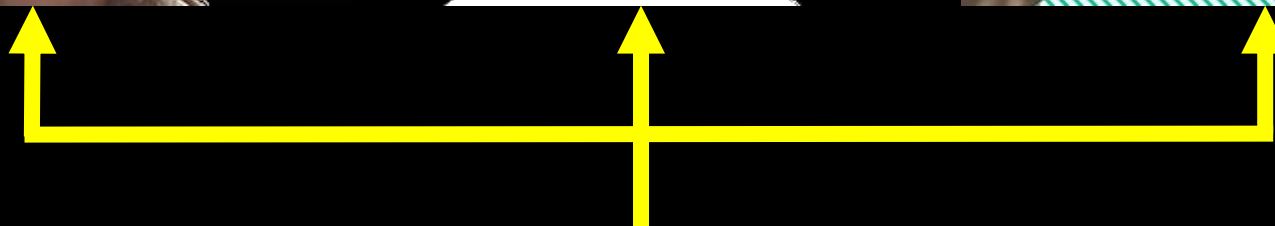
C



$$C = \alpha F + (1 - \alpha)B$$

compositing
equation

Matting

F  α  B 

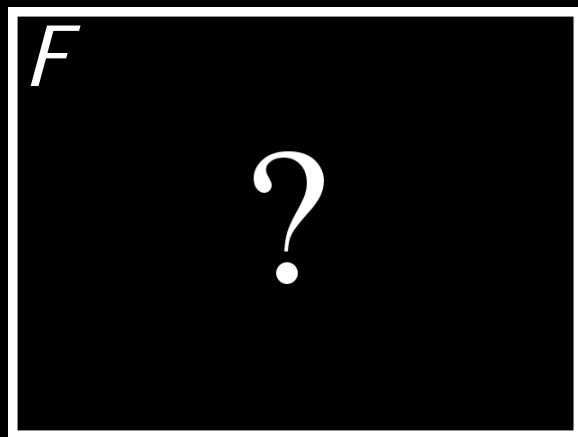
Three approaches:
1 reduce #unknowns
2 add observations
3 add priors

 C 

$$C = \alpha F + (1 - \alpha)B$$

compositing
equation

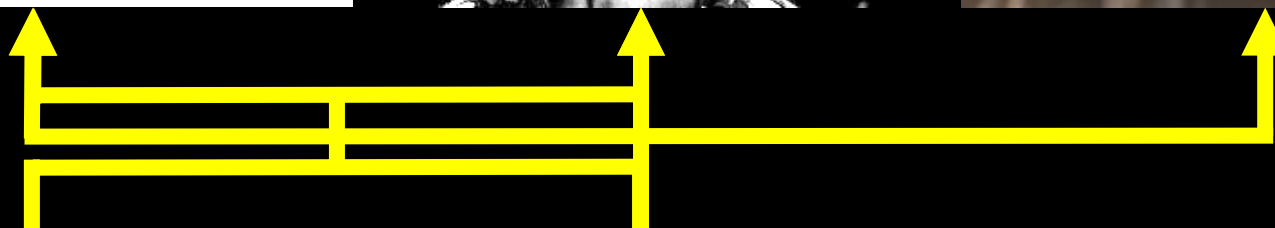
Matting



α



B

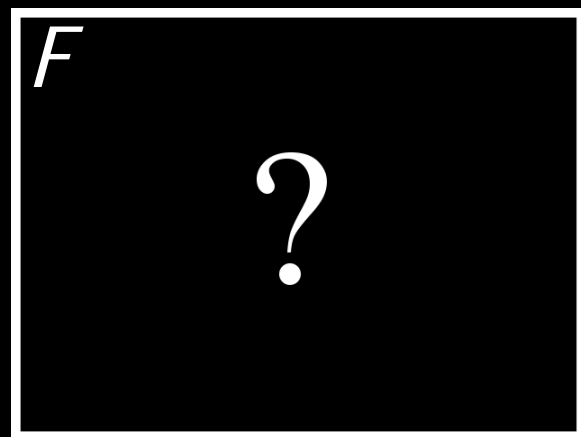


C

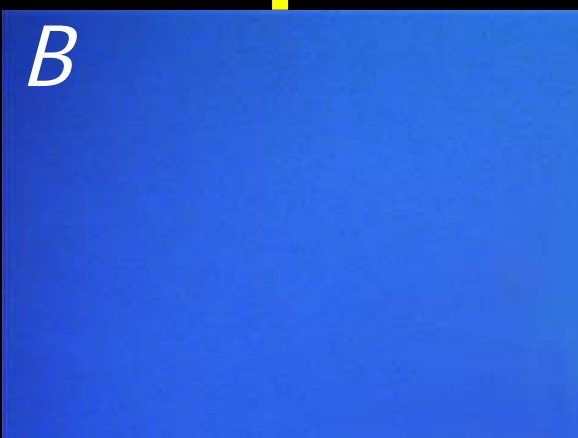
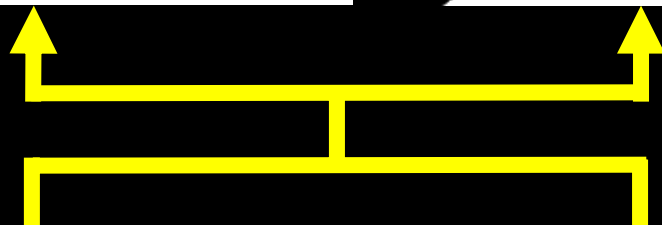
$$C = \alpha F + (1 - \alpha)B$$

difference
matting

Matting (reduce #unknowns)



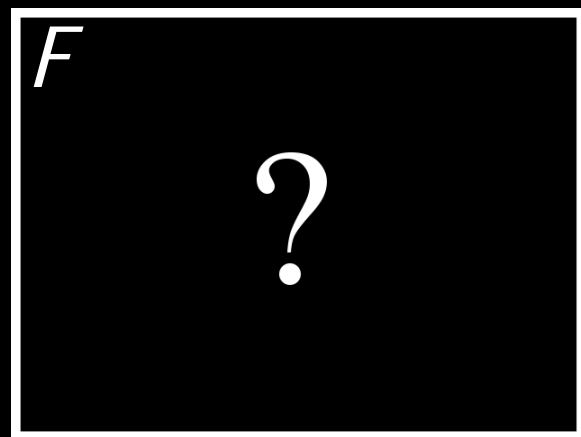
α



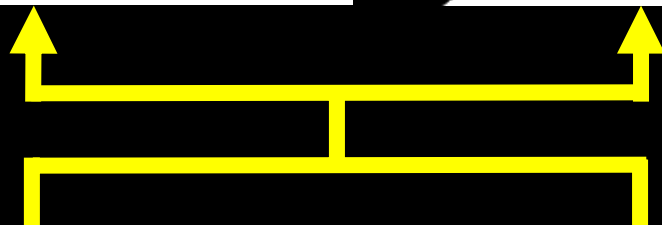
$$C = \alpha F + (1 - \alpha)B$$

blue screen
matting

Matting (reduce #unknowns)



α



B

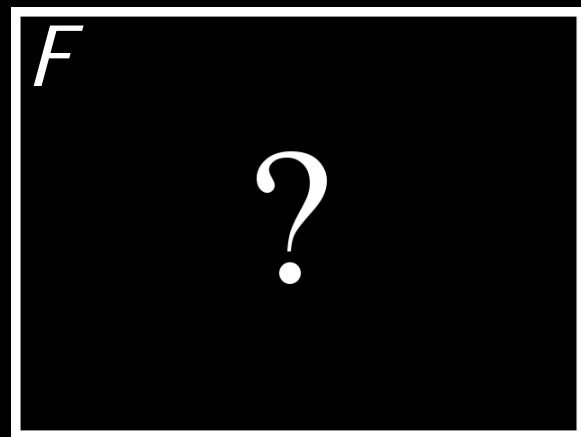


$$C = \alpha F + (1 - \alpha)B$$

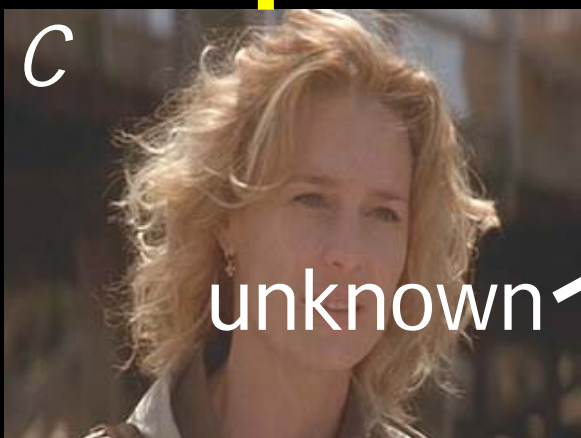
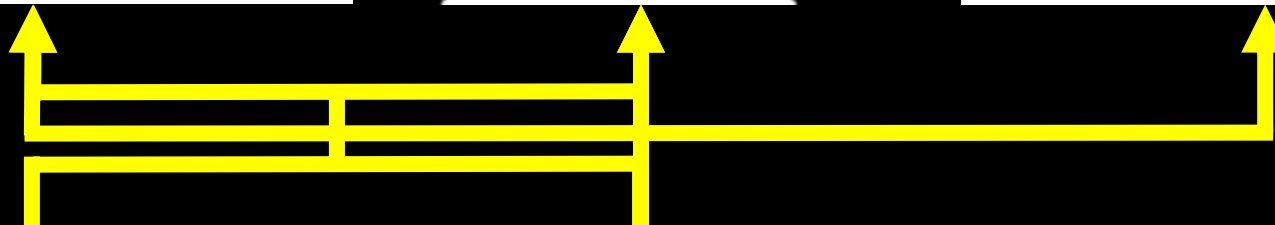
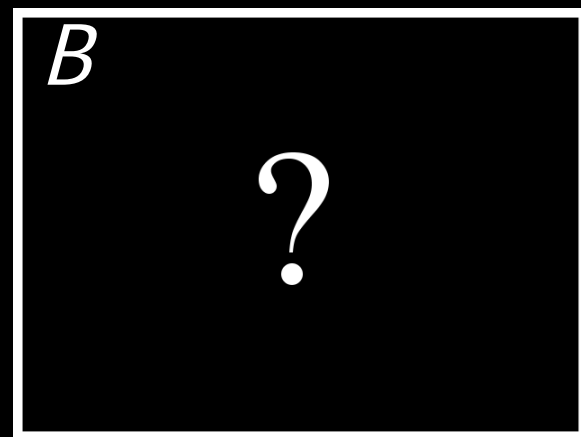
$$C = \alpha F + (1 - \alpha)B$$

triangulation

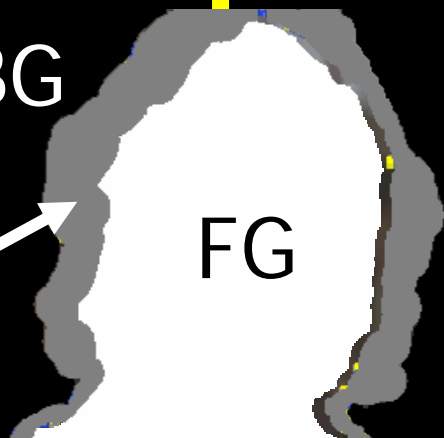
Matting (add observations)



α



BG



$$C = \alpha F + (1 - \alpha)B$$

Roberto Cipriani

Matting (add priors)

Bayesian image matting

posterior probability

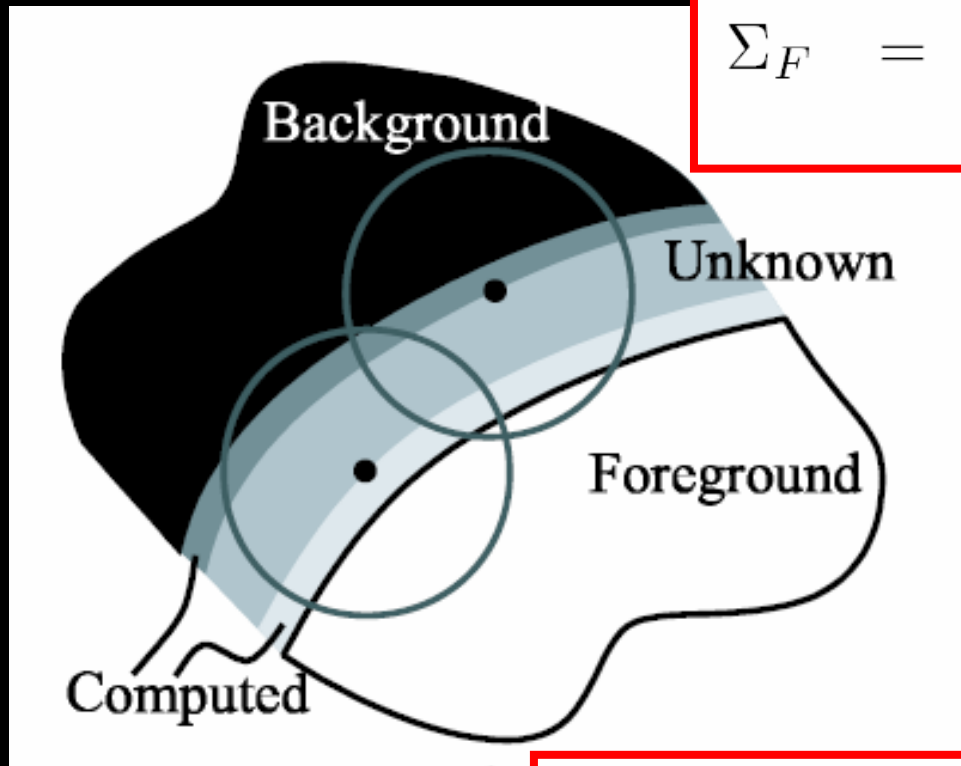
likelihood

priors

$$\begin{aligned} & \arg \max_{F, B, \alpha} P(F, B, \alpha | C) \\ &= \arg \max_{F, B, \alpha} P(C | F, B, \alpha) P(F) P(B) P(\alpha) / P(C) \end{aligned}$$

$$L(C | F, B, \alpha) = -\|C - \alpha F - (1 - \alpha)B\|^2 / 2\sigma_C^2$$

Bayesian framework



$$\bar{F} = \frac{1}{W} \sum_{i \in N} w_i F_i$$

$$\Sigma_F = \frac{1}{W} \sum_{i \in N} w_i (F_i - \bar{F})(F_i - \bar{F})^T$$

$$L(F) = -(F - \bar{F})^T \Sigma_F^{-1} (F - \bar{F}) / 2$$

Priors

repeat

1. fix alpha

$$\begin{bmatrix} \Sigma_F^{-1} + I\alpha^2/\sigma_C^2 & I\alpha(1-\alpha)/\sigma_C^2 \\ I\alpha(1-\alpha)/\sigma_C^2 & \Sigma_B^{-1} + I(1-\alpha)^2/\sigma_C^2 \end{bmatrix} \begin{bmatrix} F \\ B \end{bmatrix} \\ = \begin{bmatrix} \Sigma_F^{-1}\bar{F} + C\alpha/\sigma_C^2 \\ \Sigma_B^{-1}\bar{B} + C(1-\alpha)/\sigma_C^2 \end{bmatrix}$$

2. fix F and B

$$\alpha = \frac{(C - B) \cdot (F - B)}{\|F - B\|^2}$$

until converge

Optimization



Bayesian image matting



Bayesian image matting



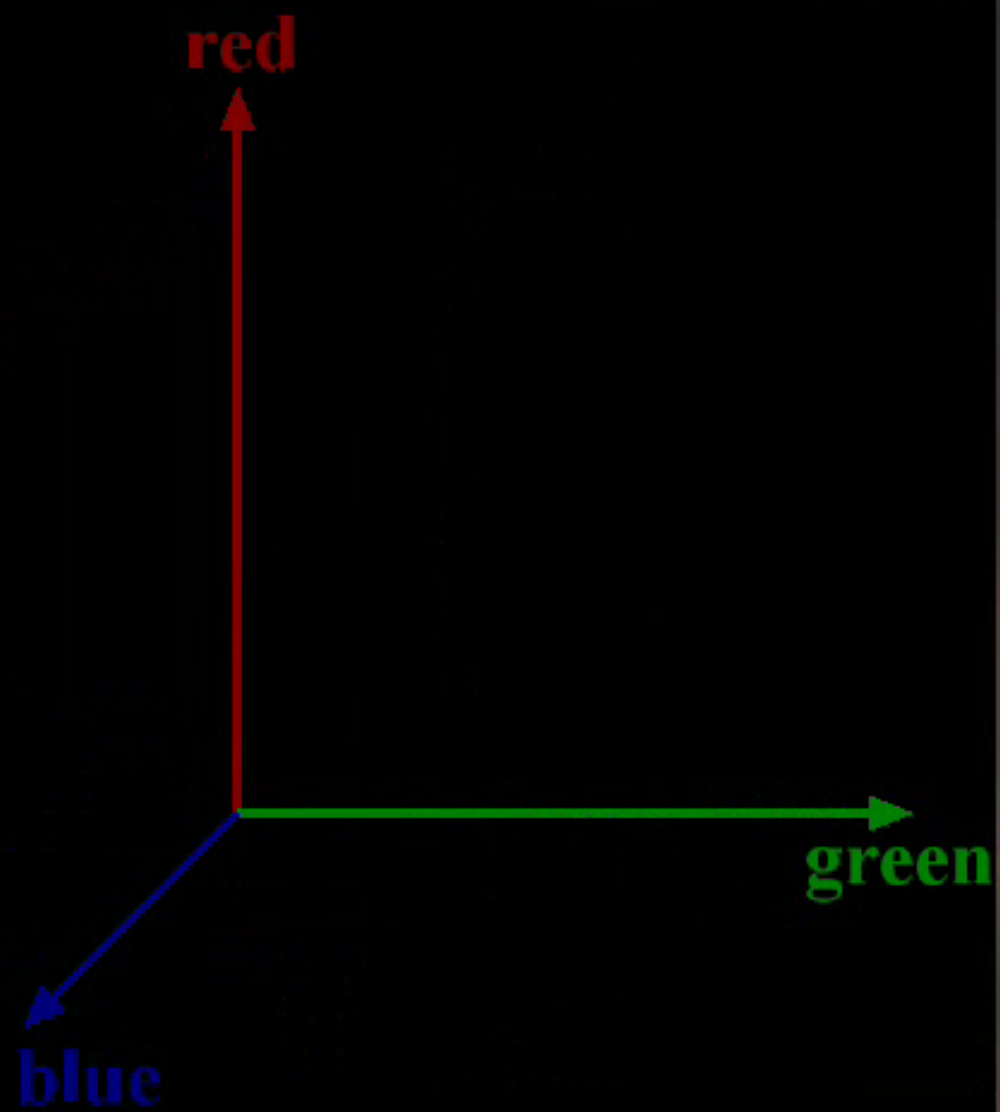
Bayesian image matting

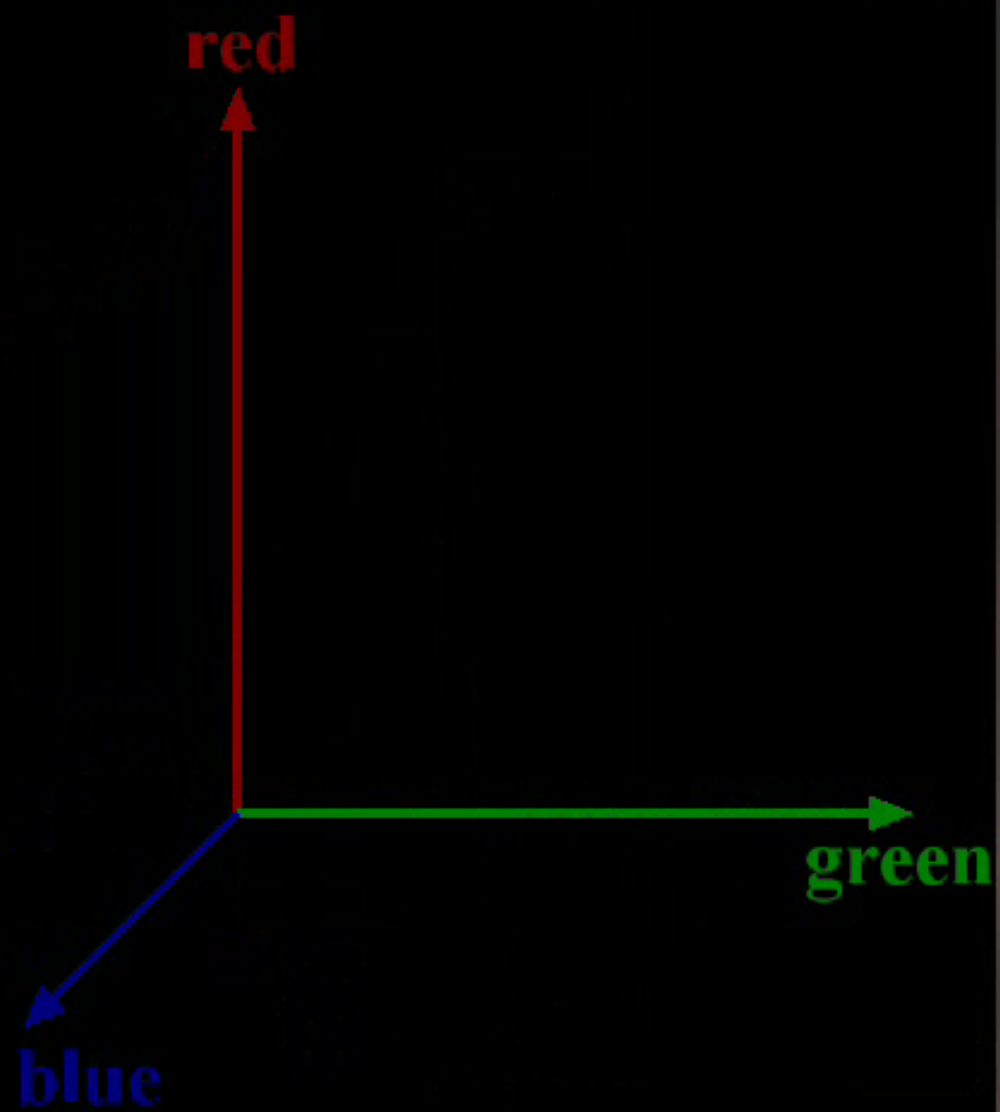


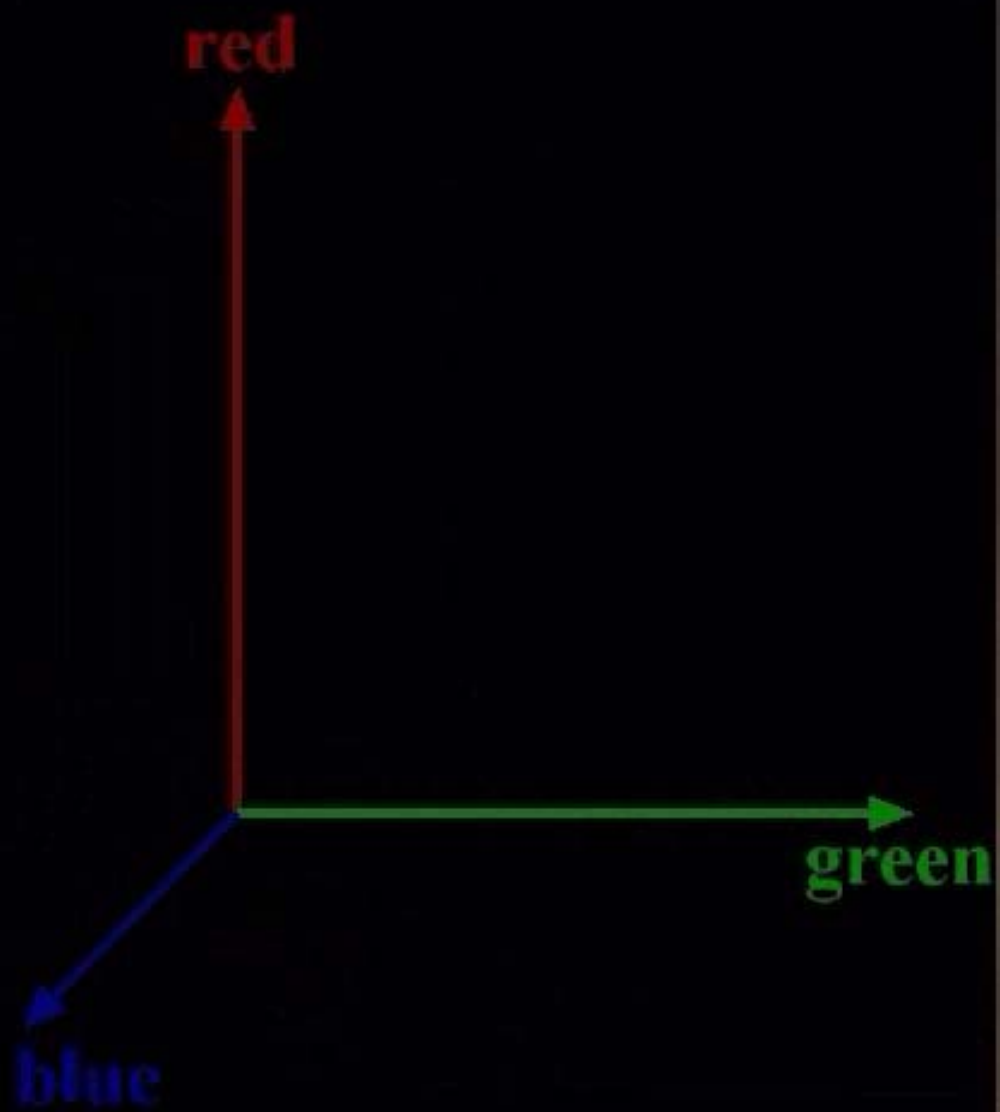
Bayesian image matting

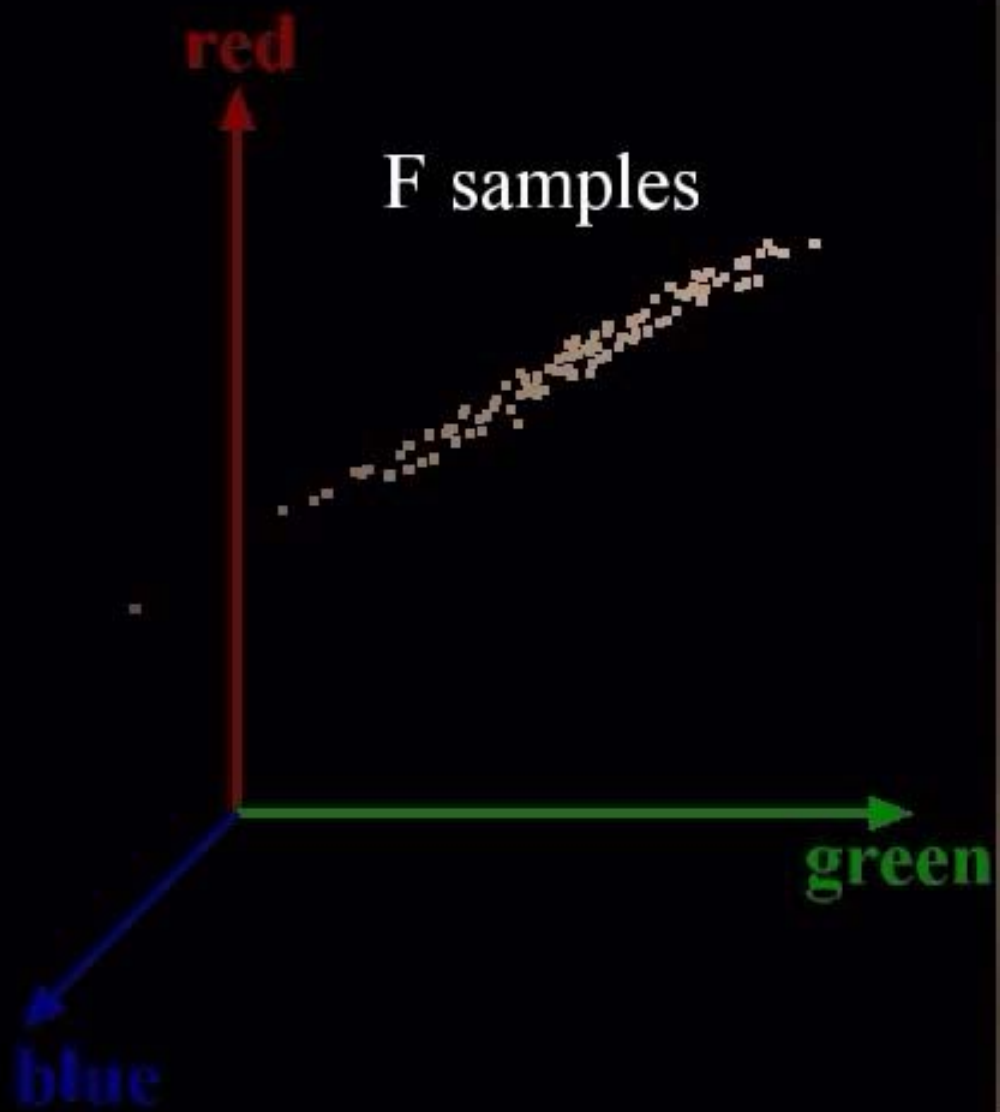


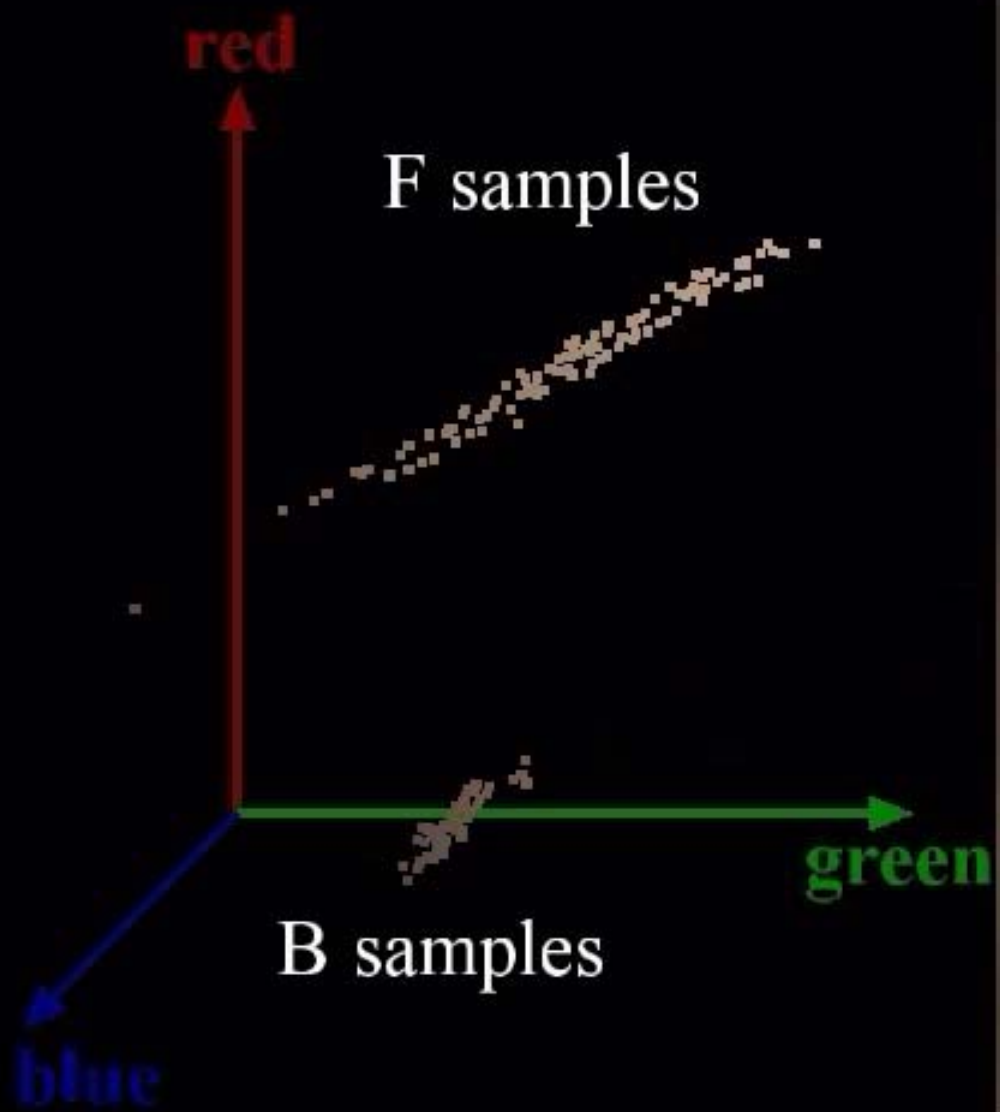
Bayesian image matting

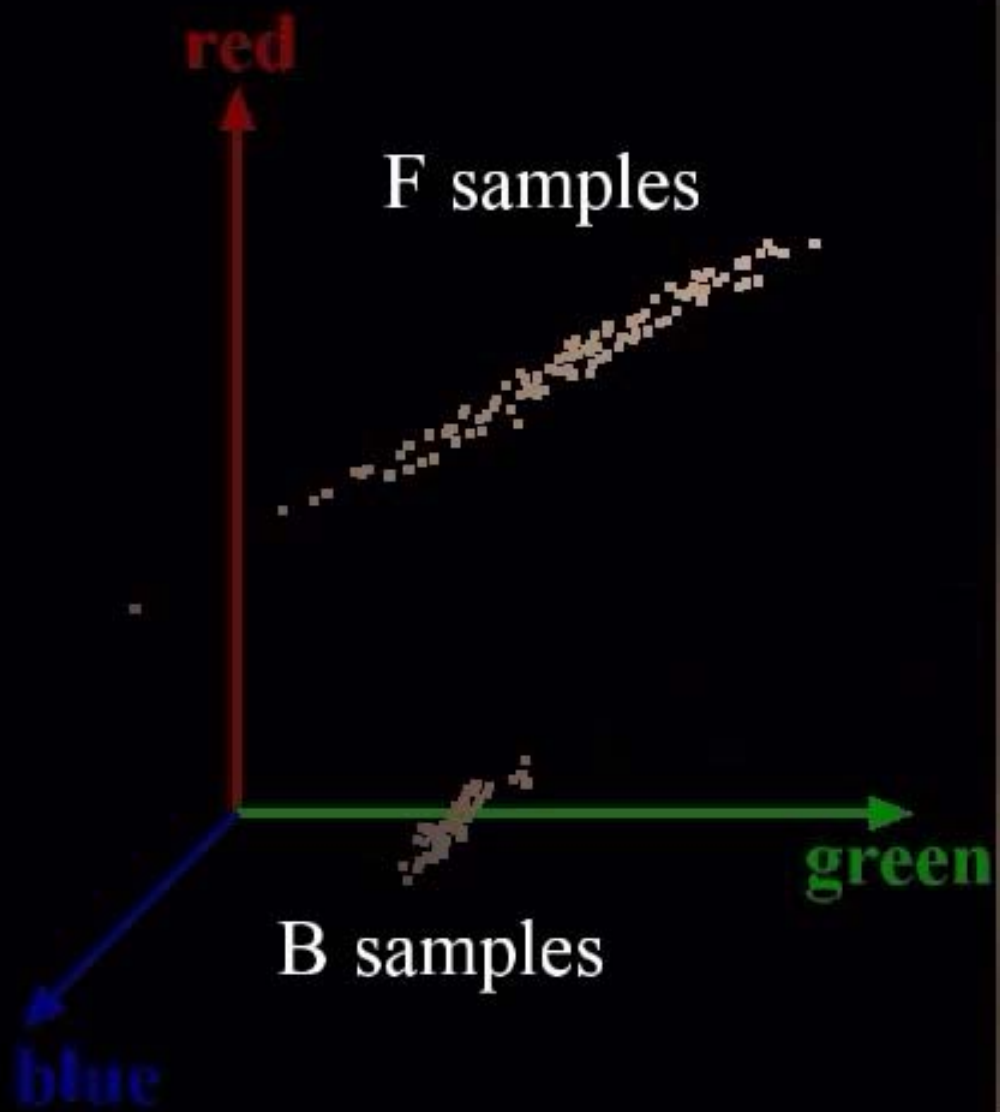


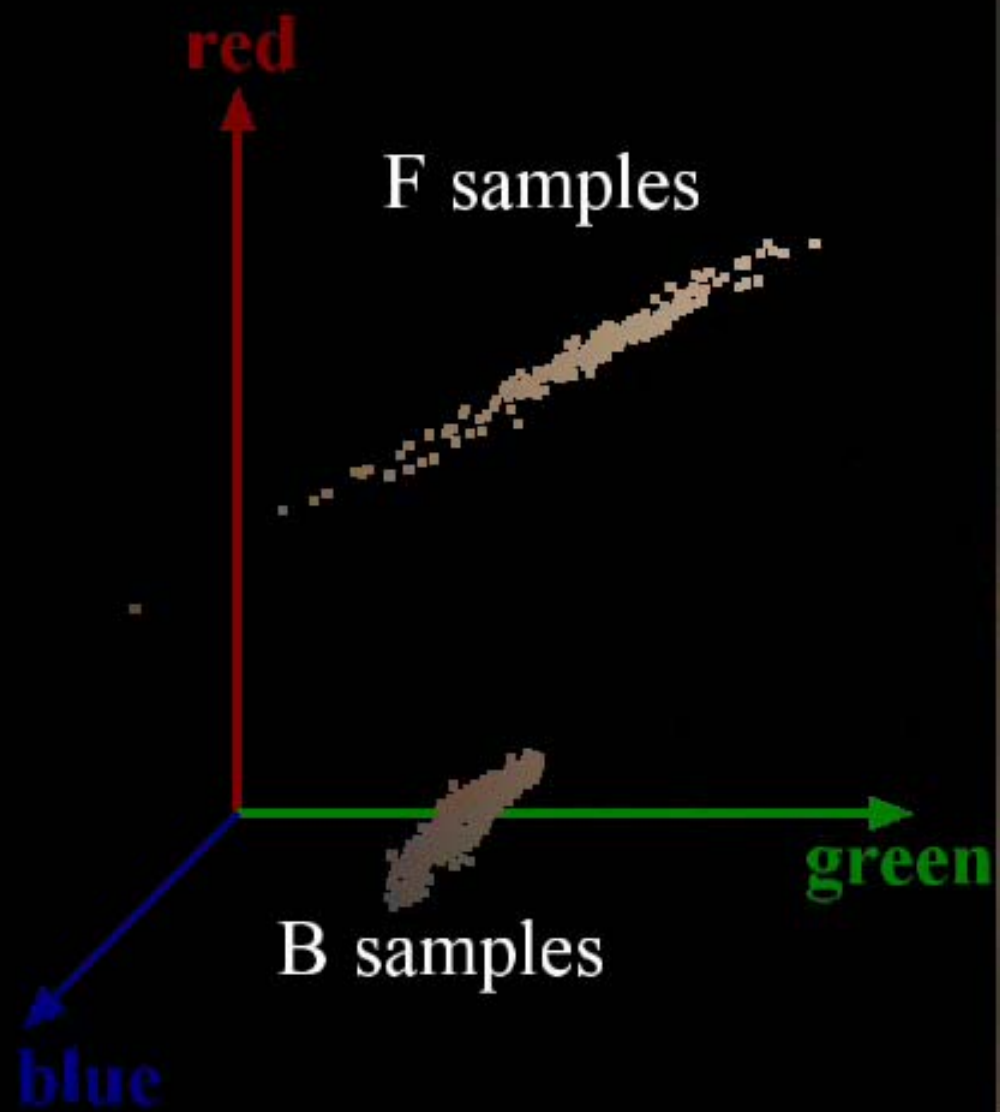


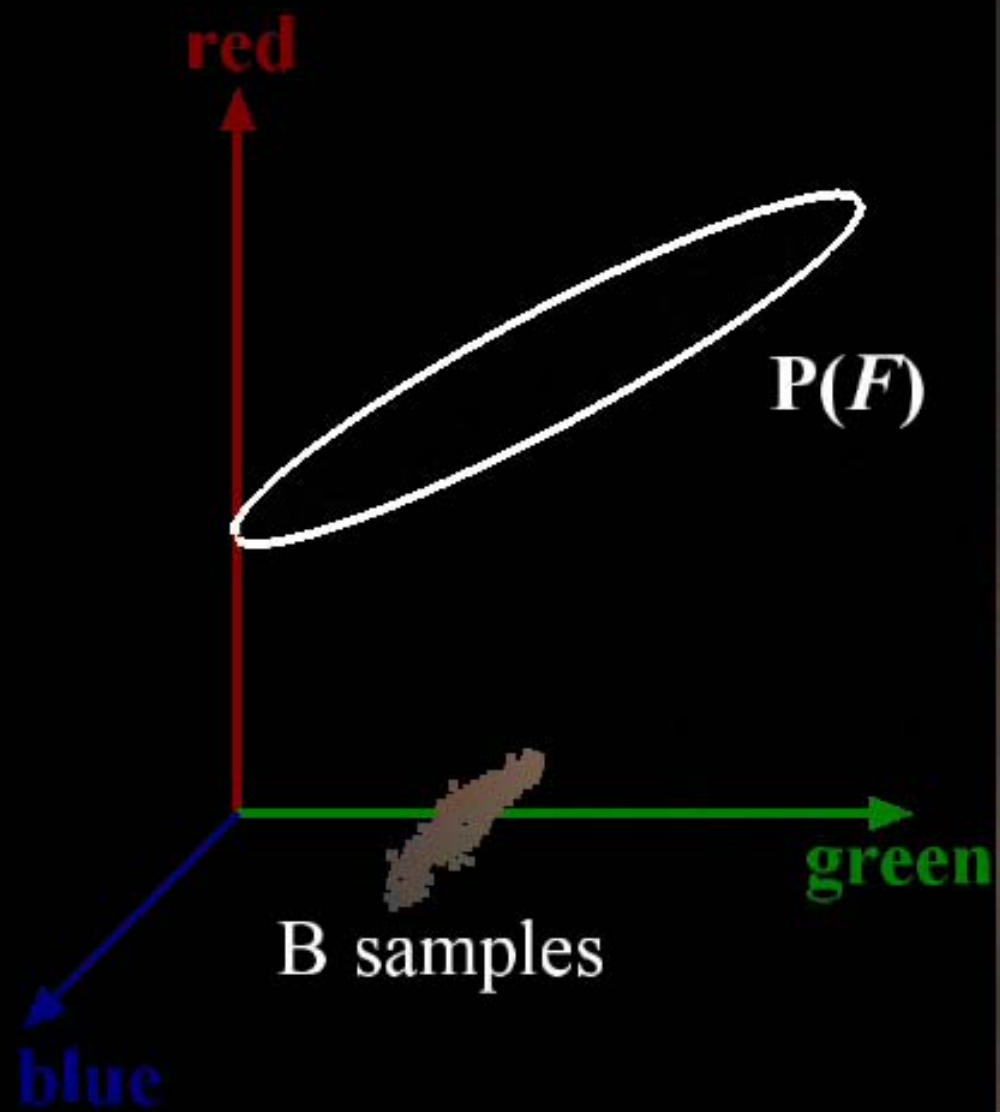


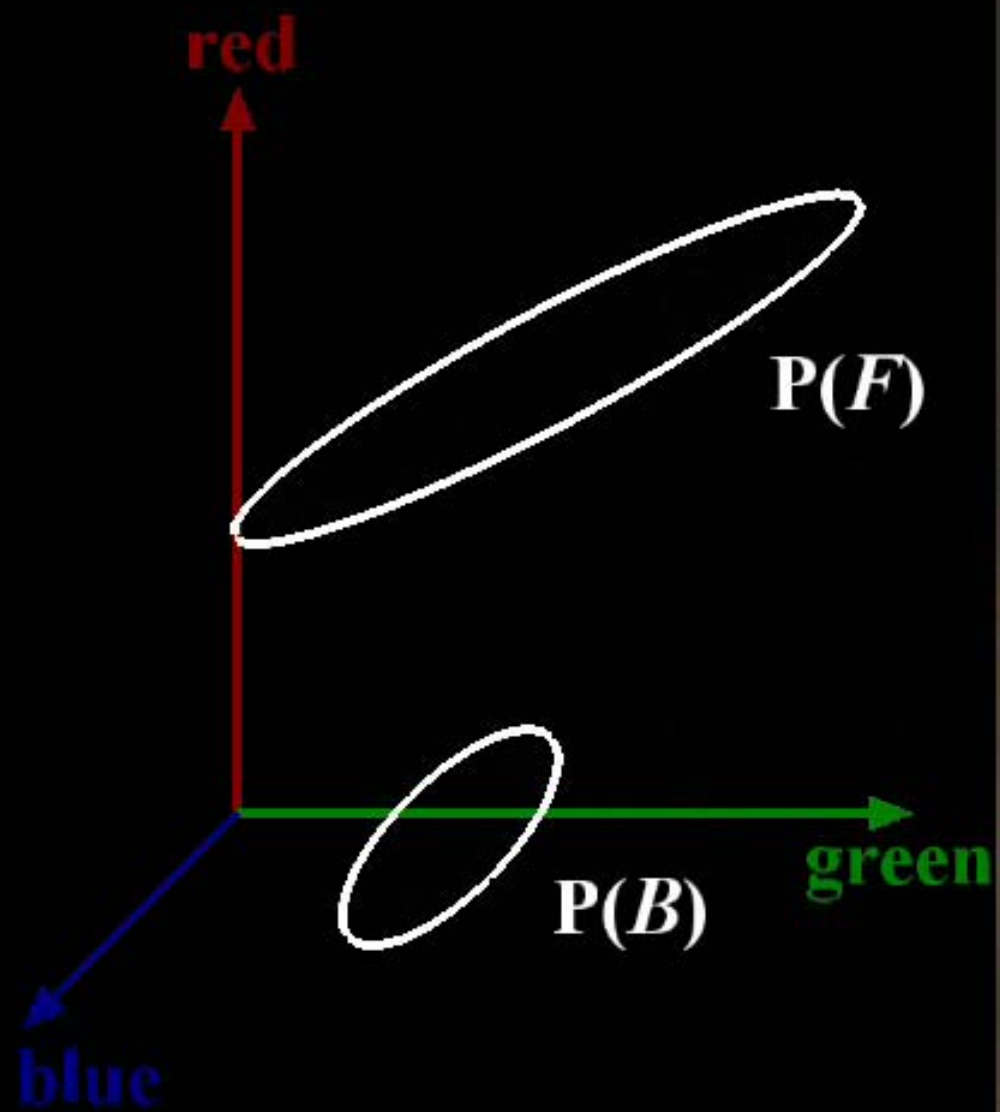


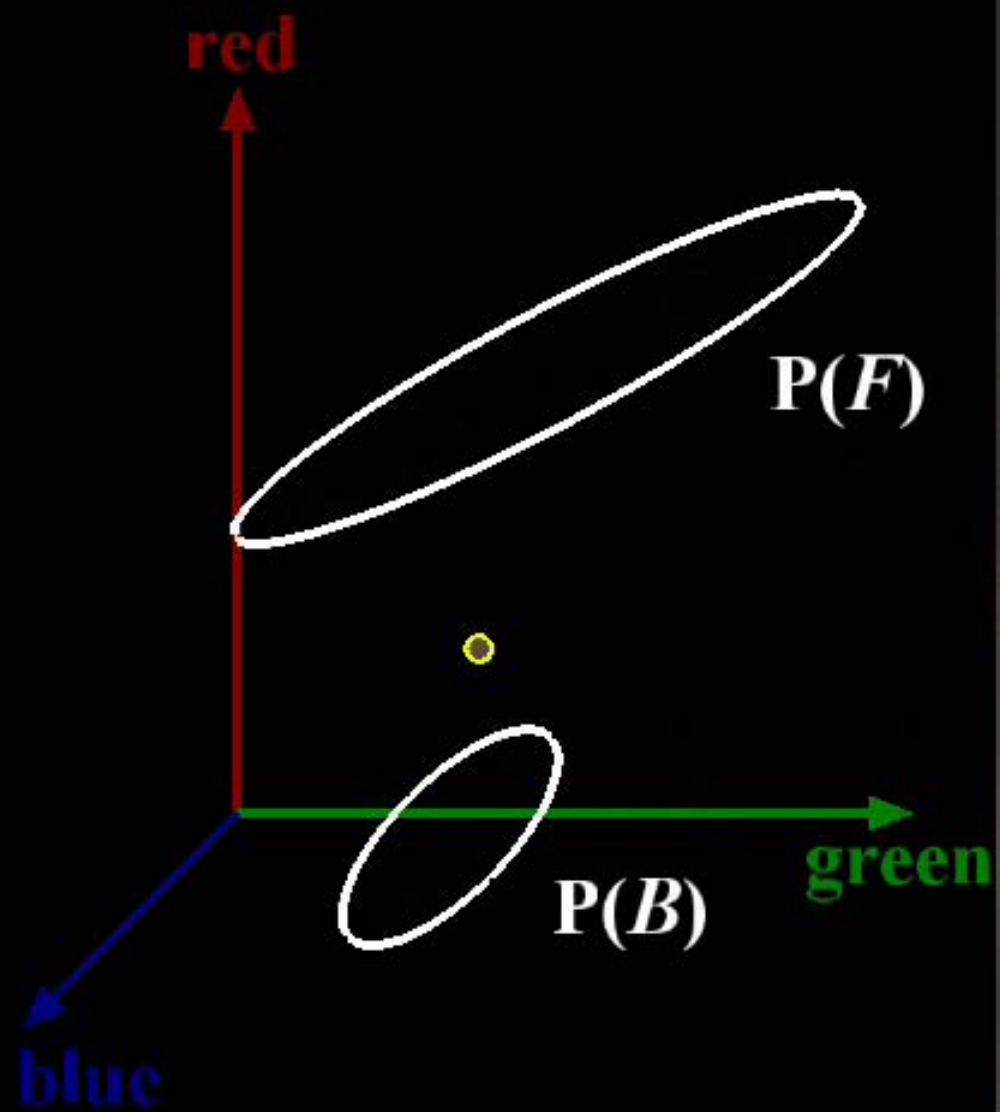


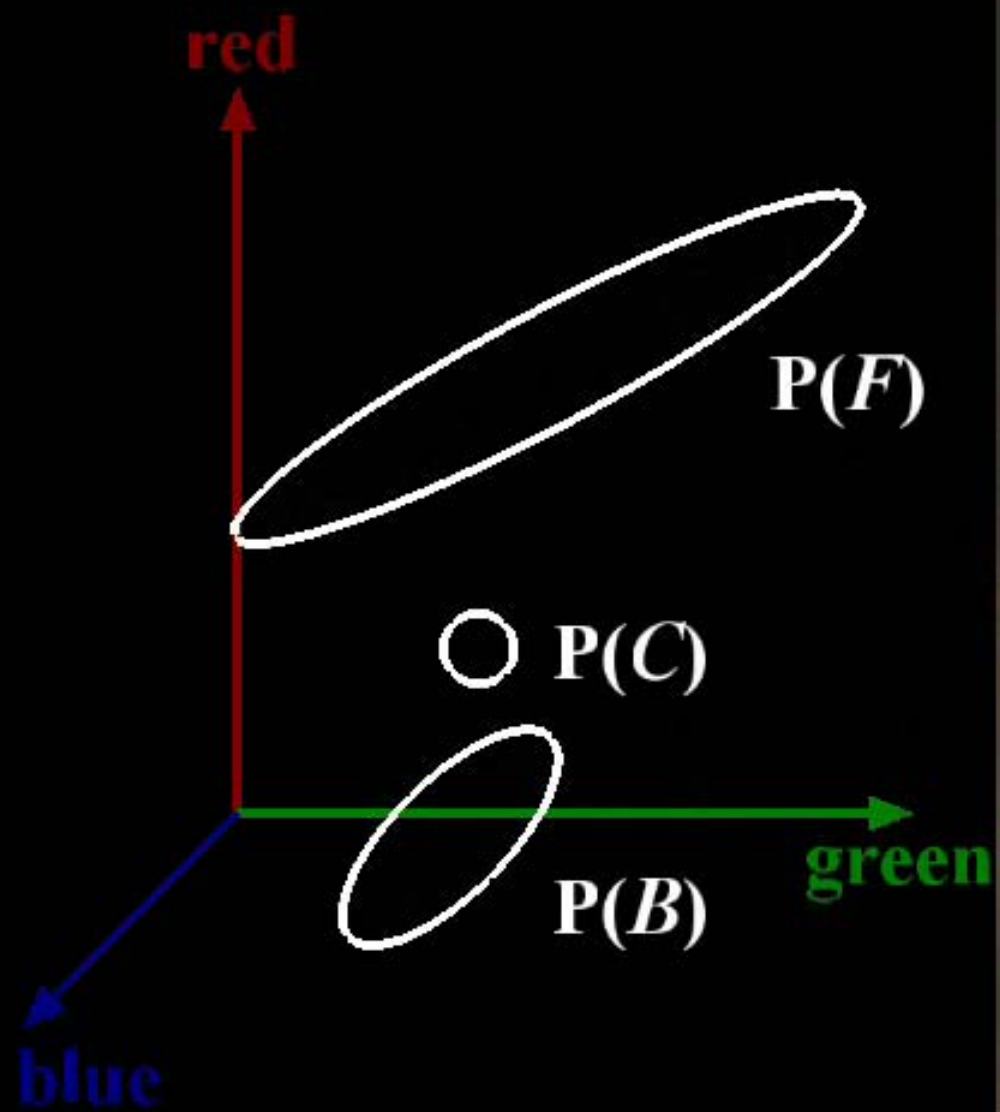


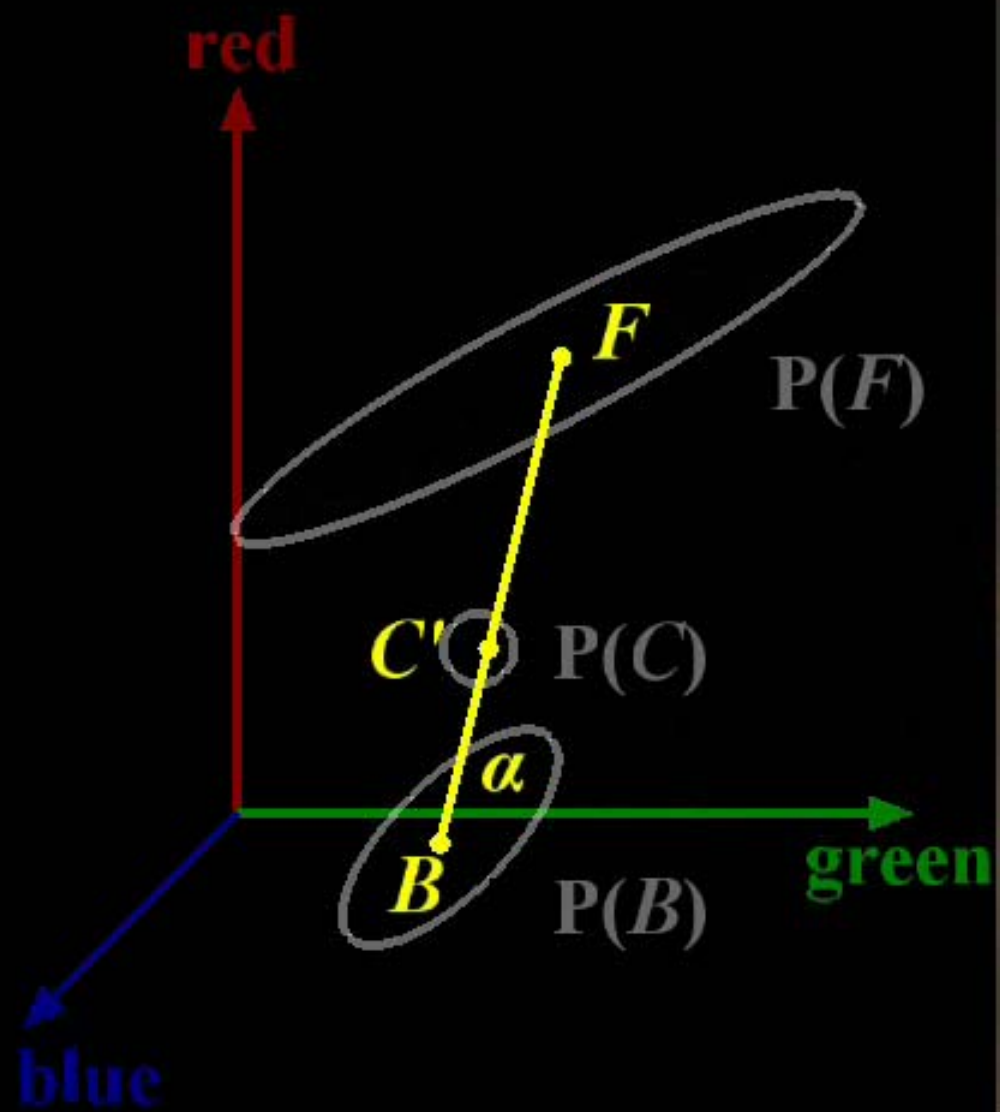












alpha



Results

input

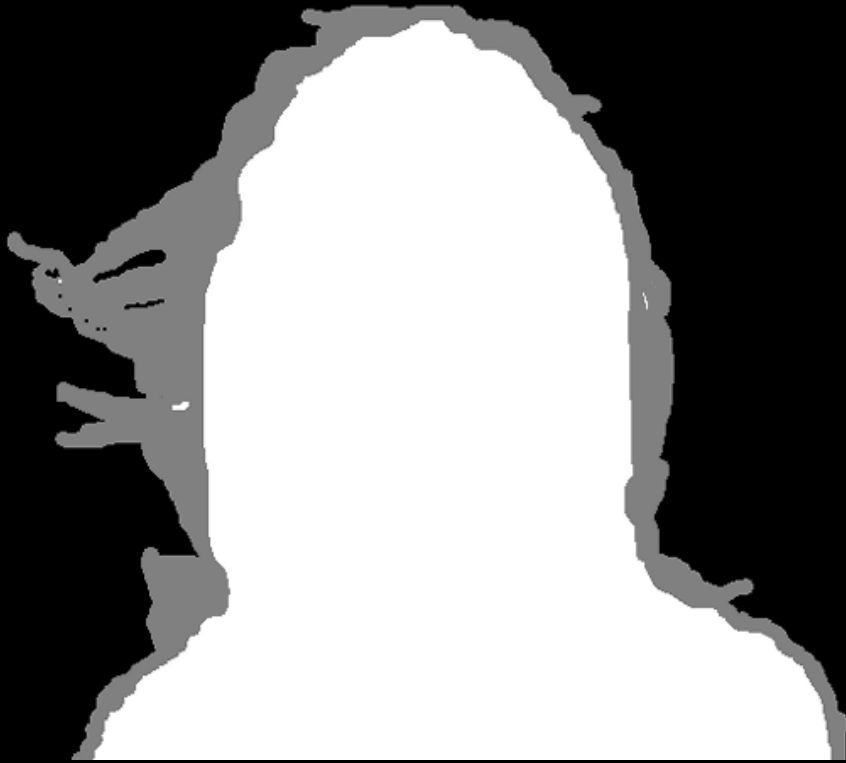


composite



Results

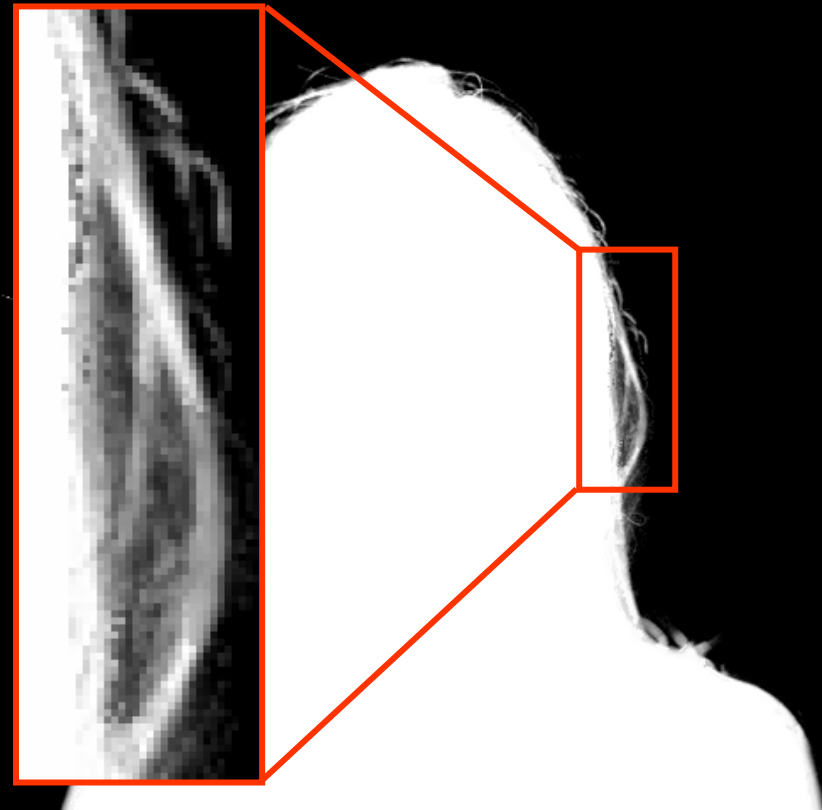
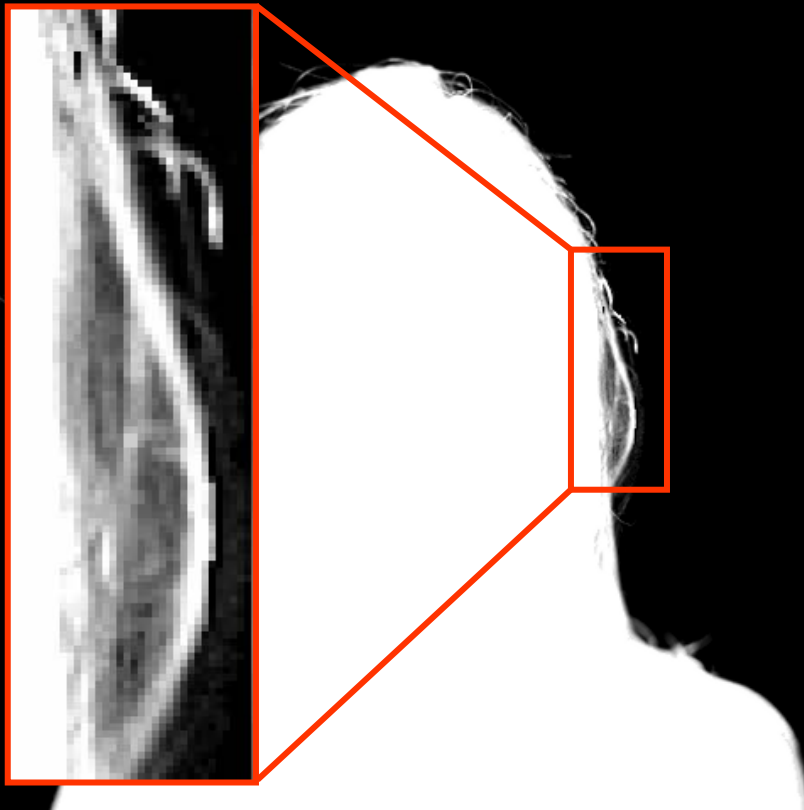
trimap



Comparisons

Bayesian

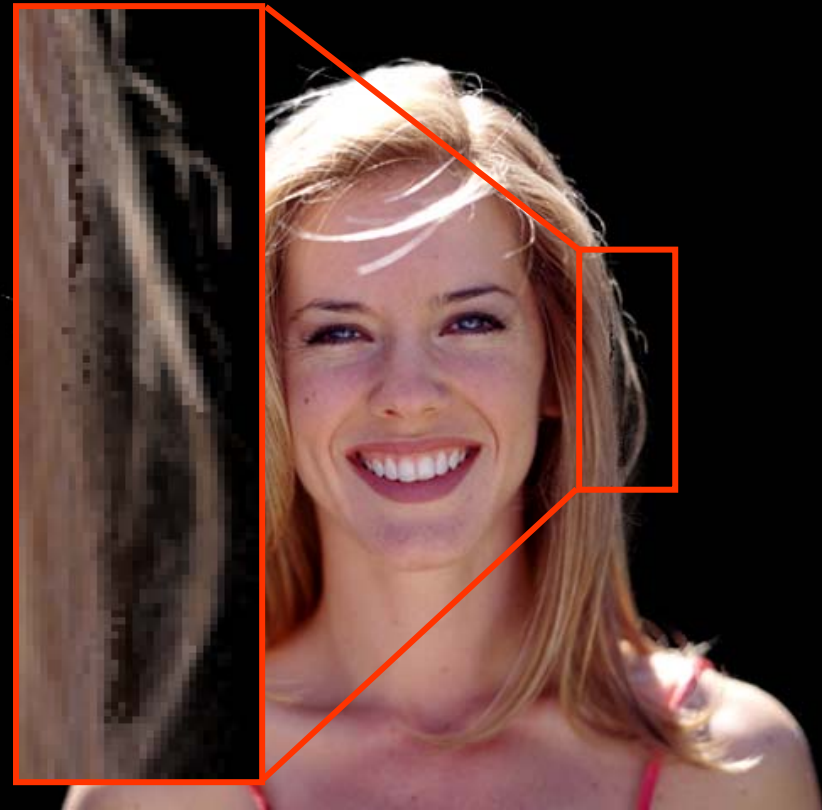
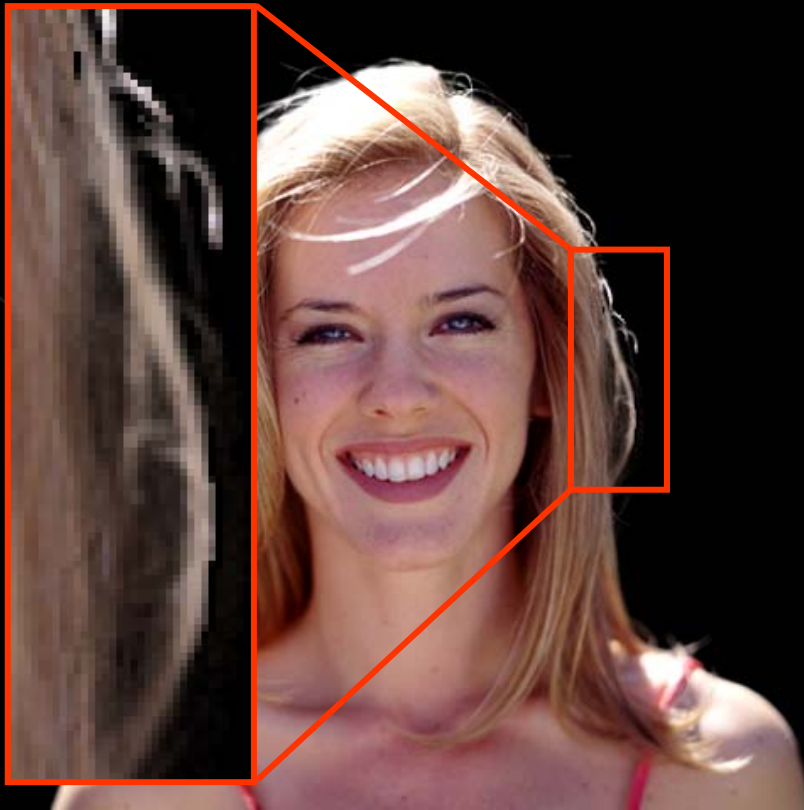
Ruzon-Tomasi



Comparisons

Bayesian

Ruzon-Tomasi



Comparisons

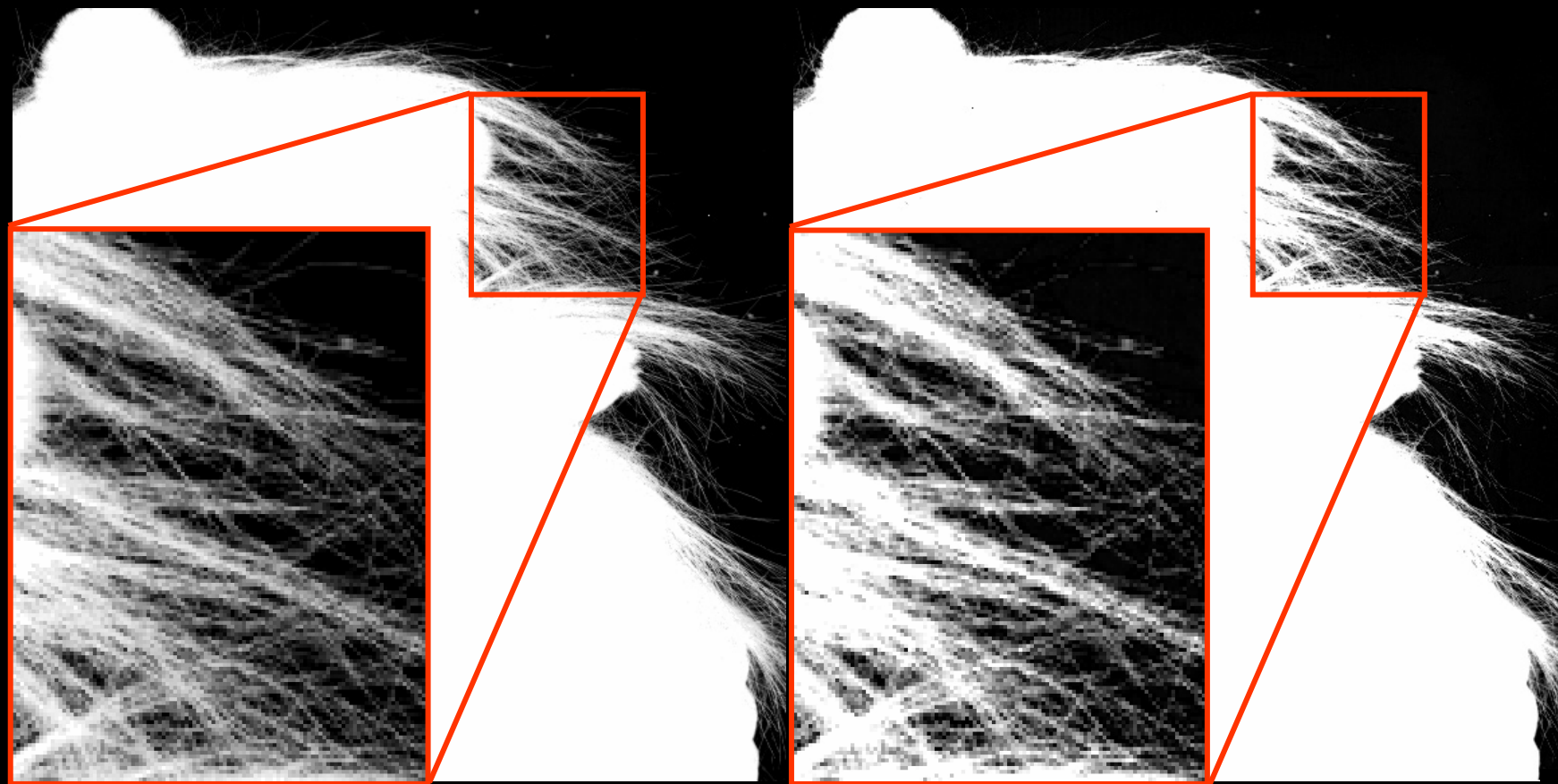
input image



Comparisons

Bayesian

Mishima



Comparisons

Bayesian



Mishima



Comparisons

Video matting

input
video

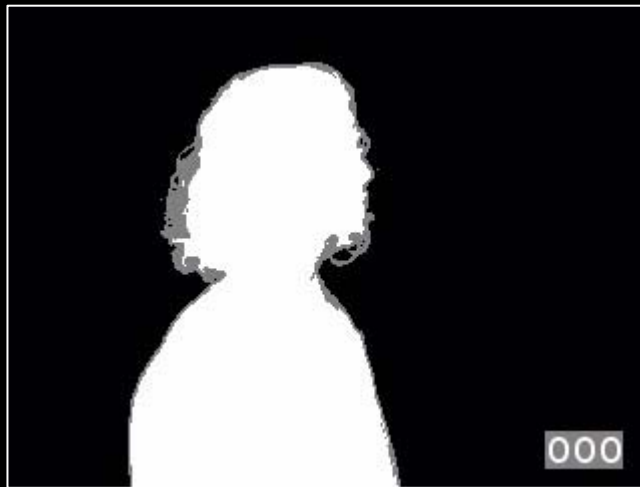


Video matting

input
video



input
key
trimaps

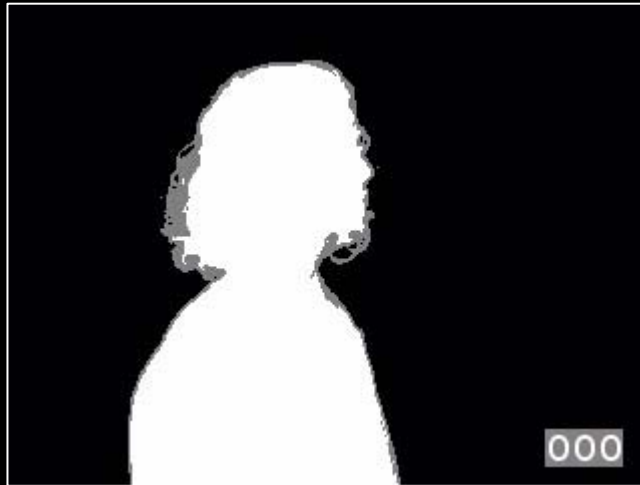


Video matting

input
video



interpo-
lated
trimaps



Video matting

input
video



interpo-
lated
trimaps



output
alpha



Video matting

input
video



Compo-
site



interpo-
lated
trimaps

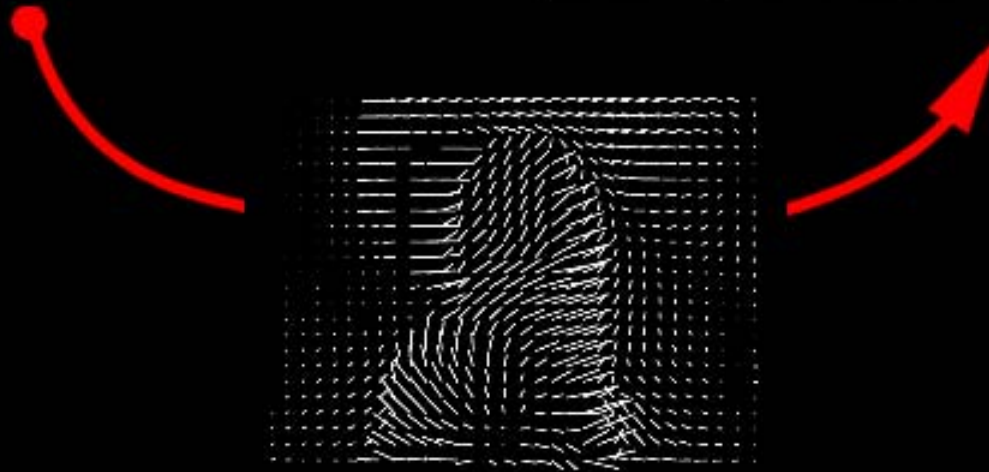


output
alpha

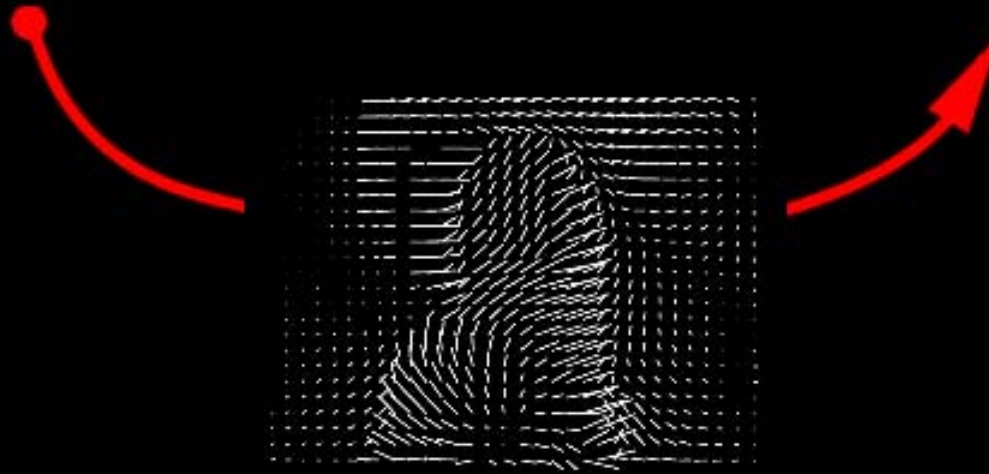


Video matting





optical flow



optical flow





t



t+1



t+2



t+3



t

t+1

t+2

t+3



t

t+1

t+2

t+3



+



t



t+1



t+2



t+3

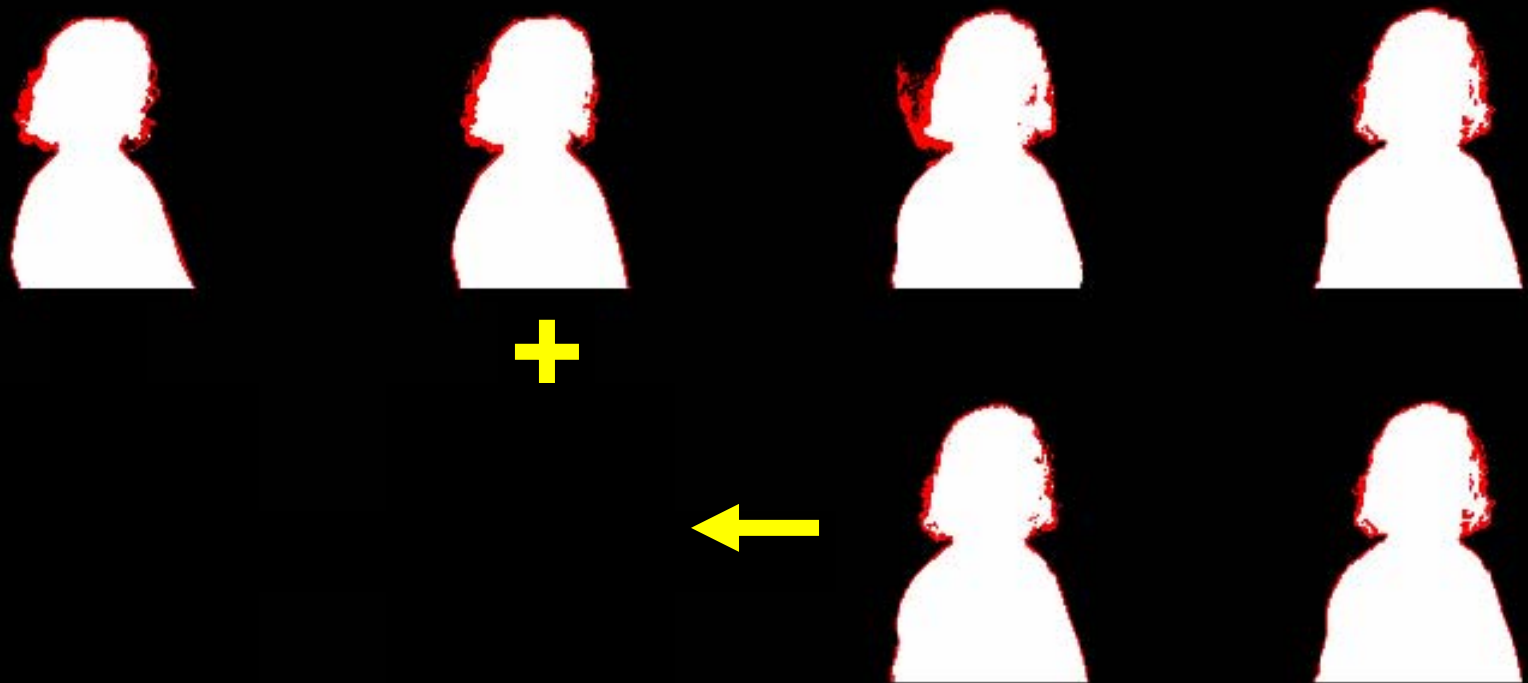


t

t+1

t+2

t+3







Sample composite



Garbage mattes



Garbage mattes



Background estimation



Background estimation



Alpha matte



*without
background*



*with
background*

Comparison

input



composite

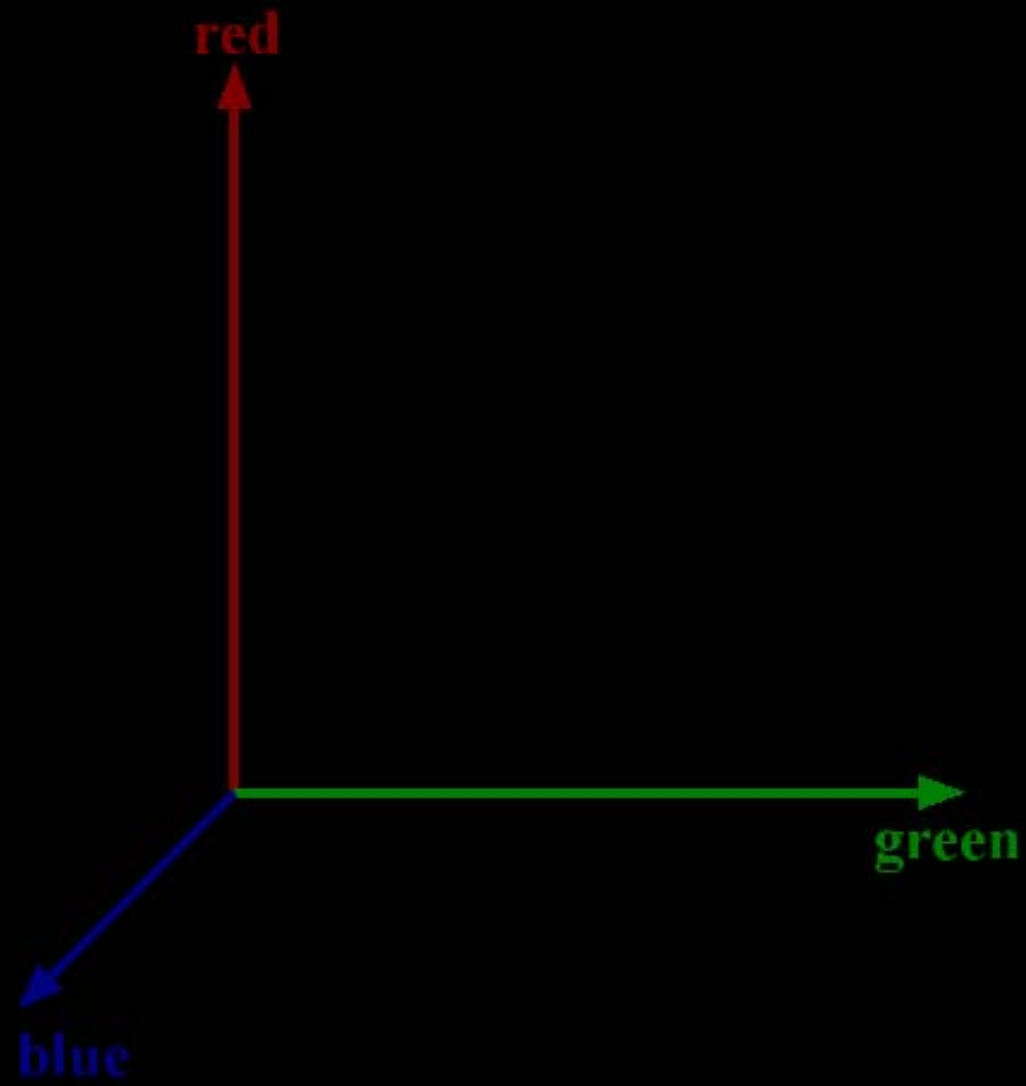




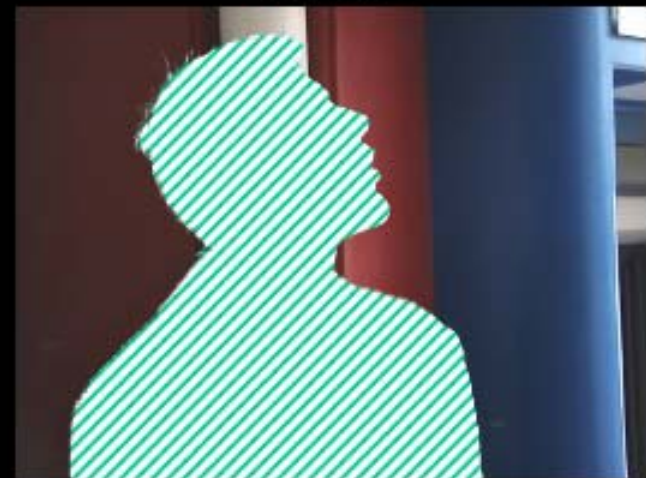




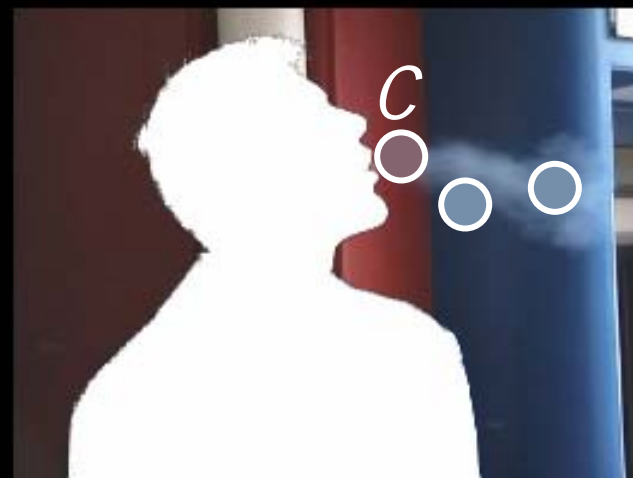
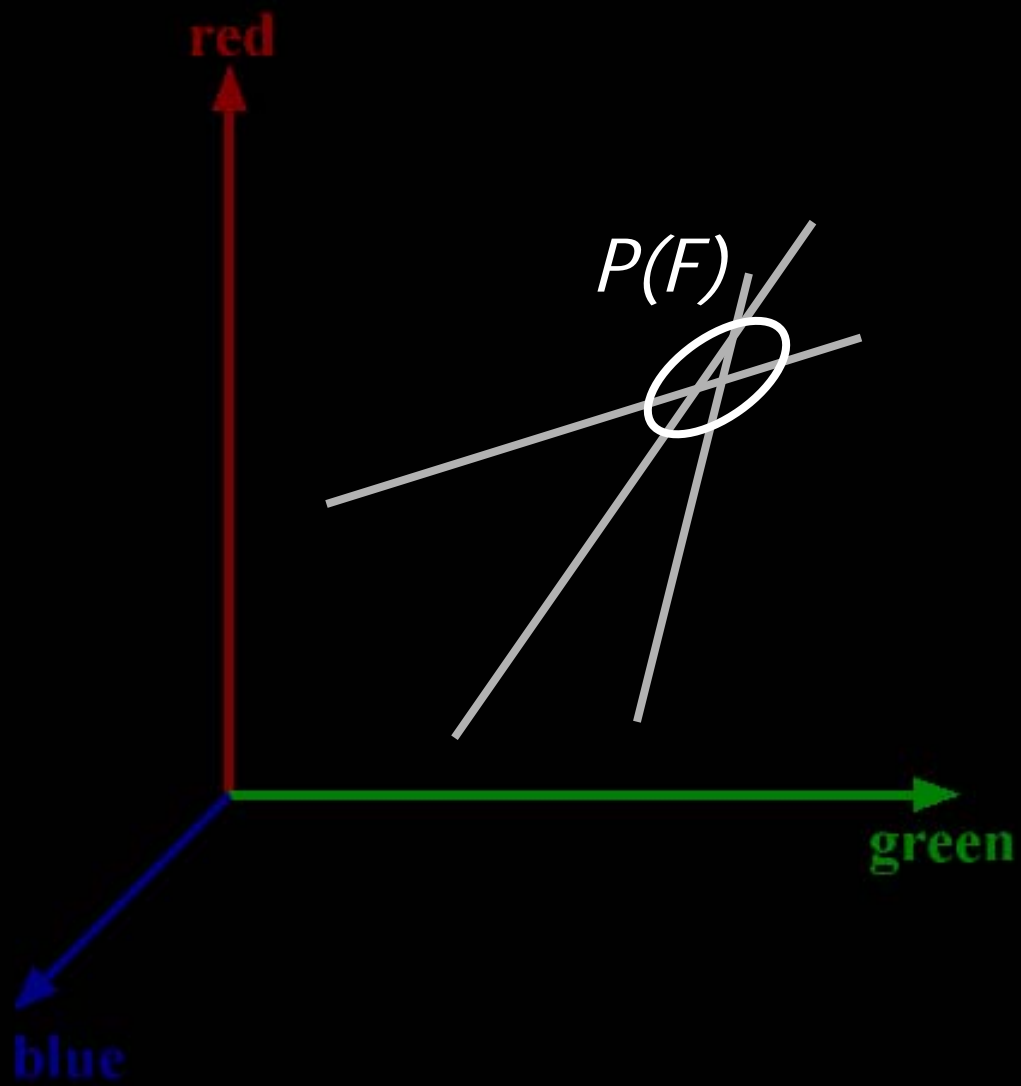




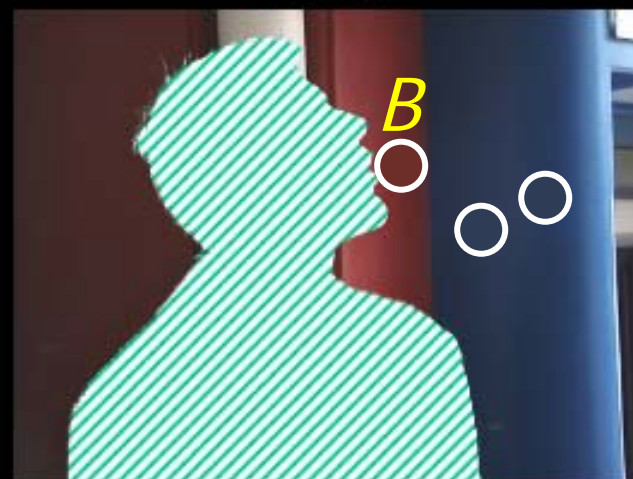
frame



clean plate



frame



clean plate







More on matting

Recent progresses on matting

- Poisson matting
- Two-camera matting methods
- Flash matting

$$I = \alpha F + (1 - \alpha)B$$

$$\nabla I = (F - B)\nabla\alpha + \alpha\nabla F + (1 - \alpha)\nabla B$$

$$\nabla\alpha \approx \frac{1}{F - B}\nabla I$$

$$\alpha^* = \arg \min_{\alpha} \int \int_{p \in \Omega} \left\| \nabla\alpha_p - \frac{1}{F_p - B_p} \nabla I_p \right\|^2 dp$$

Poisson matting



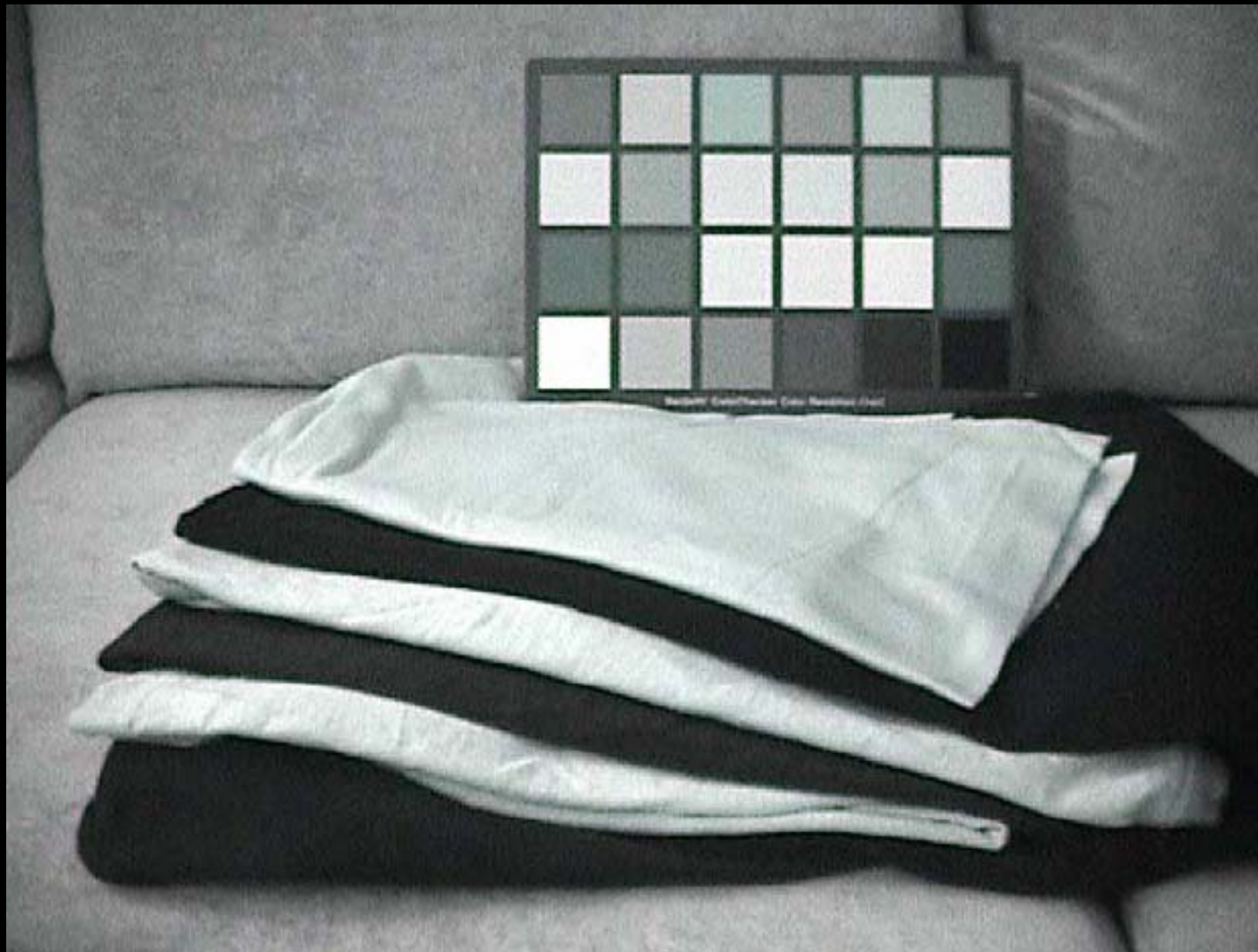
Poisson matting

Two-camera matting methods

- Invisible lights
 - Polarized lights
 - Infrared
- Thermo-key
- Depth Keying (ZCam)



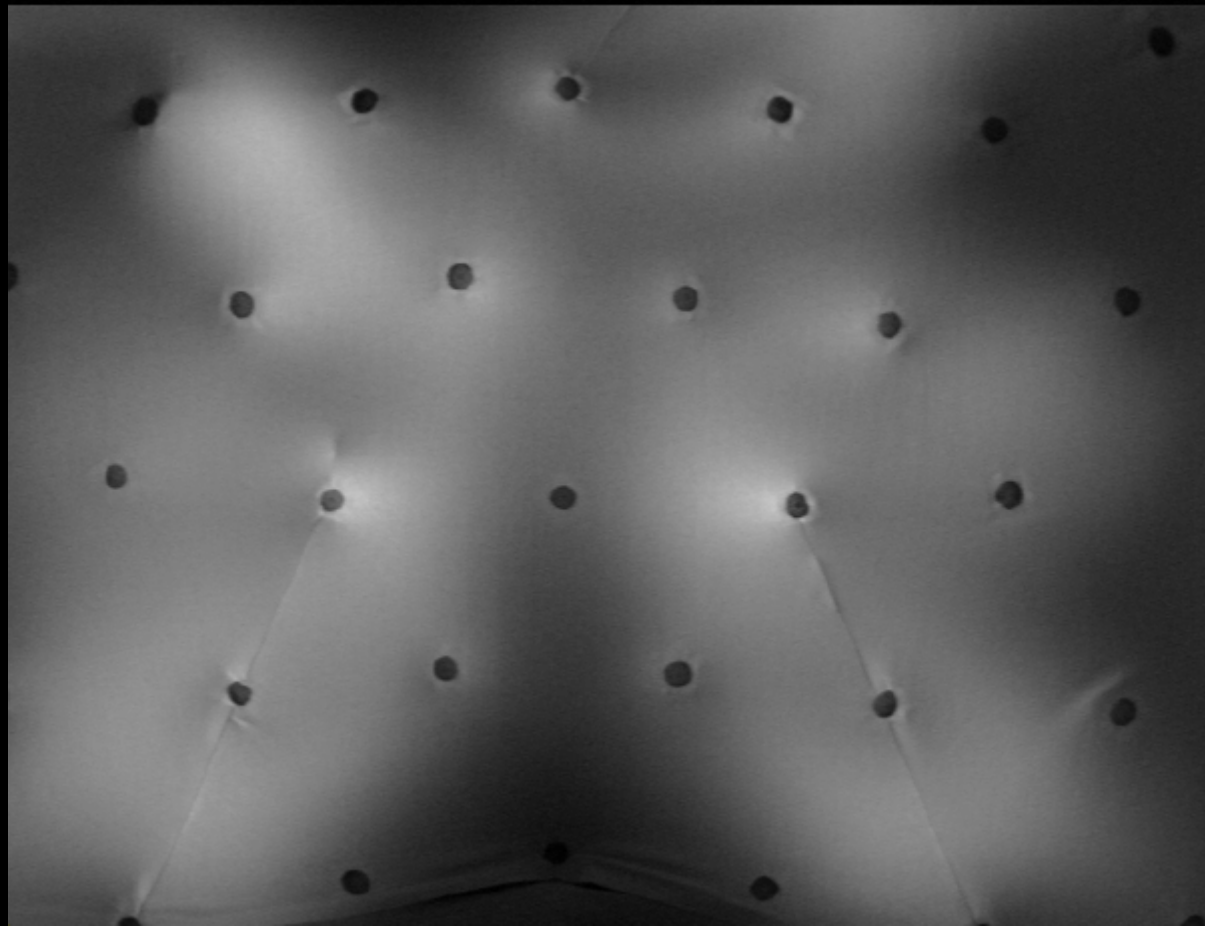
Invisible lights (Infared)



Invisible lights (Infared)



Invisible lights (Infared)



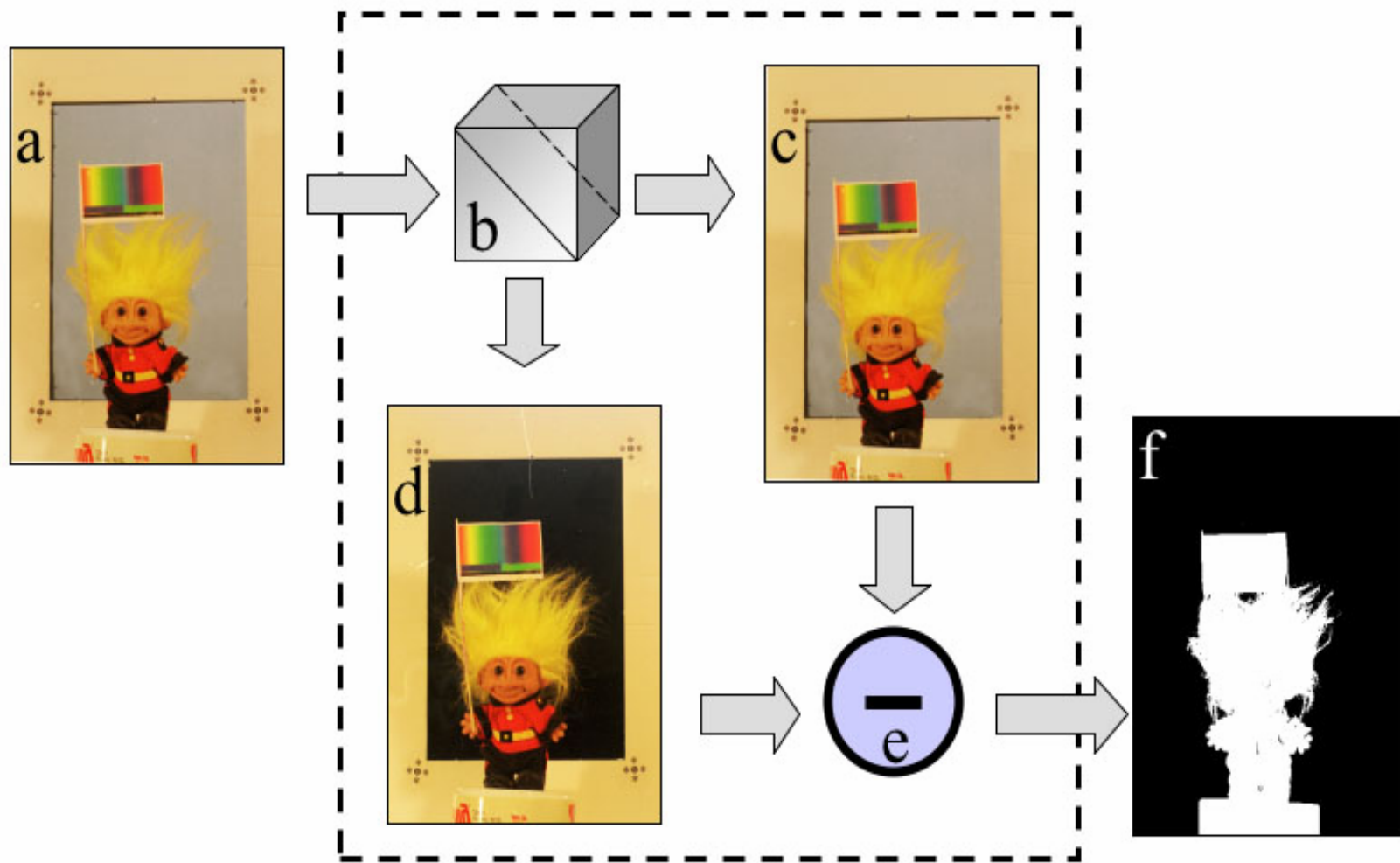
Invisible lights (Infared)



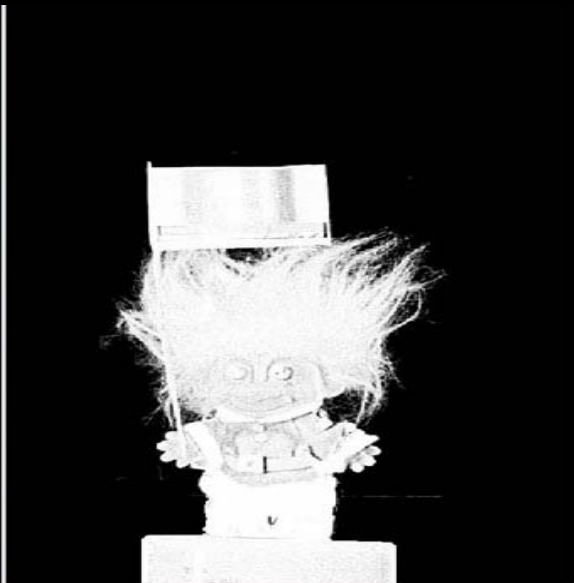
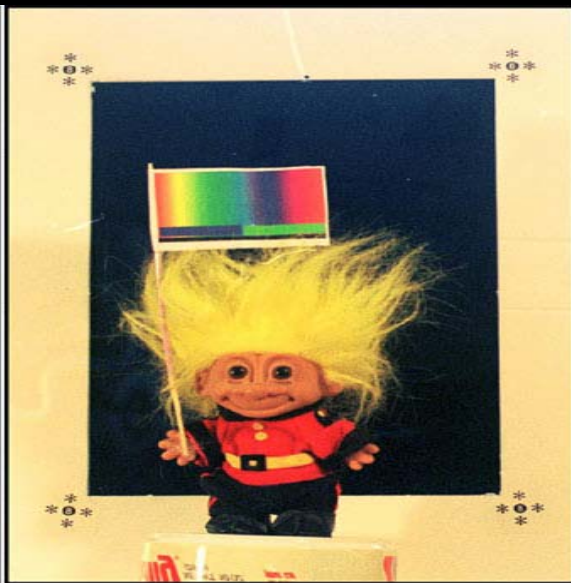
Invisible lights (Infared)



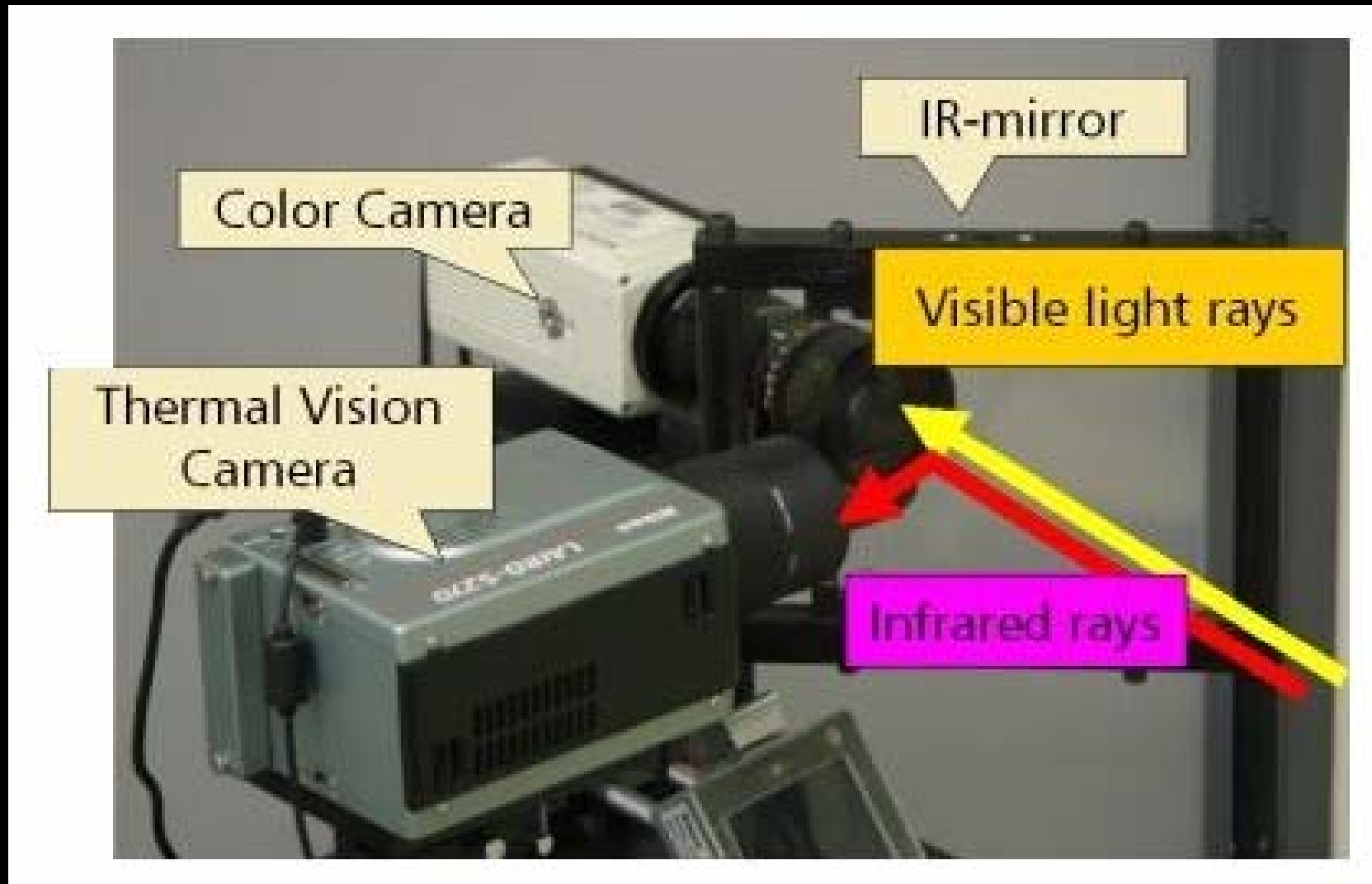
Invisible lights (Infared)



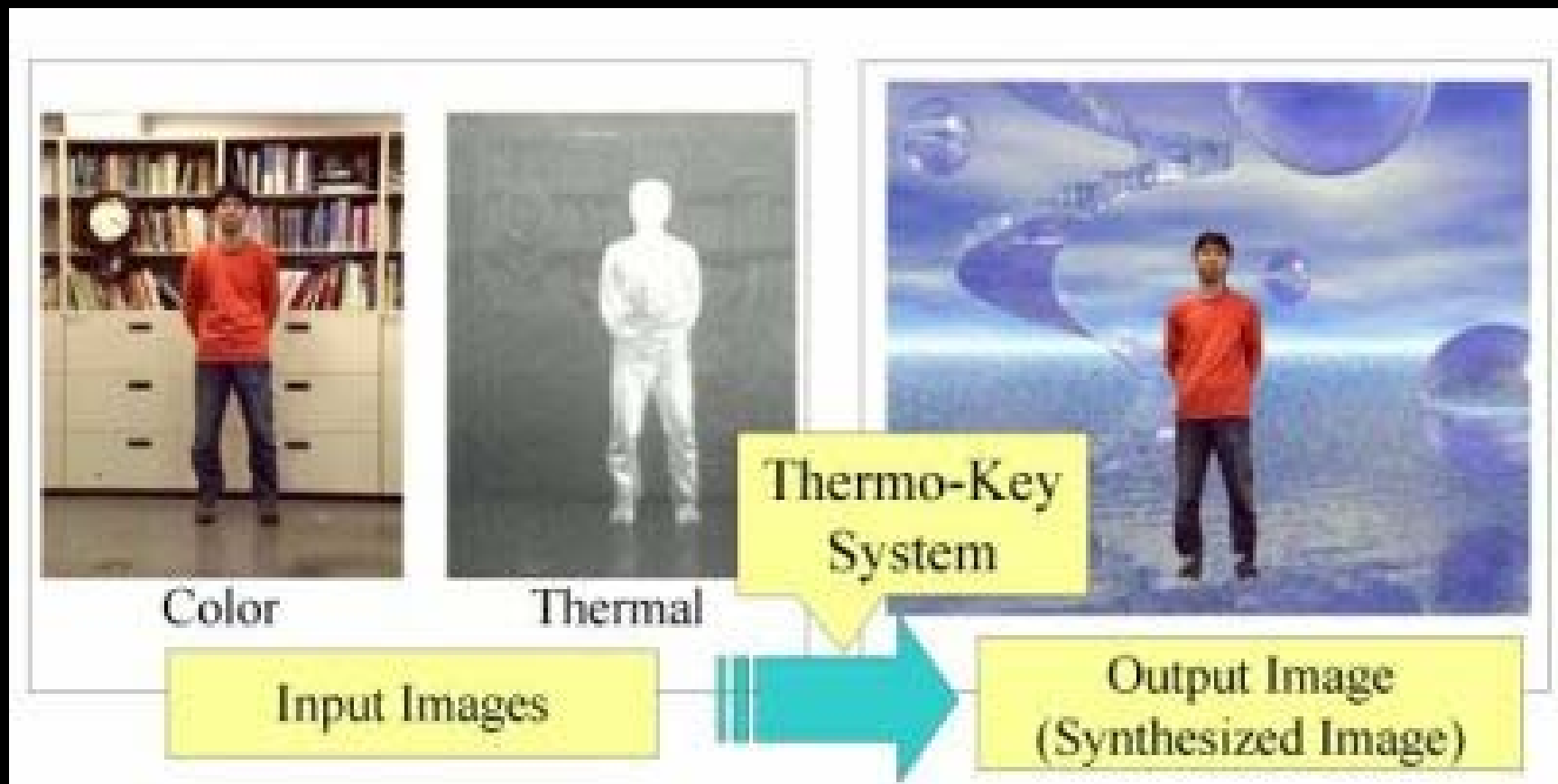
Invisible lights (Polarized)



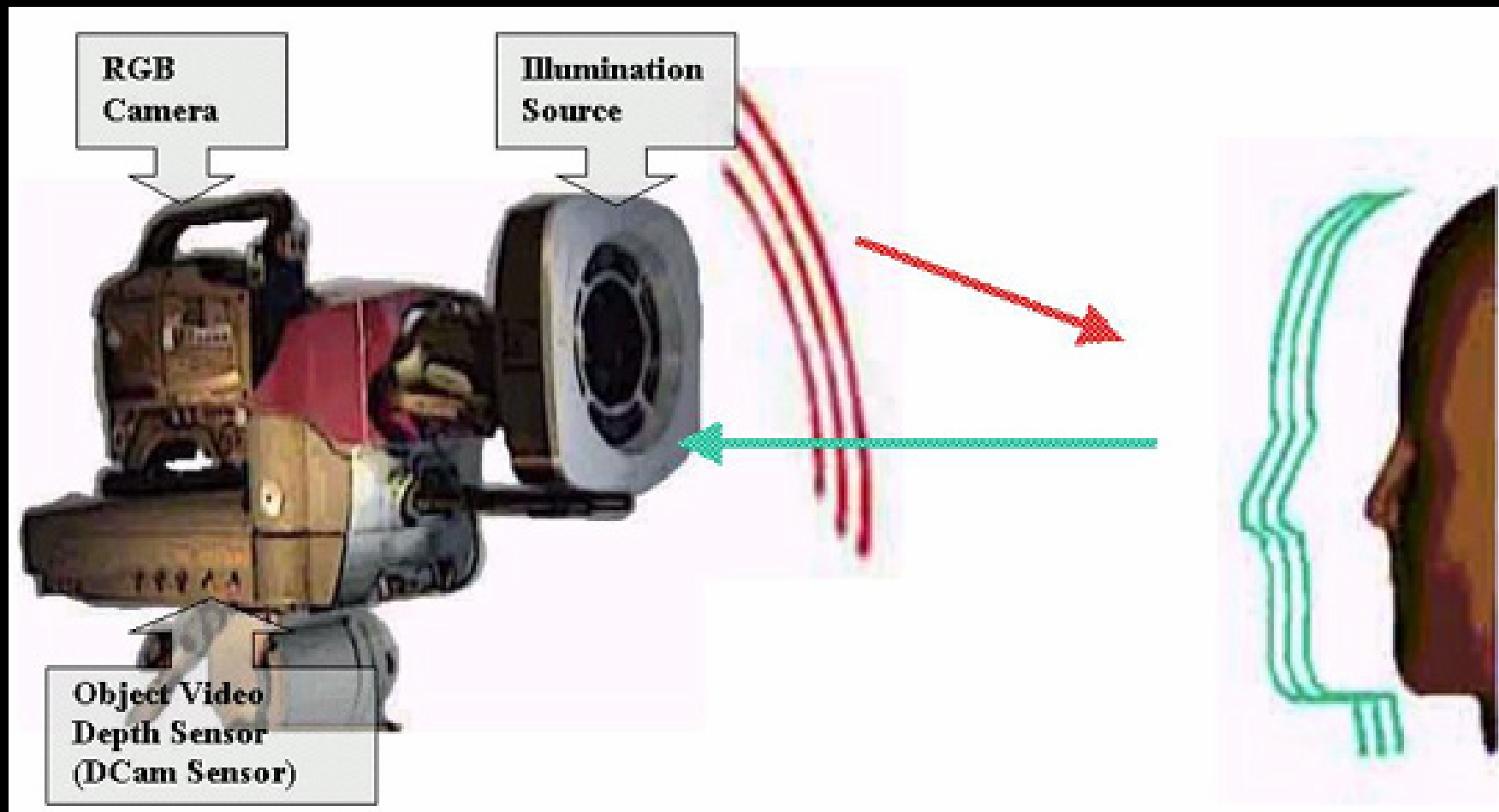
Invisible lights (Polarized)



Thermo-Key



Thermo-Key



ZCam



ZCam

flash



no flash



matte



Flash matting

$$I = \alpha F + (1 - \alpha)B,$$
$$I^f = \alpha F^f + (1 - \alpha)B^f,$$

Background is much further than foreground and receives almost no flash light

$$B^f \approx B$$

$$I^f = \alpha F^f + (1 - \alpha)B$$

Flash matting

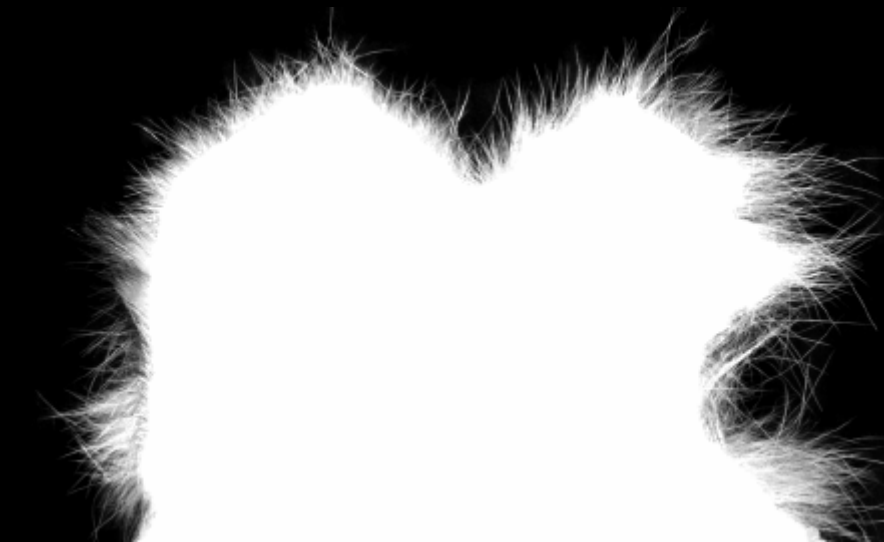
Foreground flash matting equation

$$I' = I^f - I = \alpha(F^f - F) = \alpha F'$$

Generate a trimap and directly apply Bayesian matting.

$$\begin{aligned} & \arg \max_{\alpha, F'} L(\alpha, F' | I') \\ &= \arg \max_{\alpha, F'} \{ L(I' | \alpha, F') + L(F') + L(\alpha) \} \\ L(I' | \alpha, F') &= -||I' - \alpha F'|| / \sigma_{I'}^2 \\ L(F') &= -(F' - \overline{F'})^T \Sigma_{F'}^{-1} (F' - \overline{F'}) \end{aligned}$$

Flash matting



Foreground flash matting

$$I = \alpha F + (1 - \alpha)B$$
$$I' = \alpha F'$$

$$\arg \max_{\alpha, F, B, F'} L(\alpha, F, B, F' | I, I')$$
$$= \arg \max_{\alpha, F, B, F'} \{L(I|\alpha, F, B) + L(I'|\alpha, F') +$$
$$L(F) + L(B) + L(F') + L(\alpha)\}$$

Joint Bayesian flash matting

$$\alpha = \frac{\sigma_{I'}^2 (F - B)^T (I - B) + \sigma_I^2 F'^T I'}{\sigma_{I'}^2 (F - B)^T (F - B) + \sigma_I^2 F'^T F'}$$

$$\begin{bmatrix} \Sigma_F^{-1} + \mathbf{I}\alpha^2/\sigma_I^2 & \mathbf{I}\alpha(1 - \alpha)\sigma_I^2 & \mathbf{0} \\ \mathbf{I}\alpha(1 - \alpha)\sigma_I^2 & \Sigma_B^{-1} + \mathbf{I}\alpha^2/\sigma_I^2 & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \Sigma_{F'}^{-1} + \mathbf{I}\alpha^2/\sigma_{I'}^2 \end{bmatrix} \begin{bmatrix} F \\ B \\ F' \end{bmatrix}$$

$$= \begin{bmatrix} \Sigma_F^{-1} \bar{F} + I\alpha/\sigma_I^2 \\ \Sigma_B^{-1} \bar{B} + I(1 - \alpha)/\sigma_I^2 \\ \Sigma_{F'}^{-1} \bar{F}' + I'\alpha/\sigma_{I'}^2 \end{bmatrix},$$

Joint Bayesian flash matting

flash



no flash



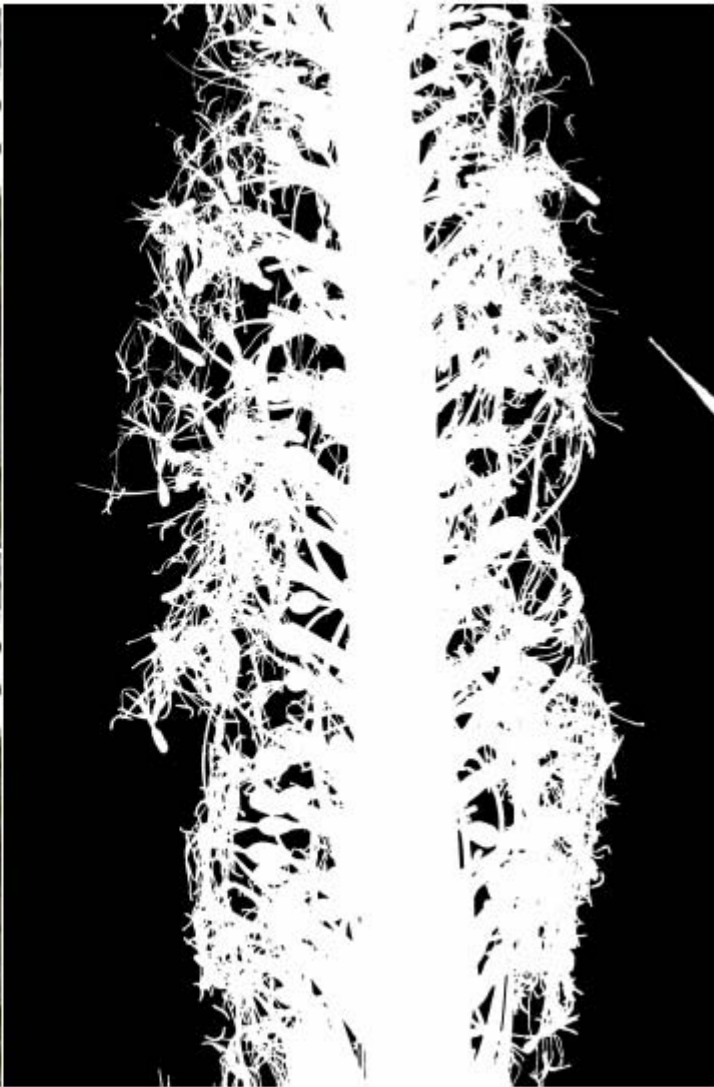
Comparison

foreground
flash matting

joint Bayesian
flash matting



Comparison



Flash matting

*Shadow matting
and composting*

source scene



target background



blue screen image



target background



blue screen composite



target background



blue screen composite

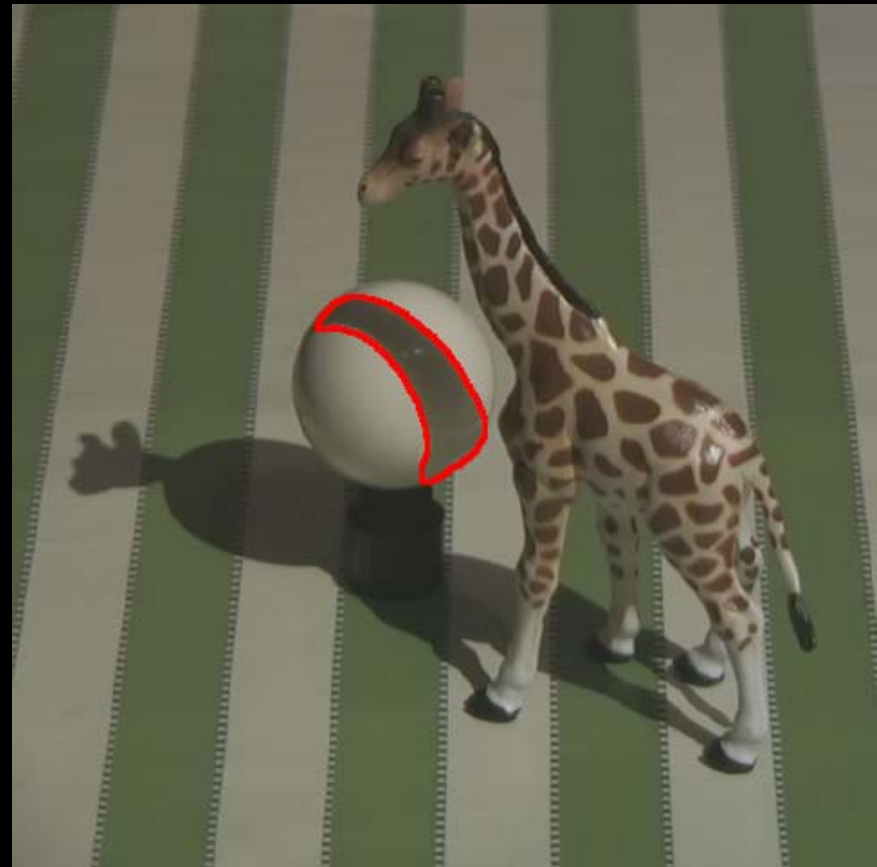
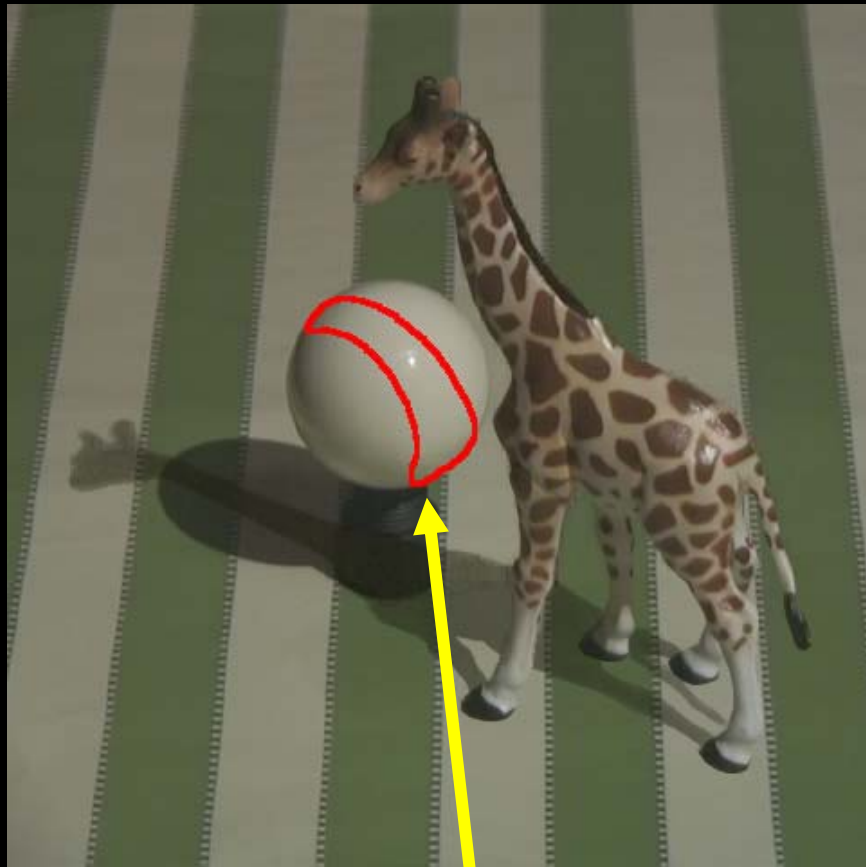


photograph



blue screen composite

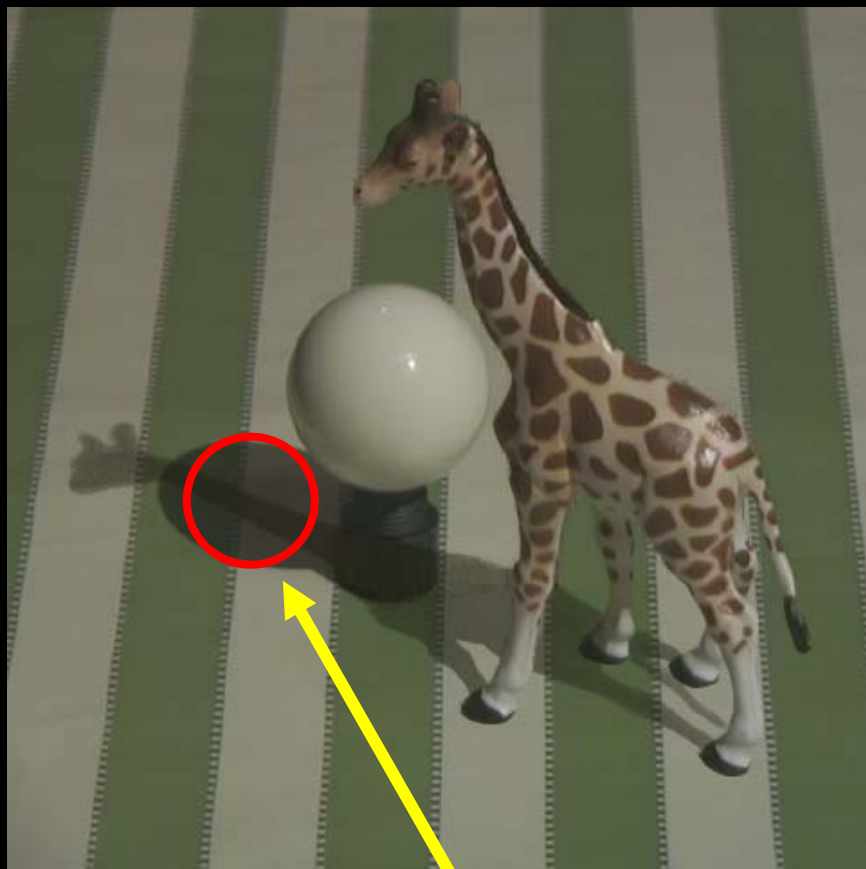
photograph



Geometric errors

blue screen composite

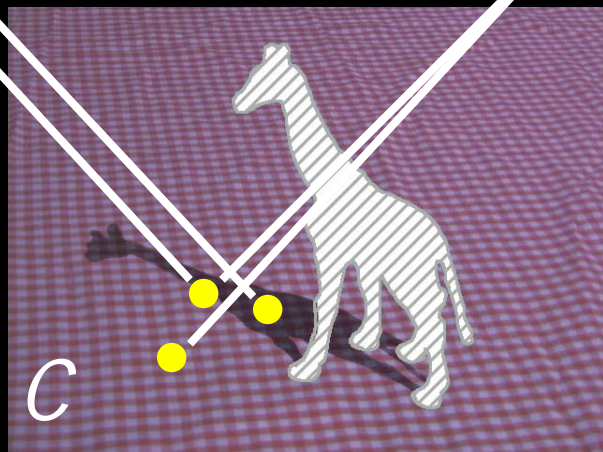
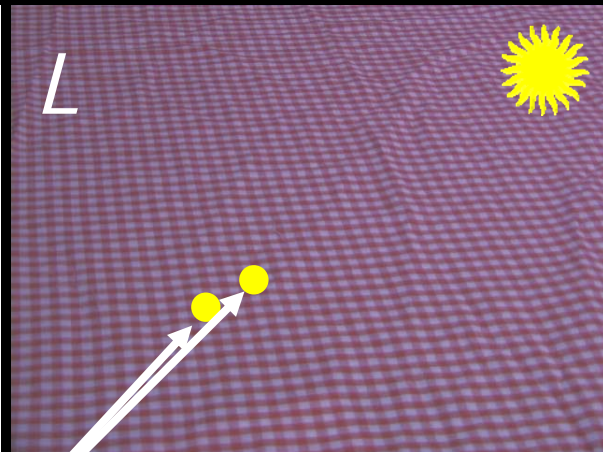
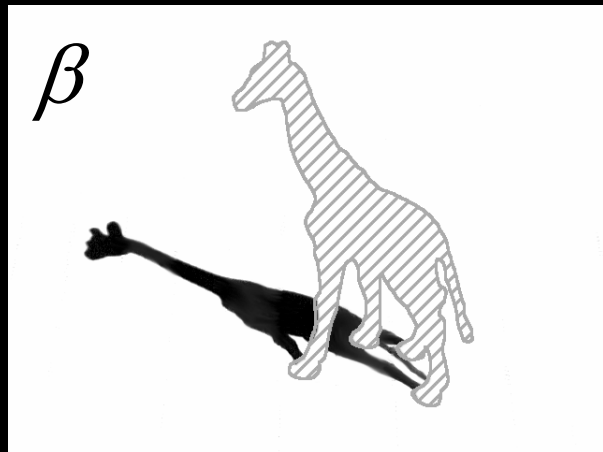
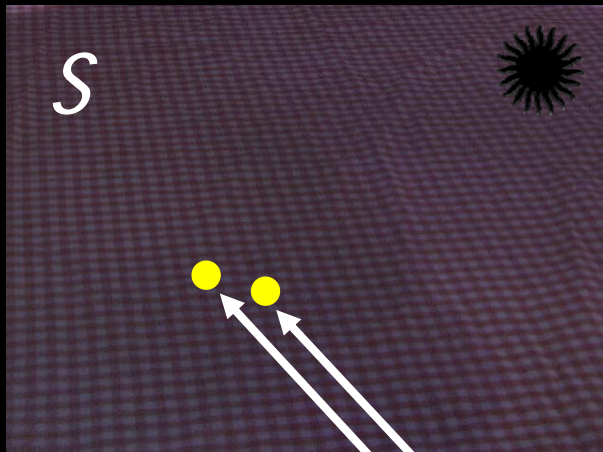
photograph

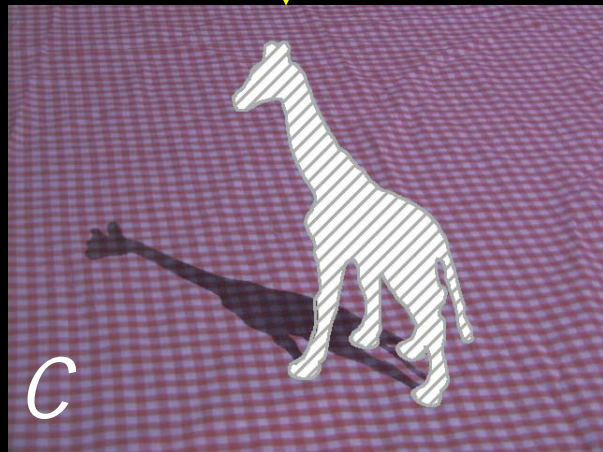
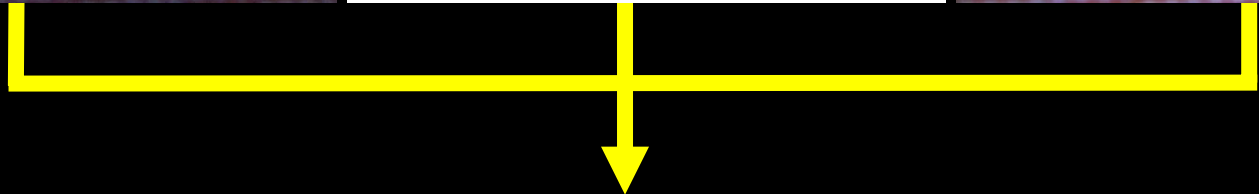
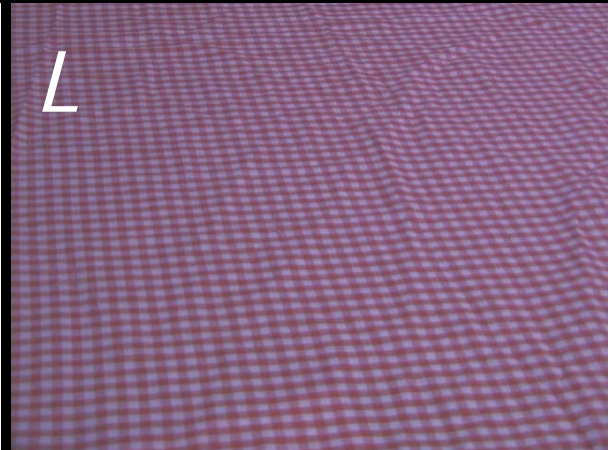
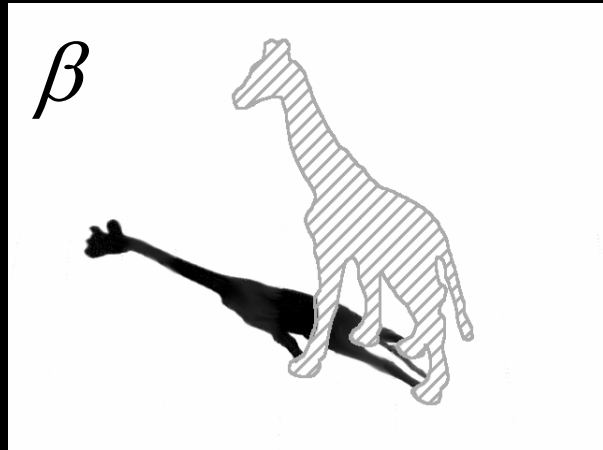


Photometric errors





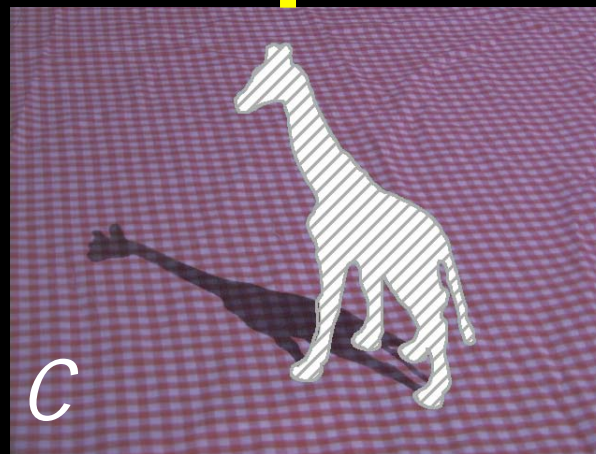
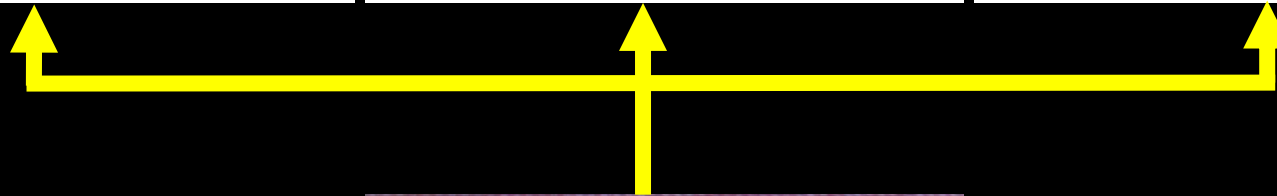
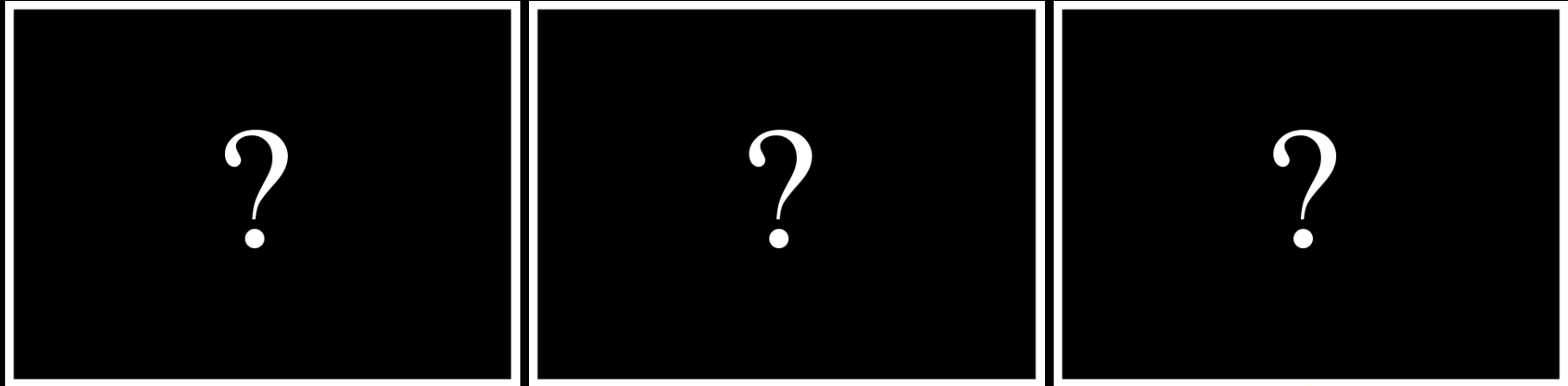




$$C = \beta L + (1 - \beta) S$$

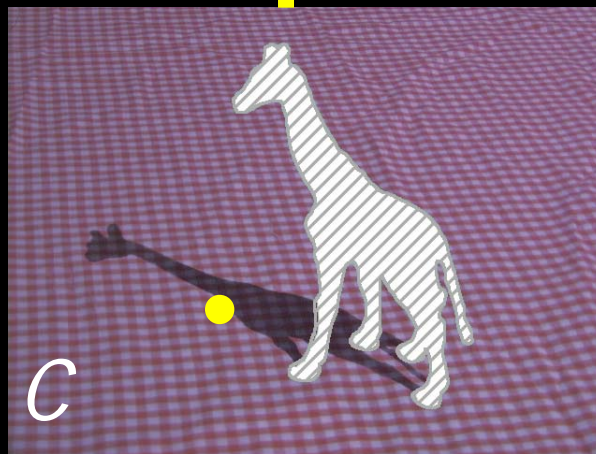
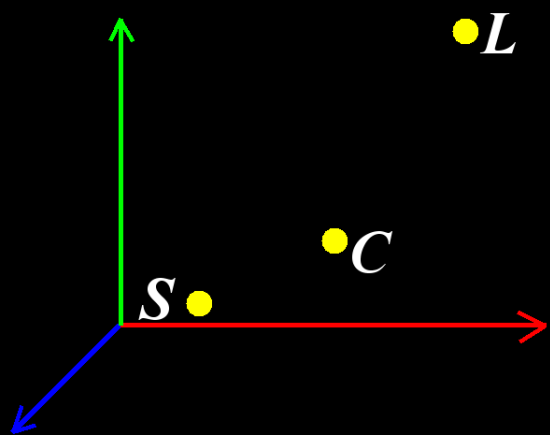
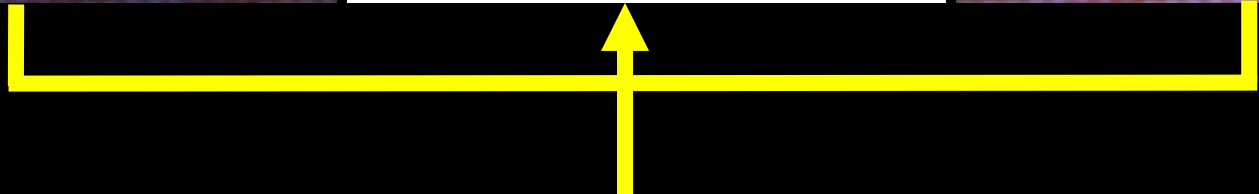
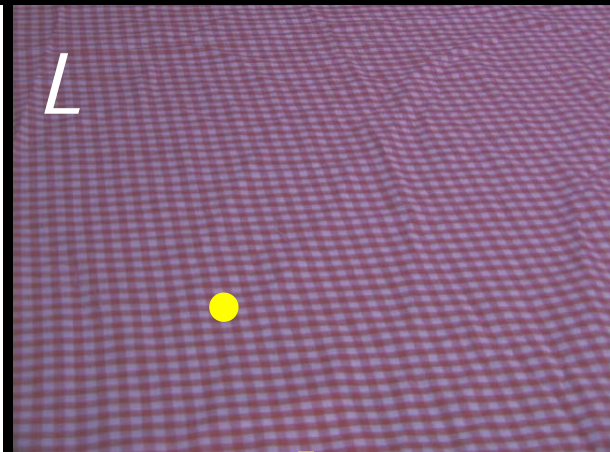
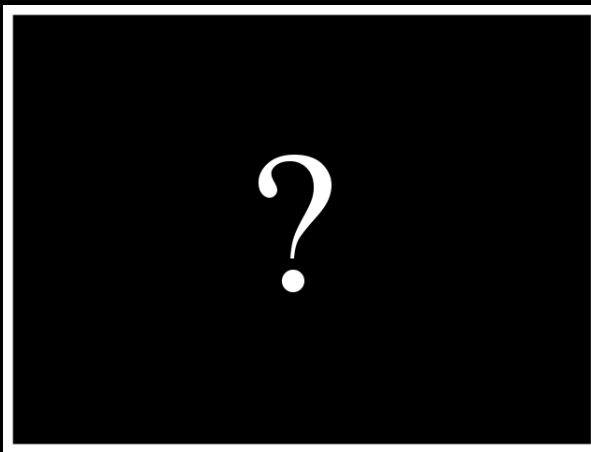
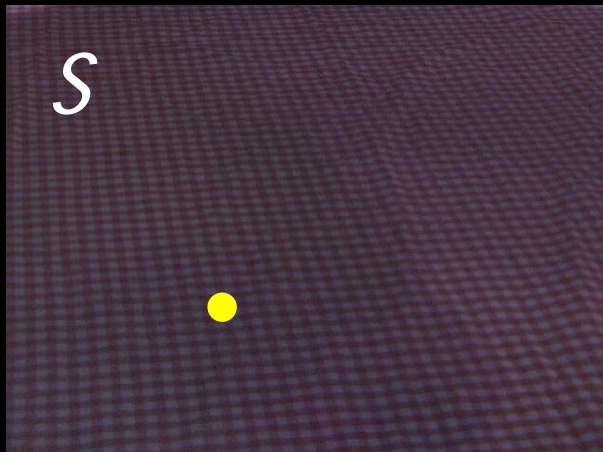
shadow
compositing
equation

Shadow compositing equation



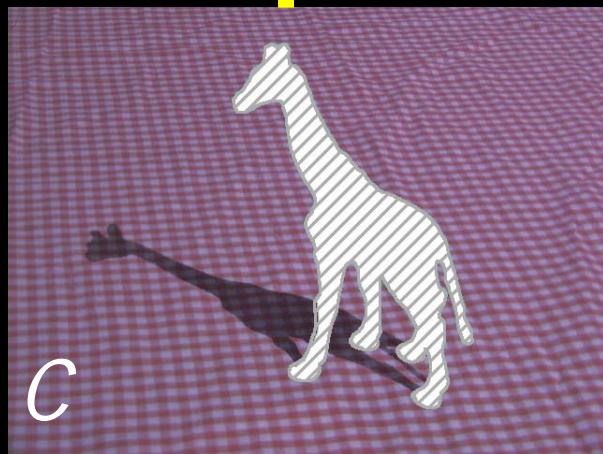
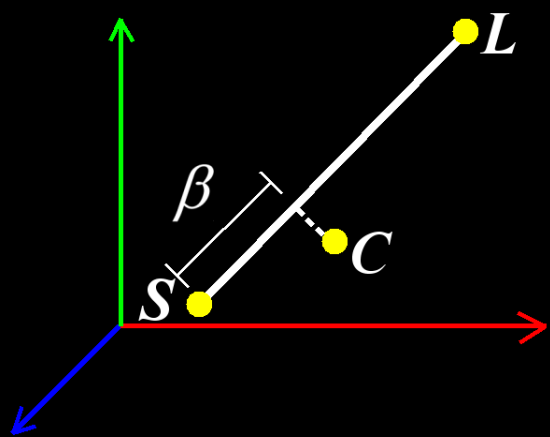
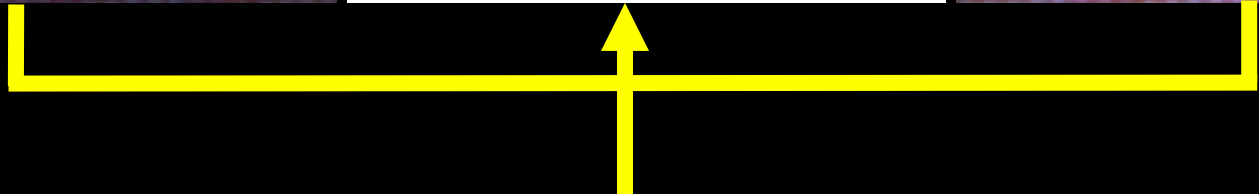
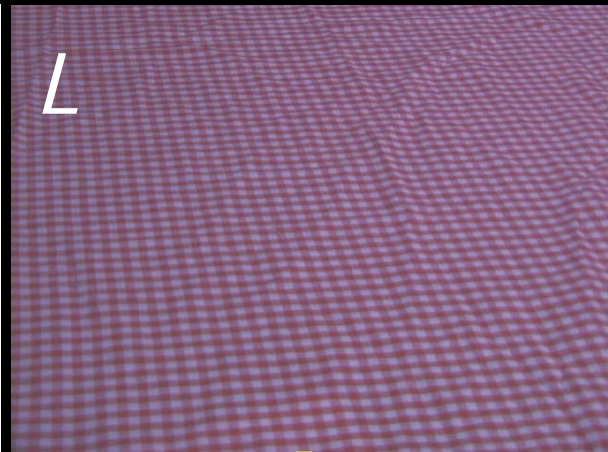
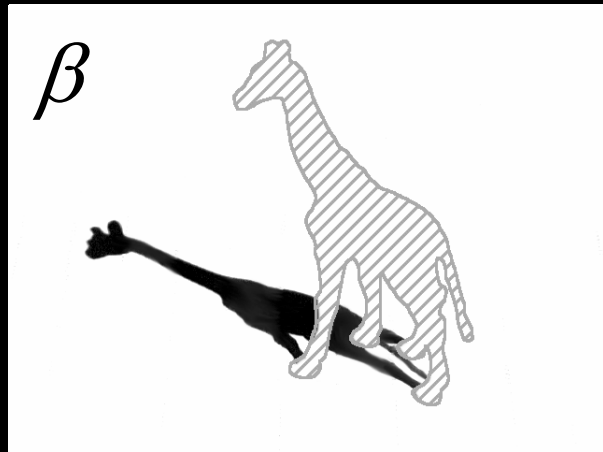
$C = \beta L + (1 - \beta)S$
shadow
compositing
equation

Shadow matting



$C = \beta L + (1 - \beta)S$
shadow
compositing
equation

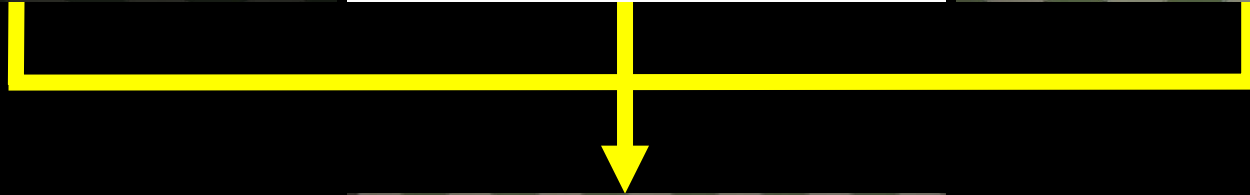
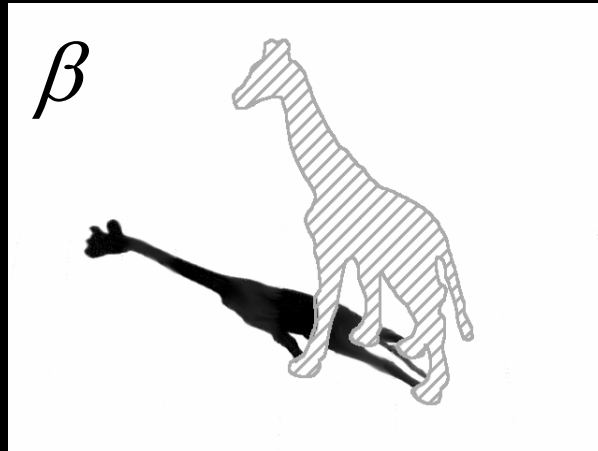
Shadow matting



$$C = \beta L + (1 - \beta)S$$

shadow
compositing
equation

Shadow matting



$$C = \beta L + (1 - \beta) S$$

shadow
compositing
equation

Shadow compositing



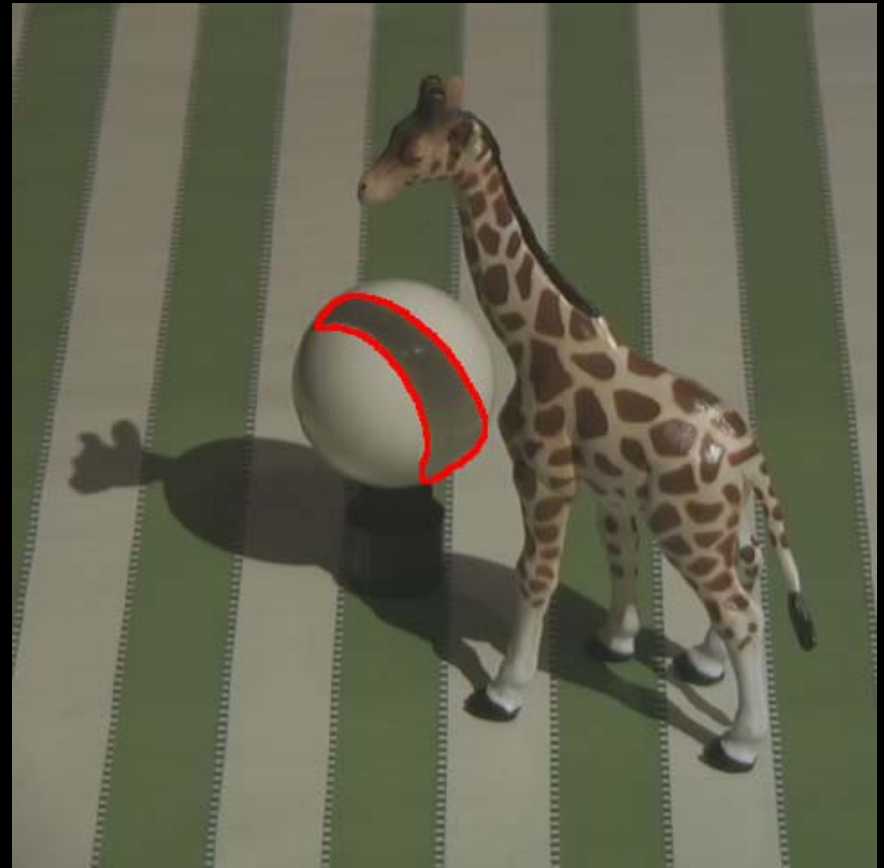
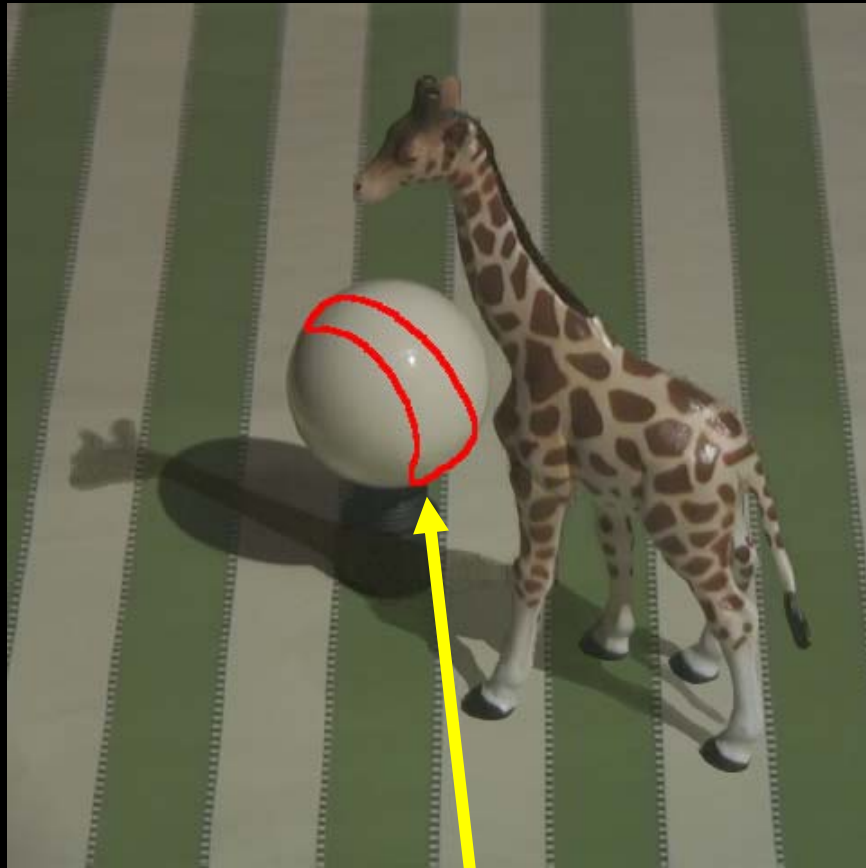












Geometric errors

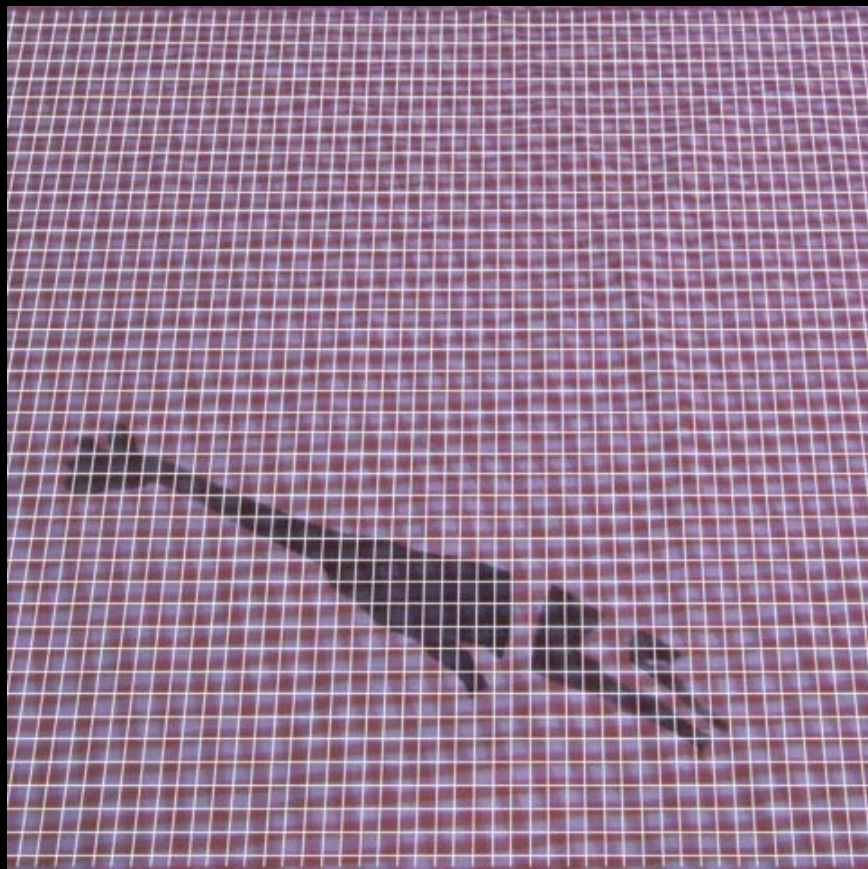
source scene



target background



source scene

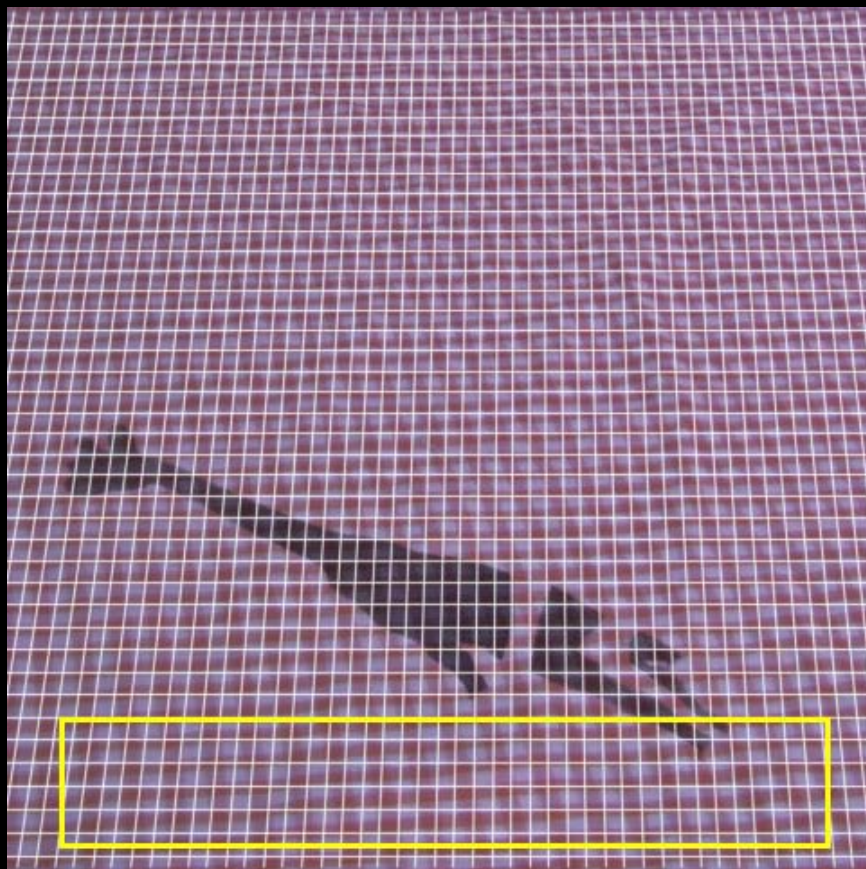


target background

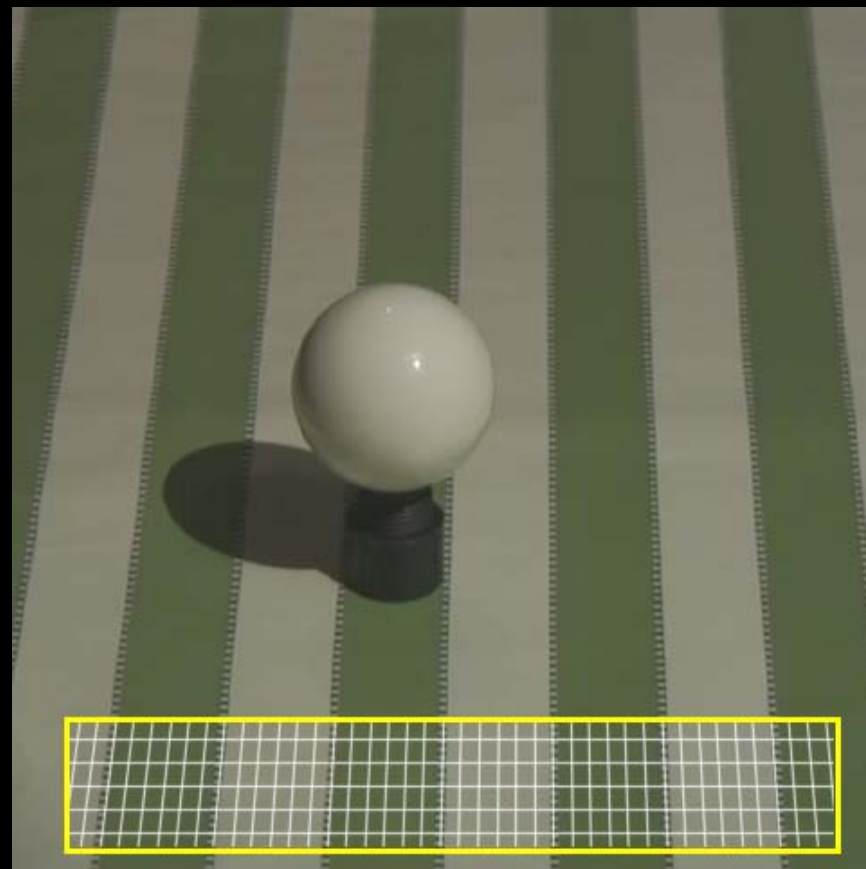


Requirement #1

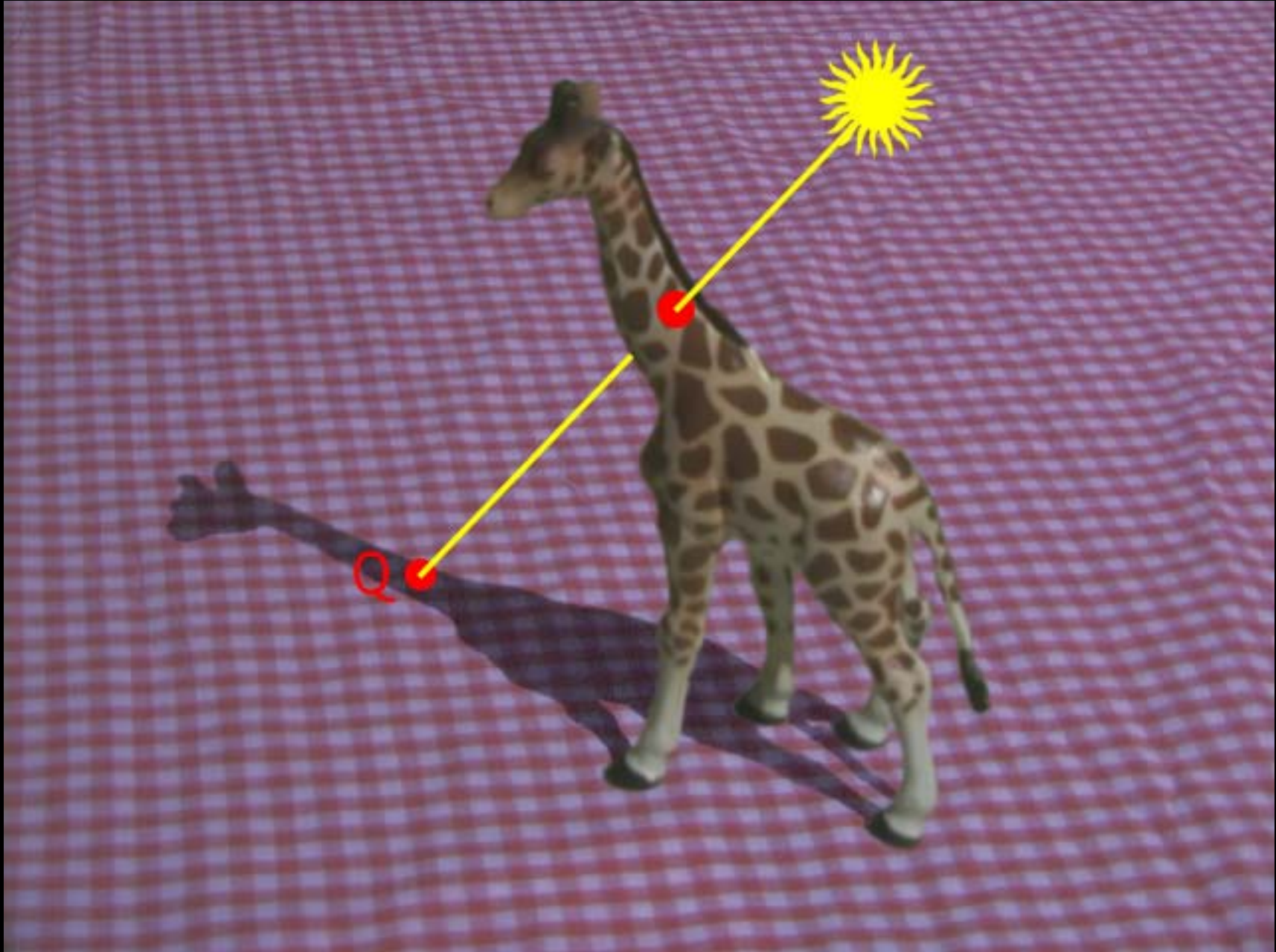
source scene

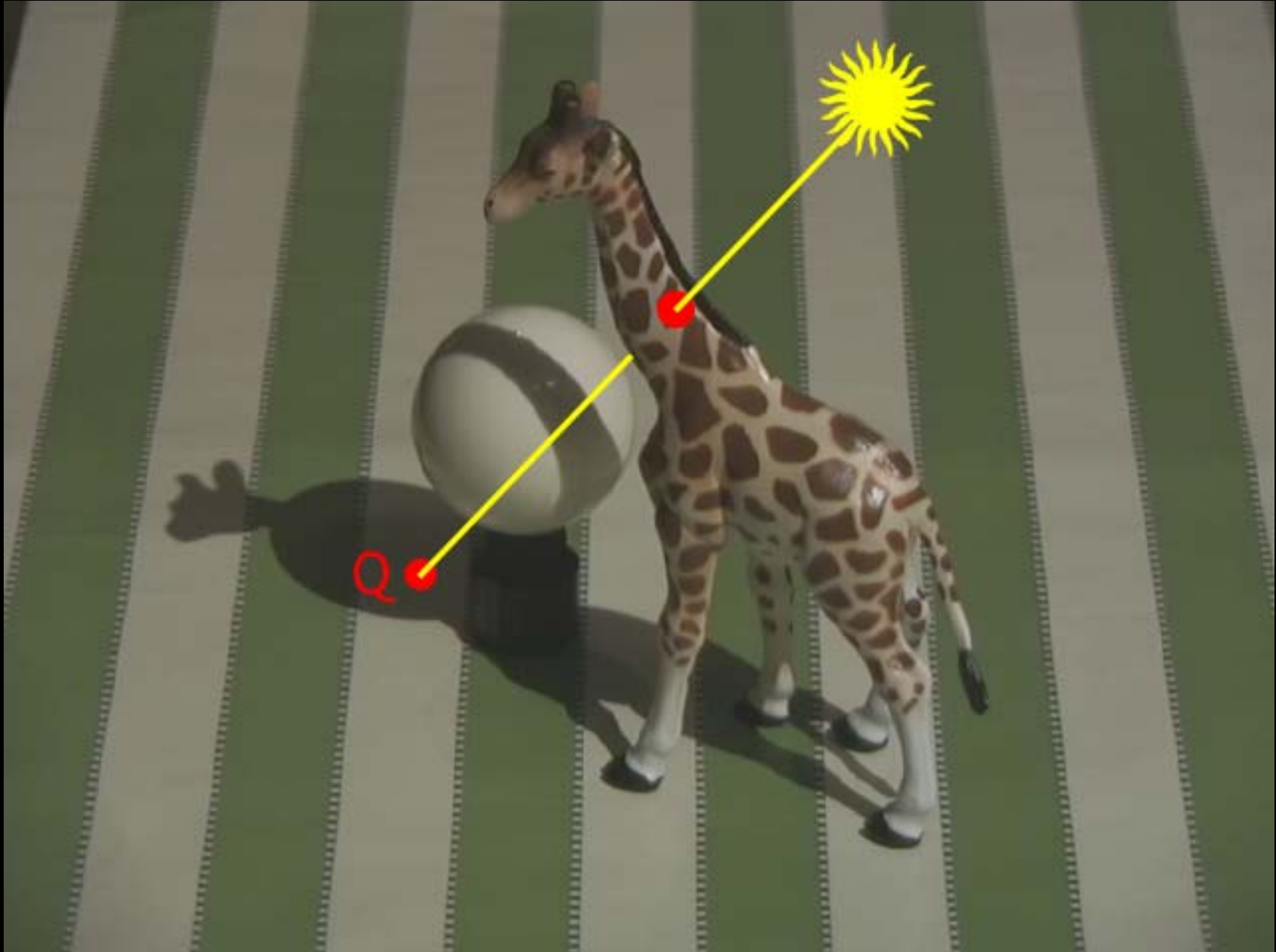


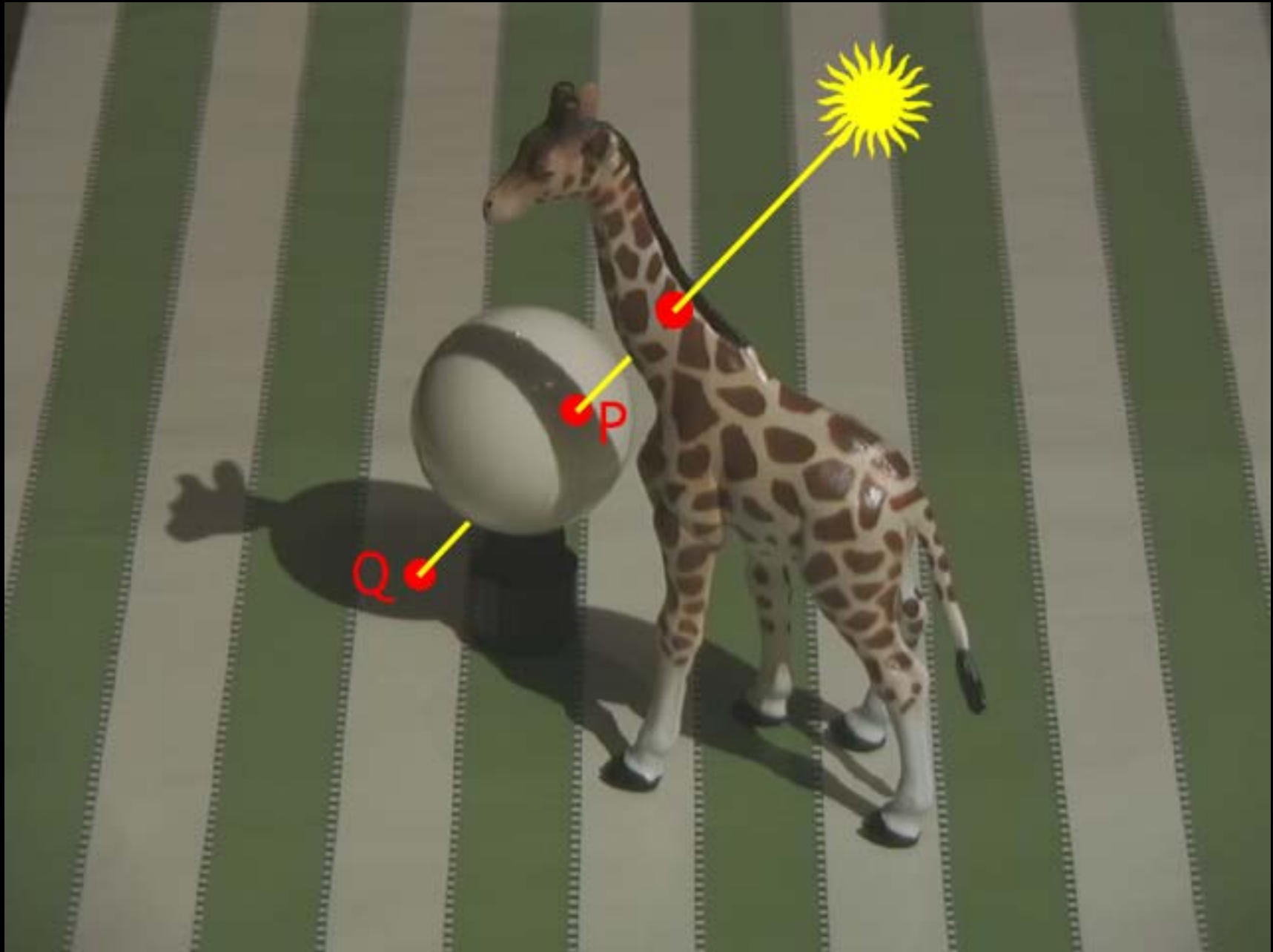
target background



Requirement #2

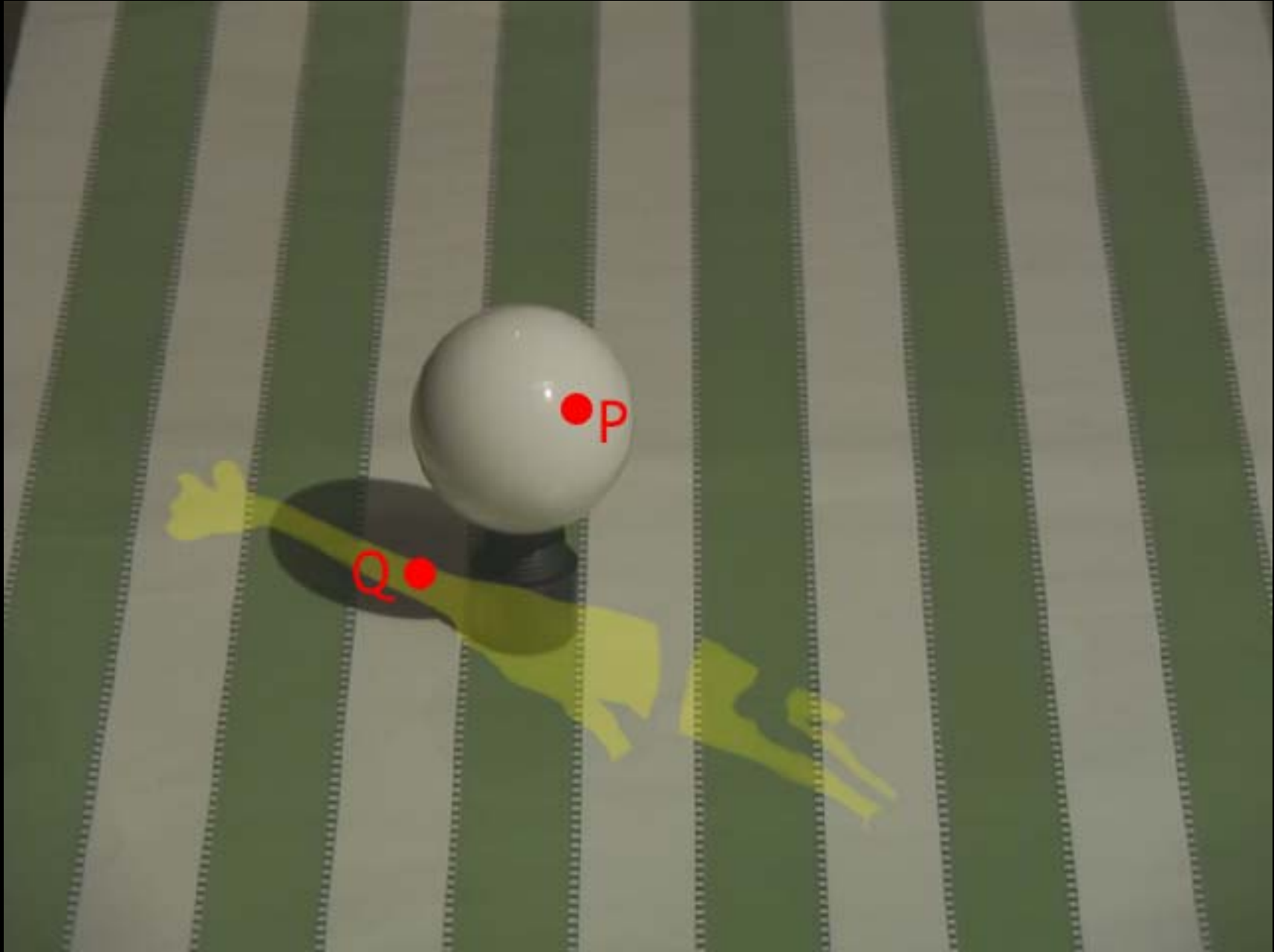


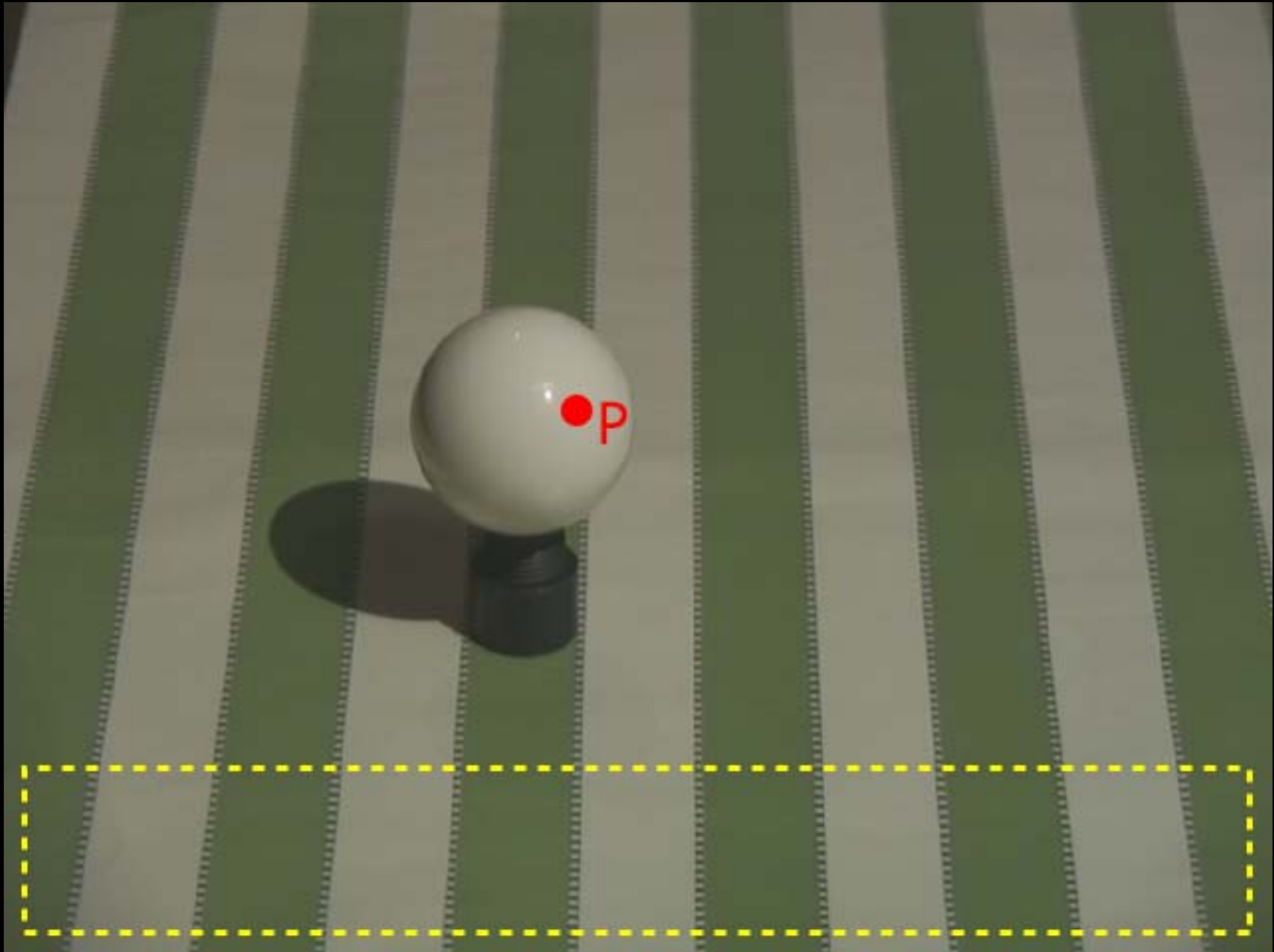


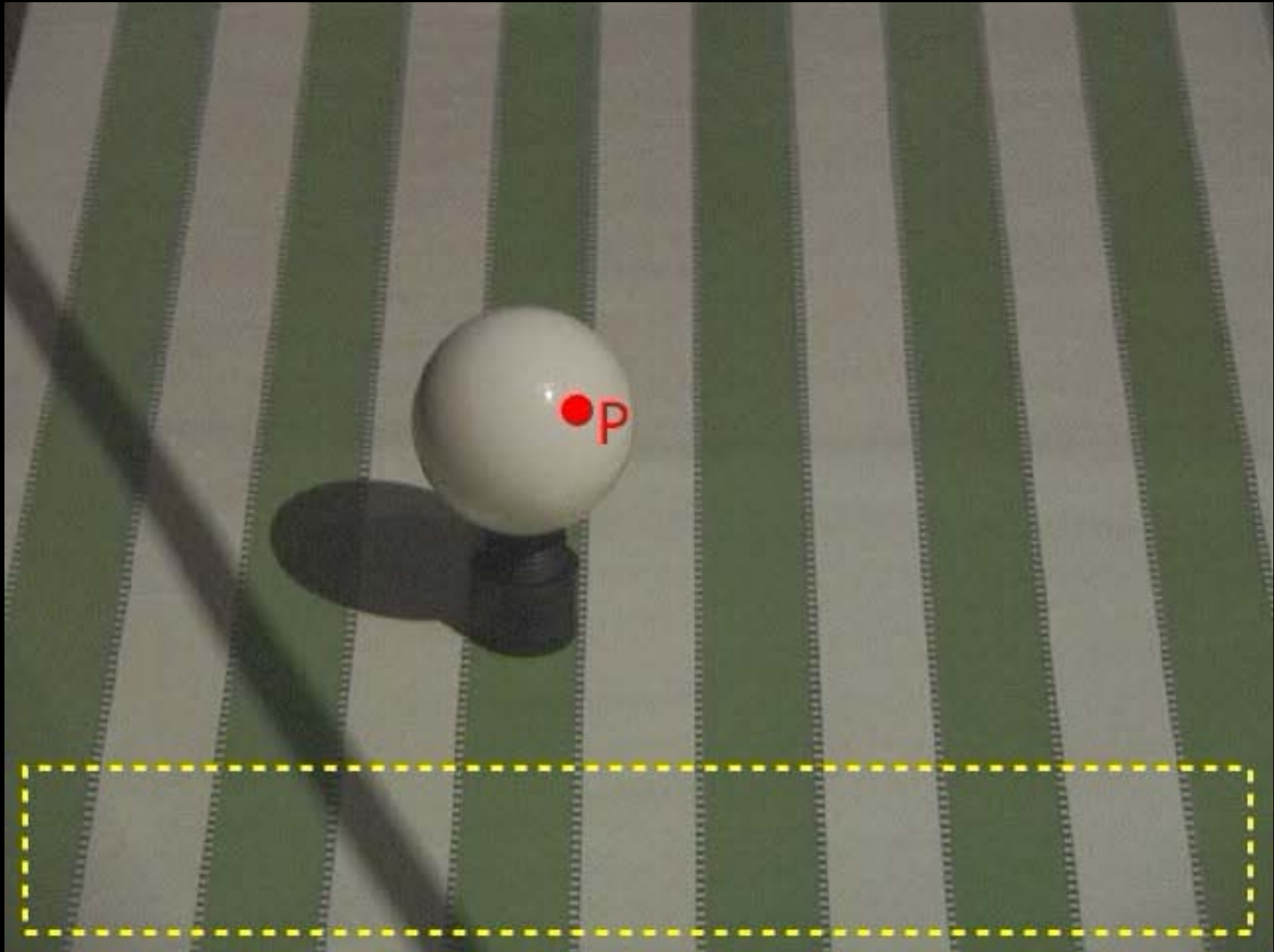


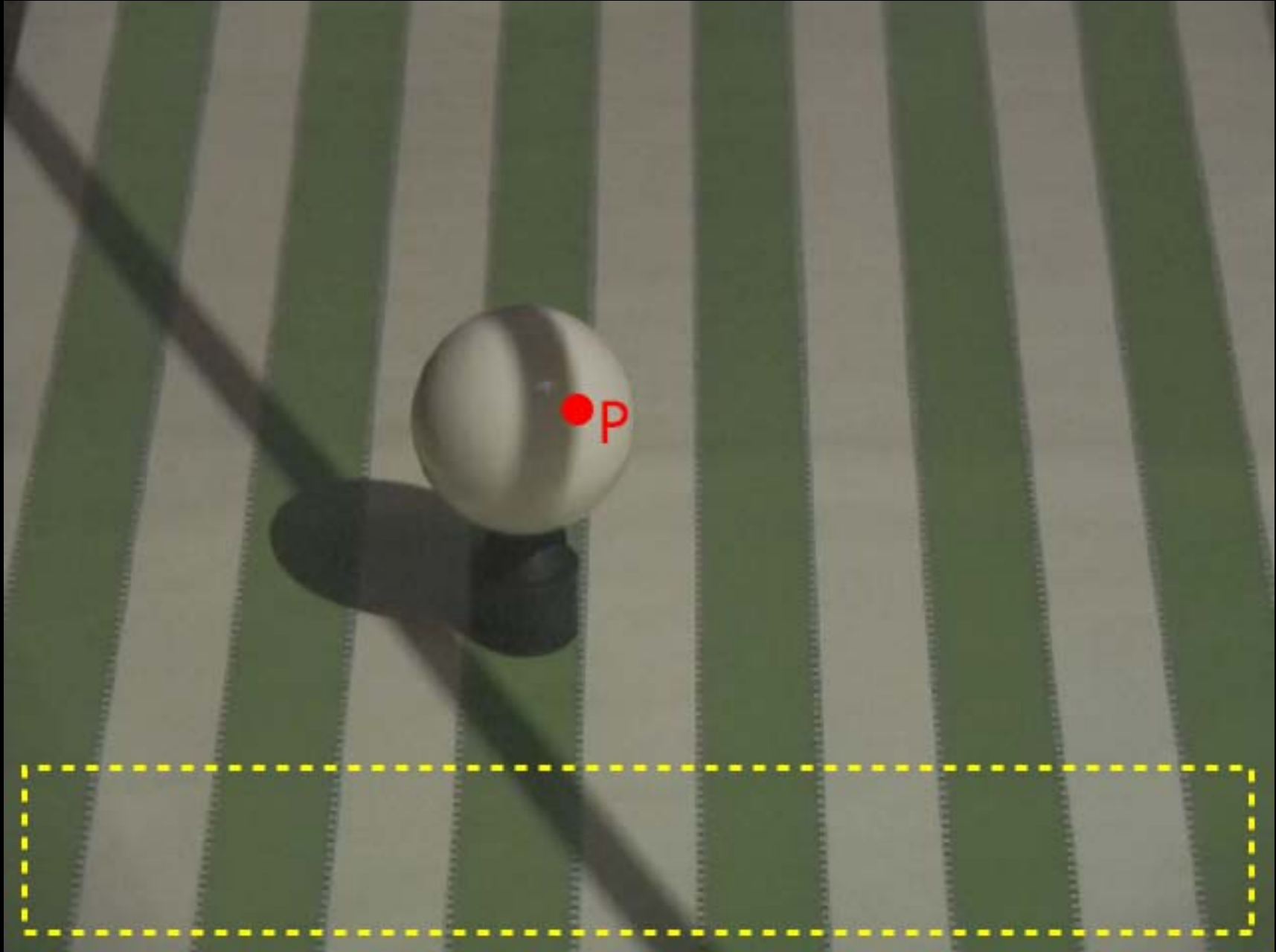
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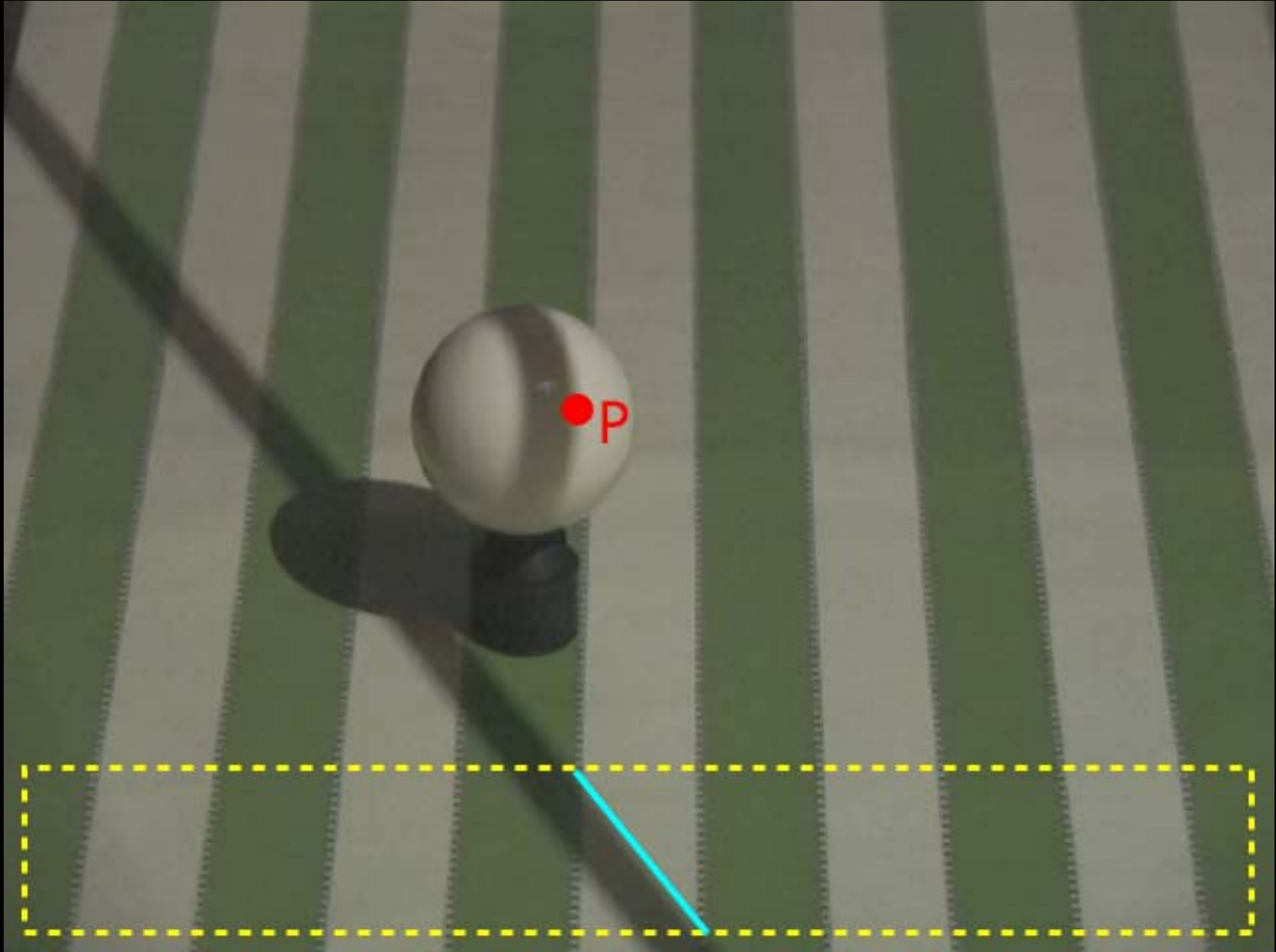
Q

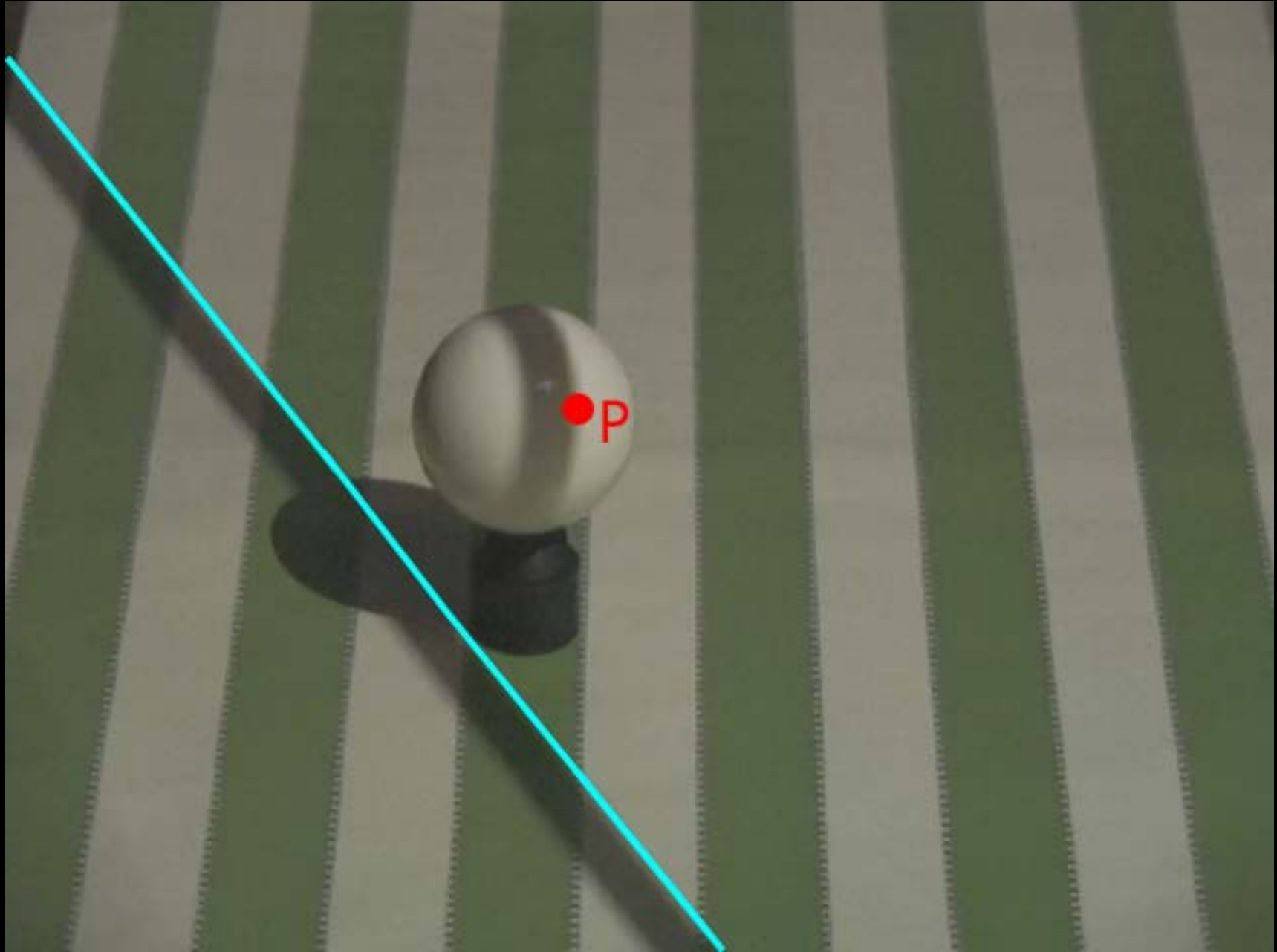


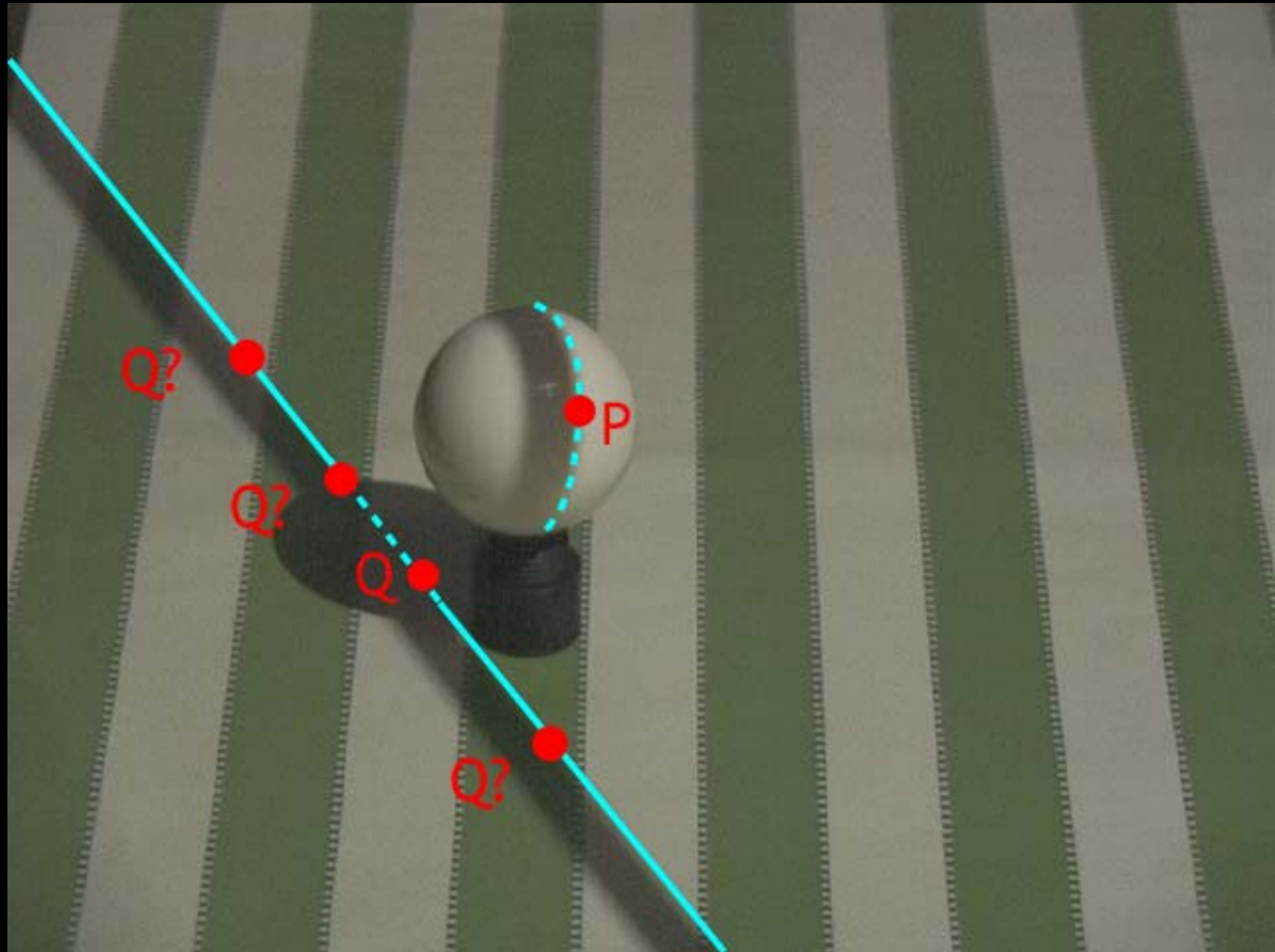


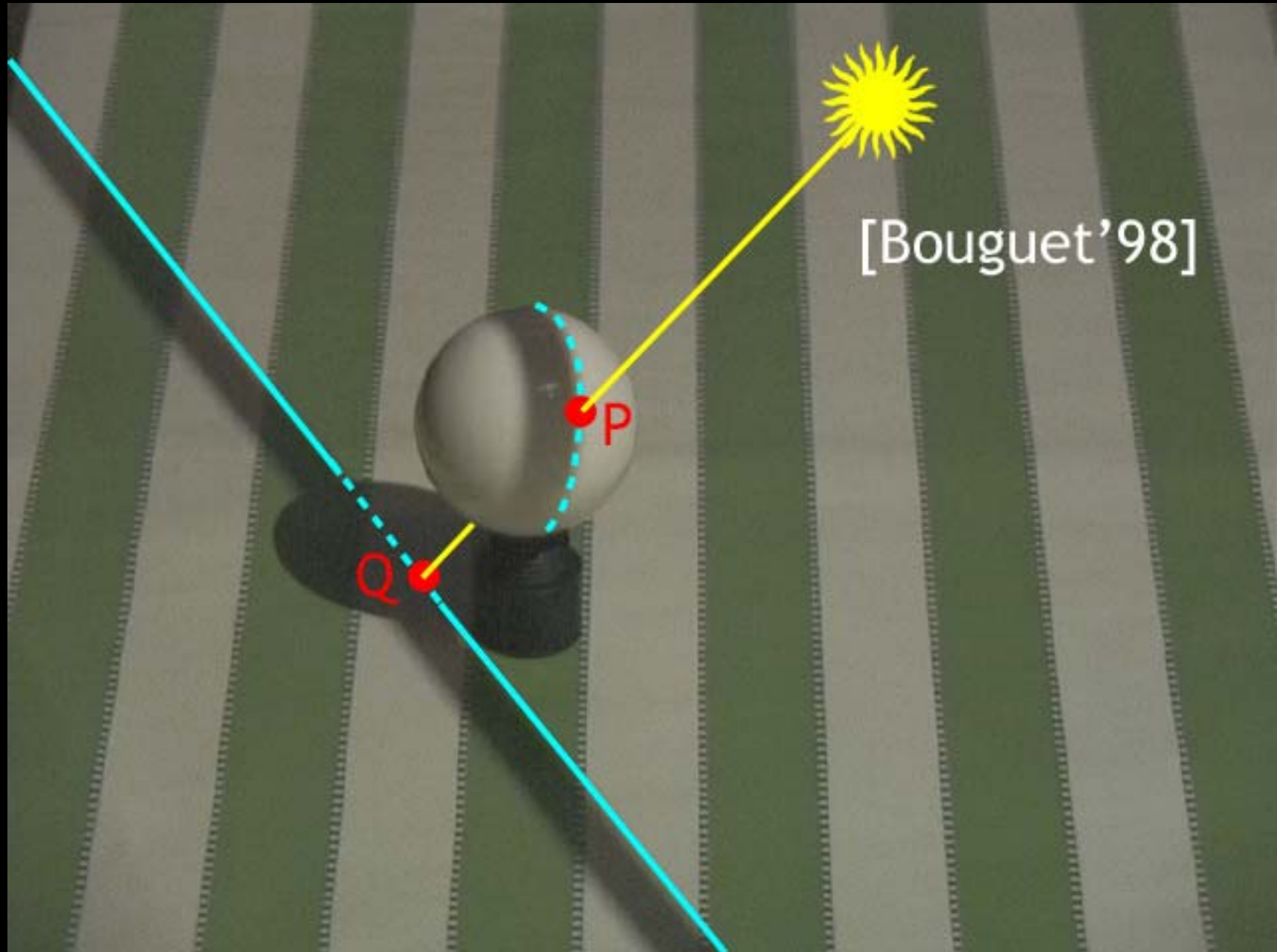


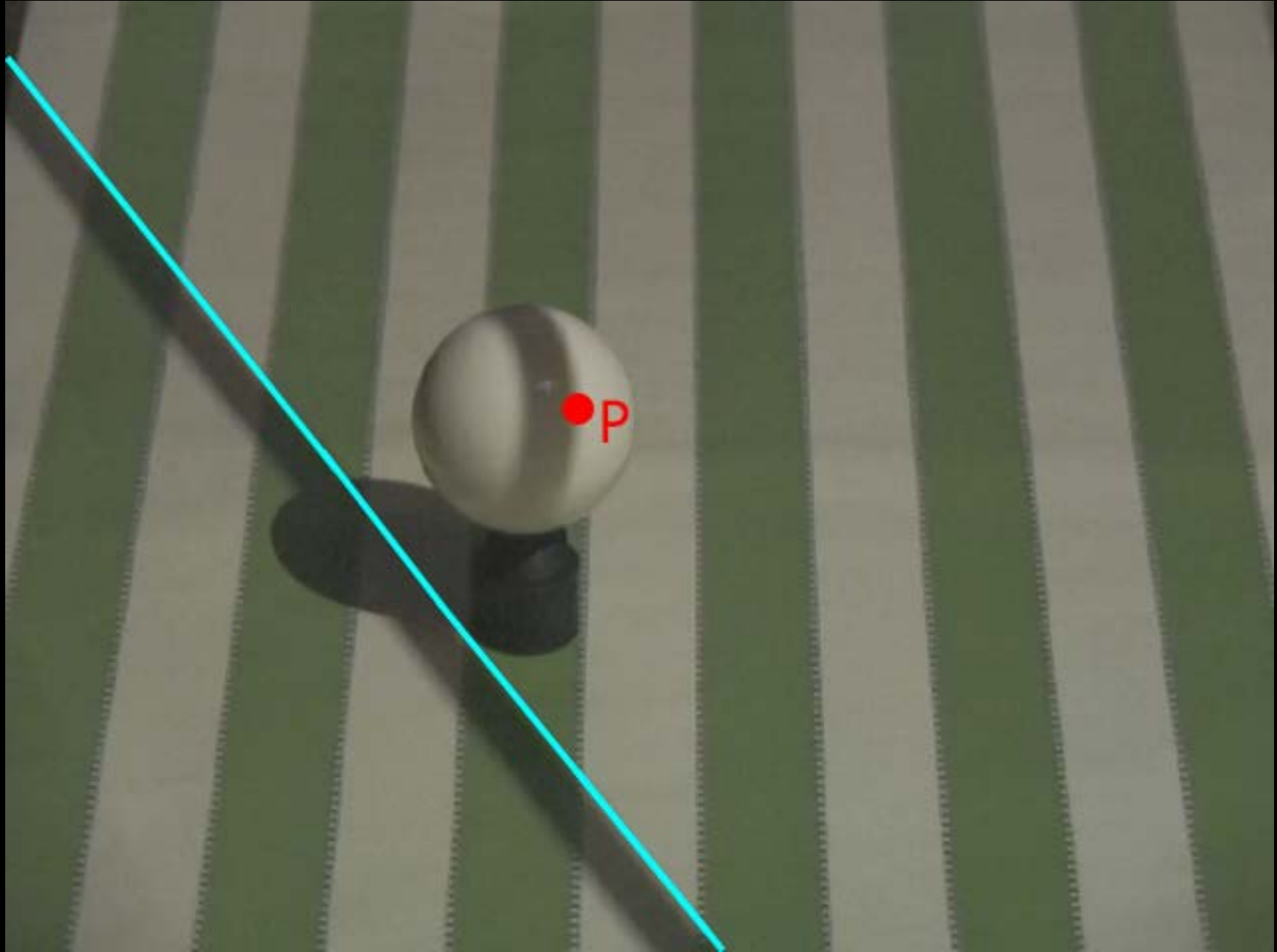


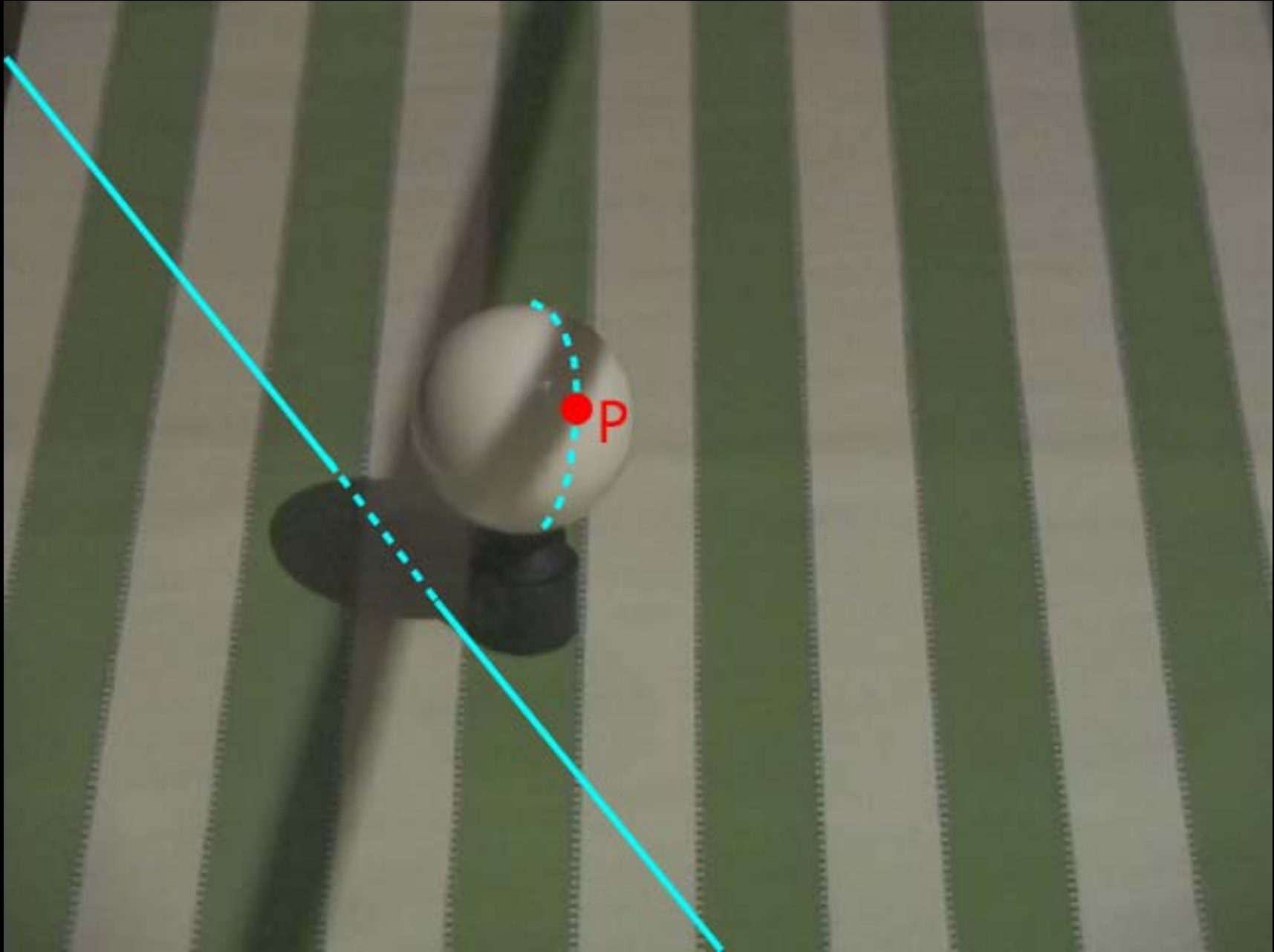


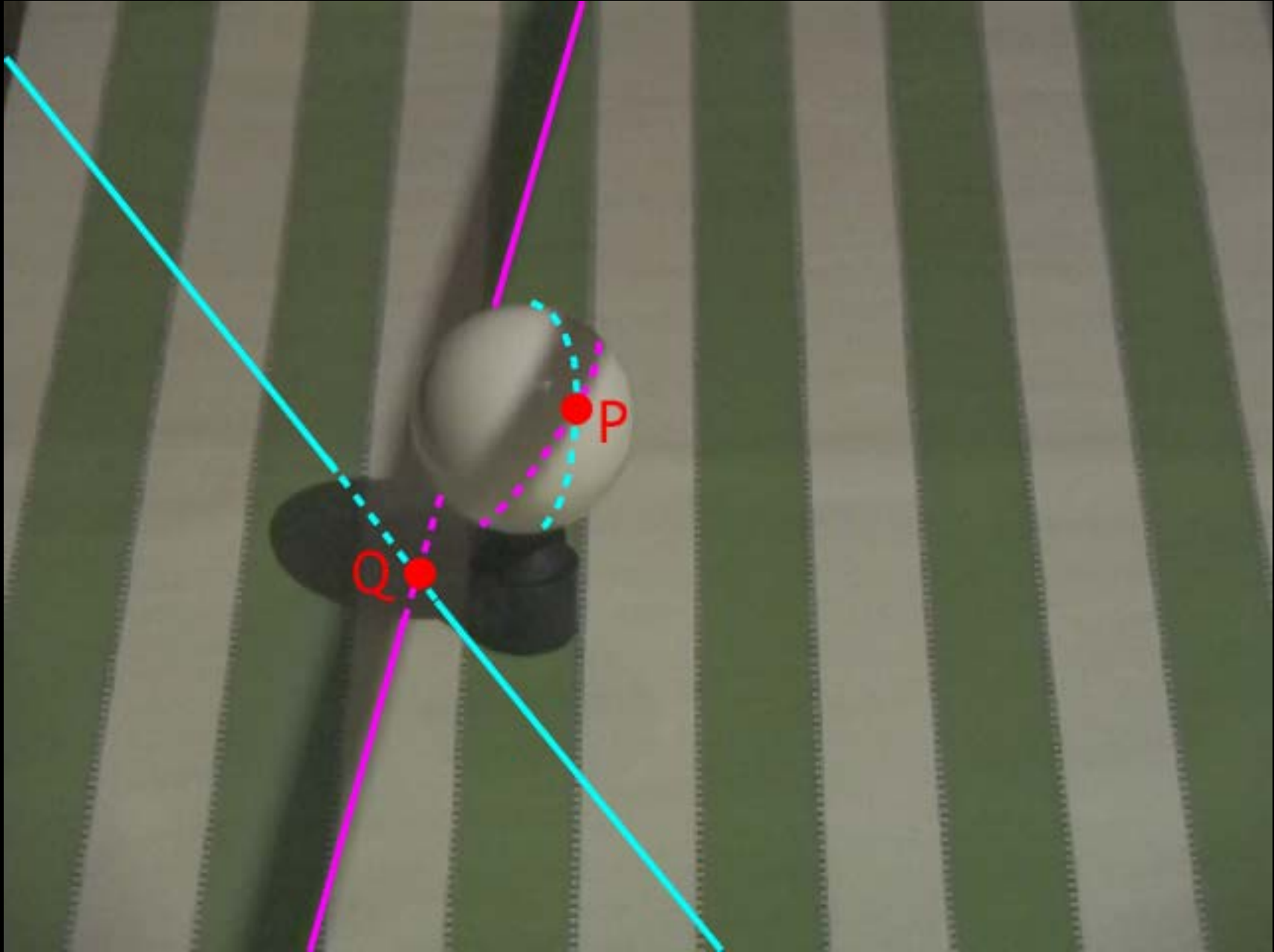


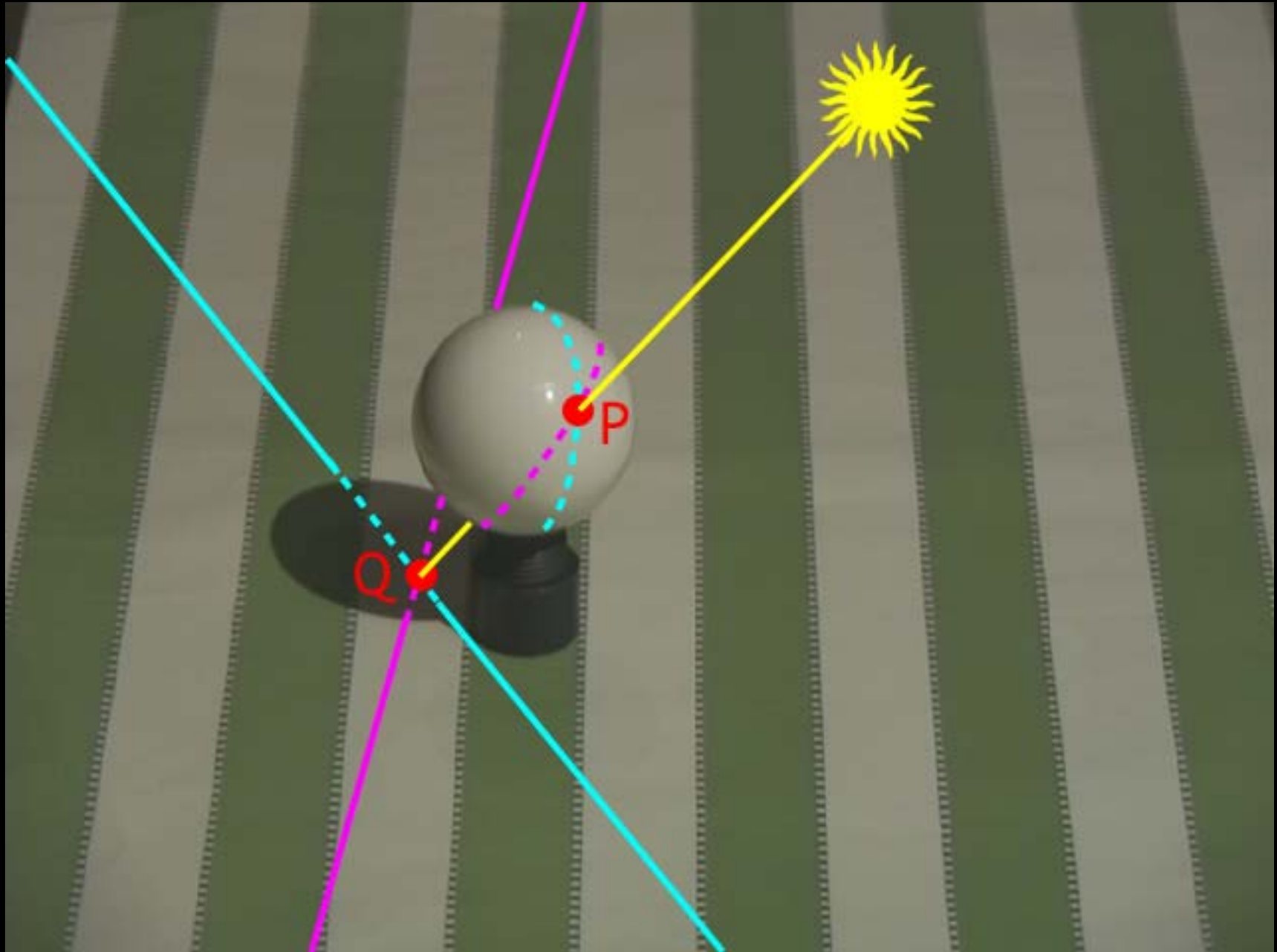


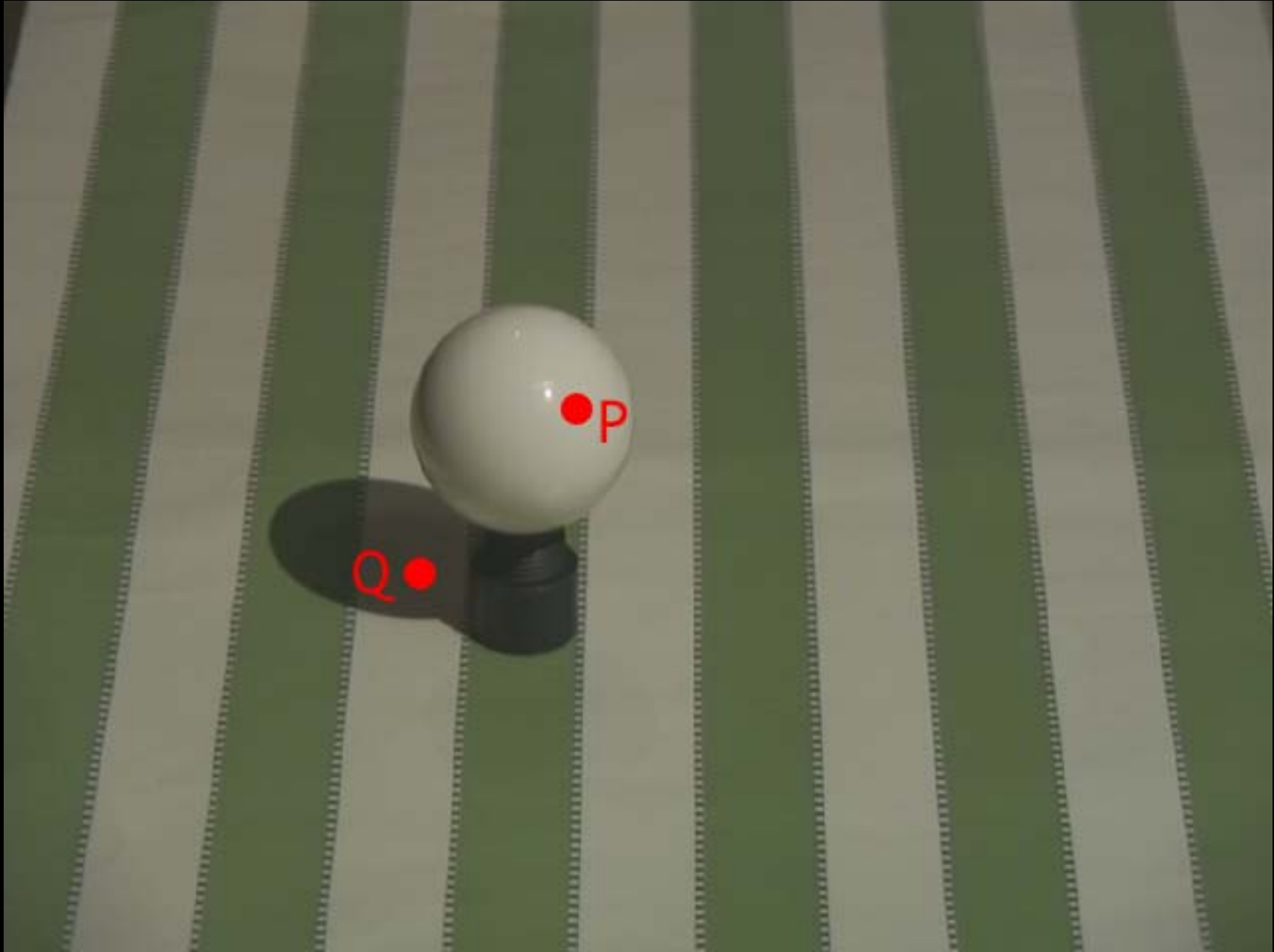


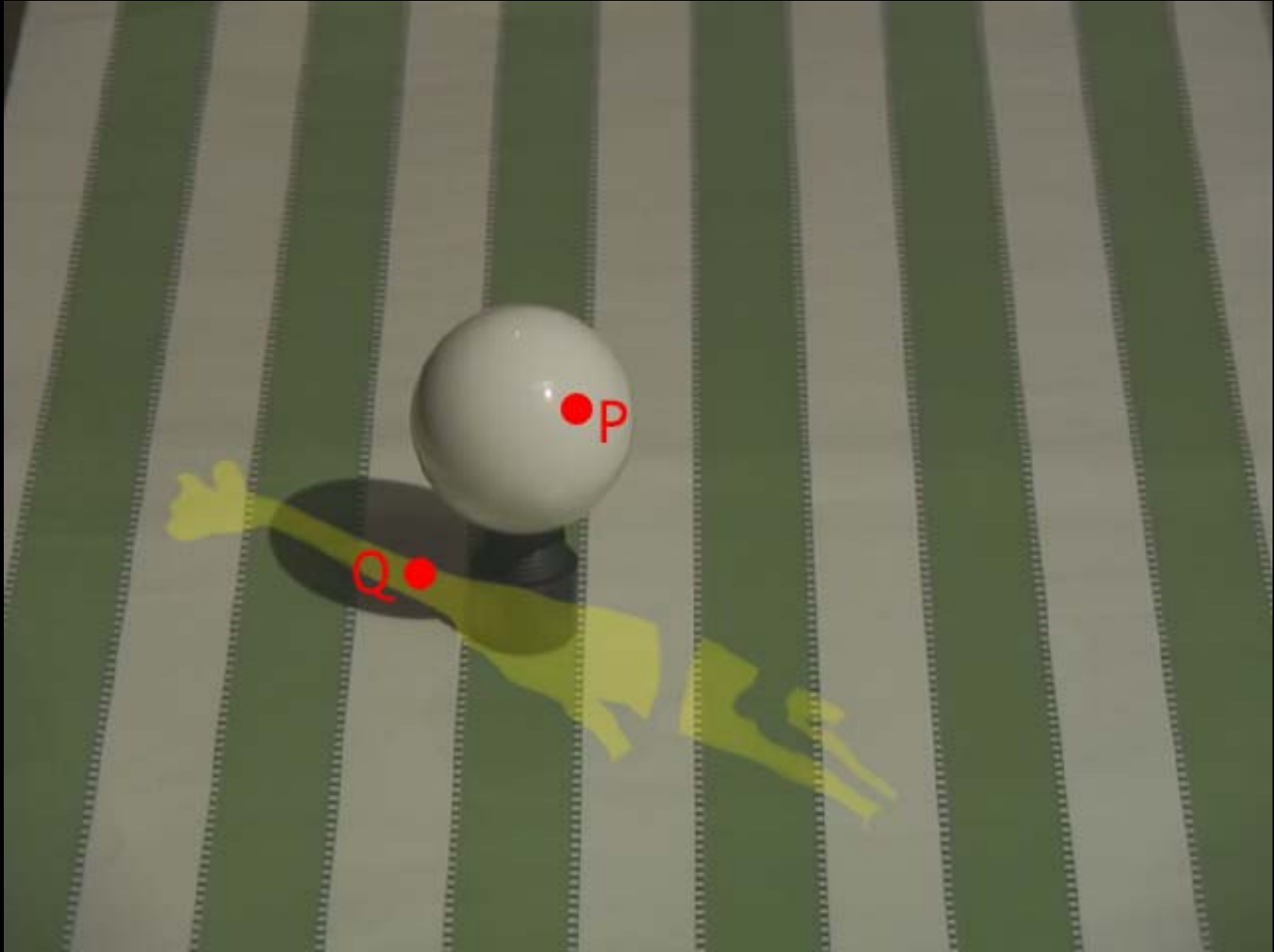


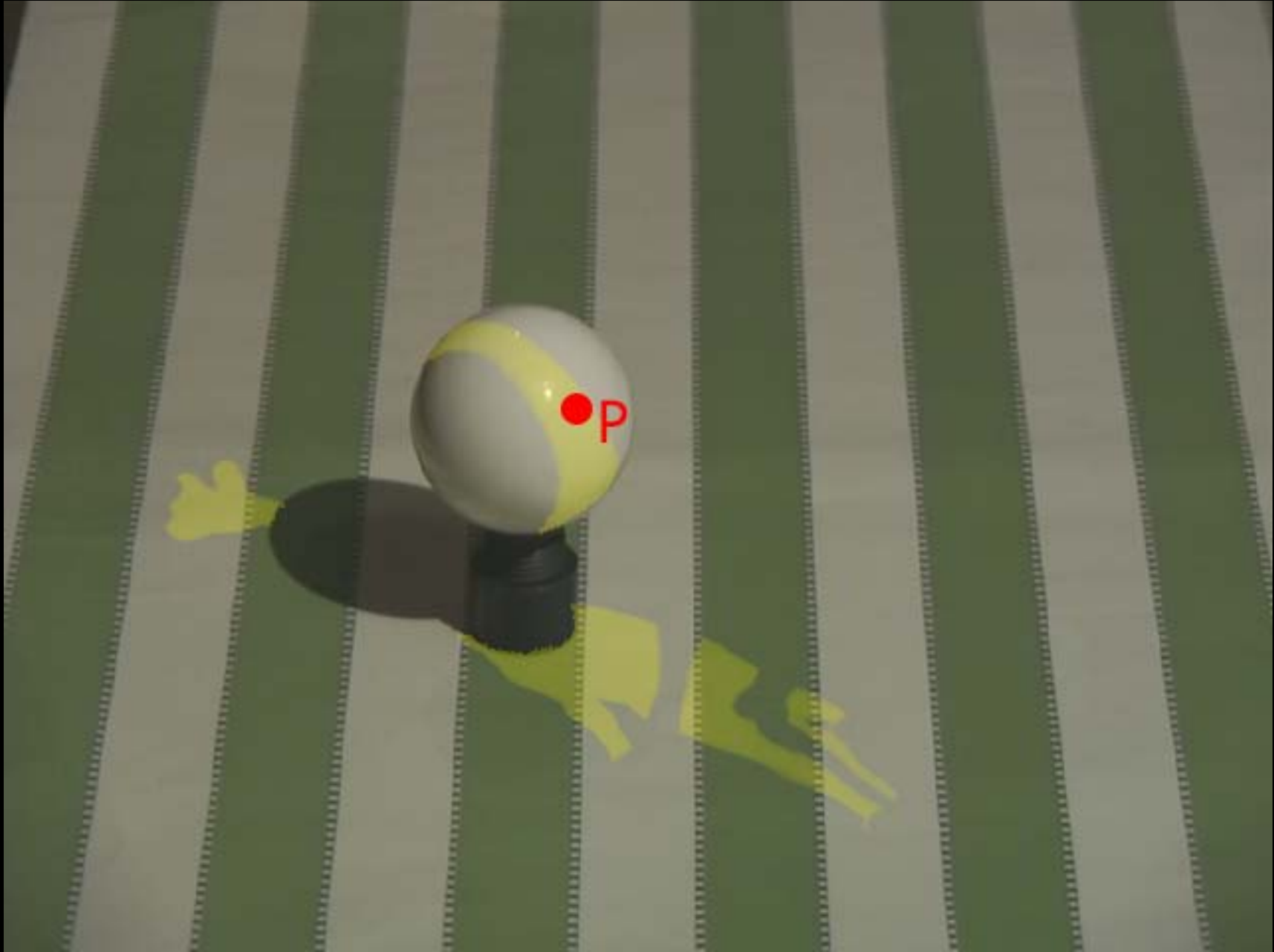
















96x3x1 stick

camera

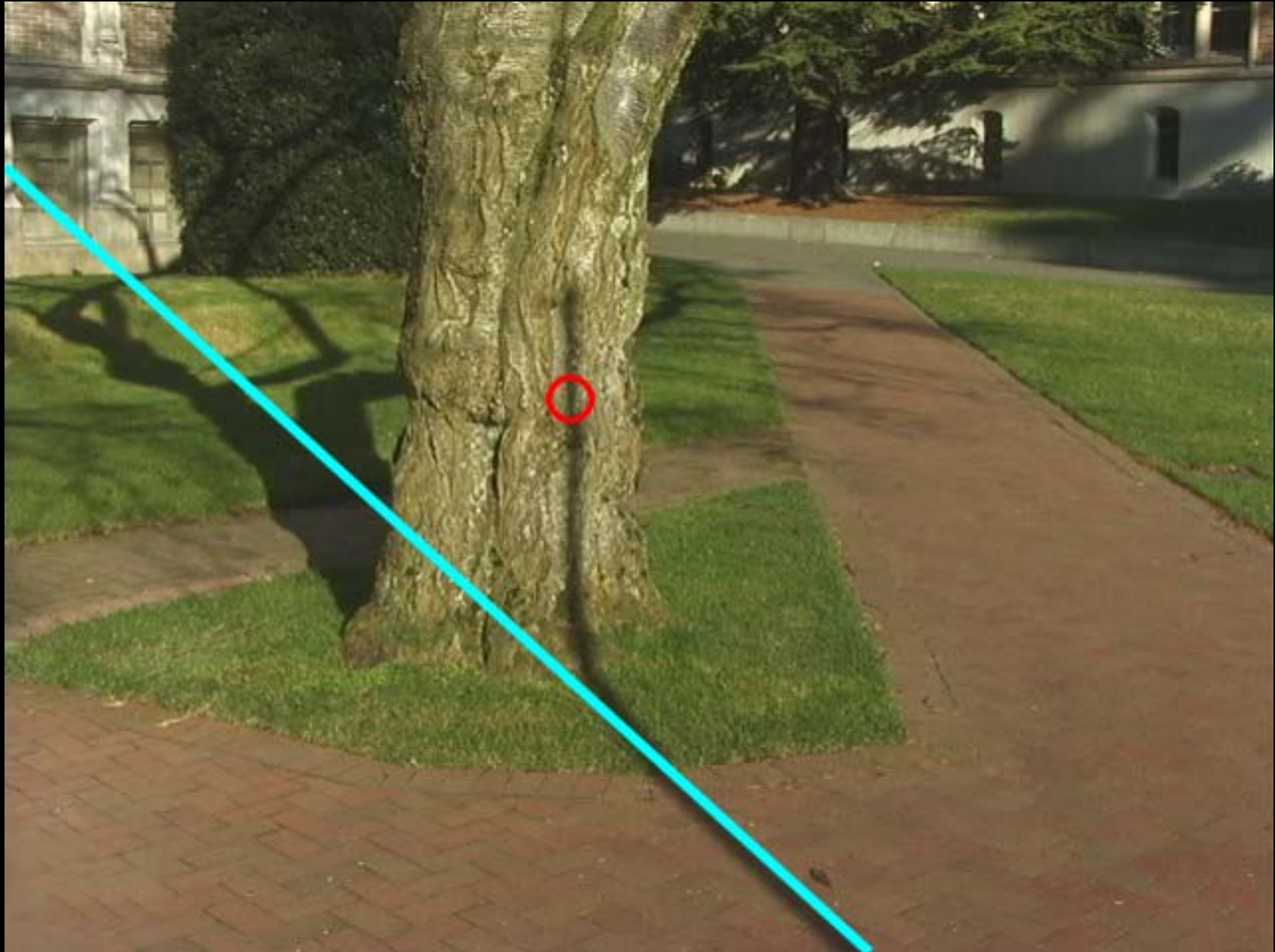
cast shadow

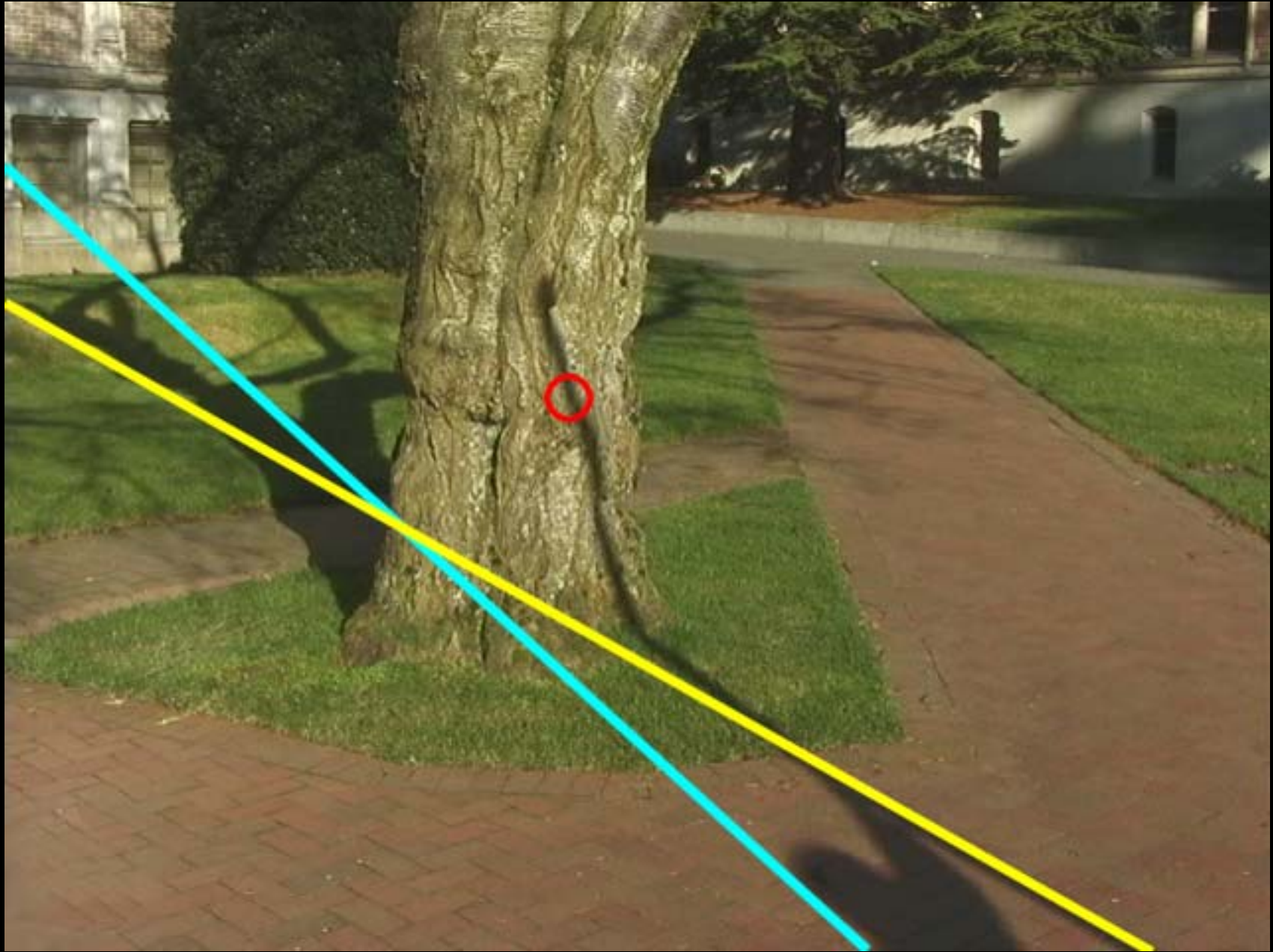


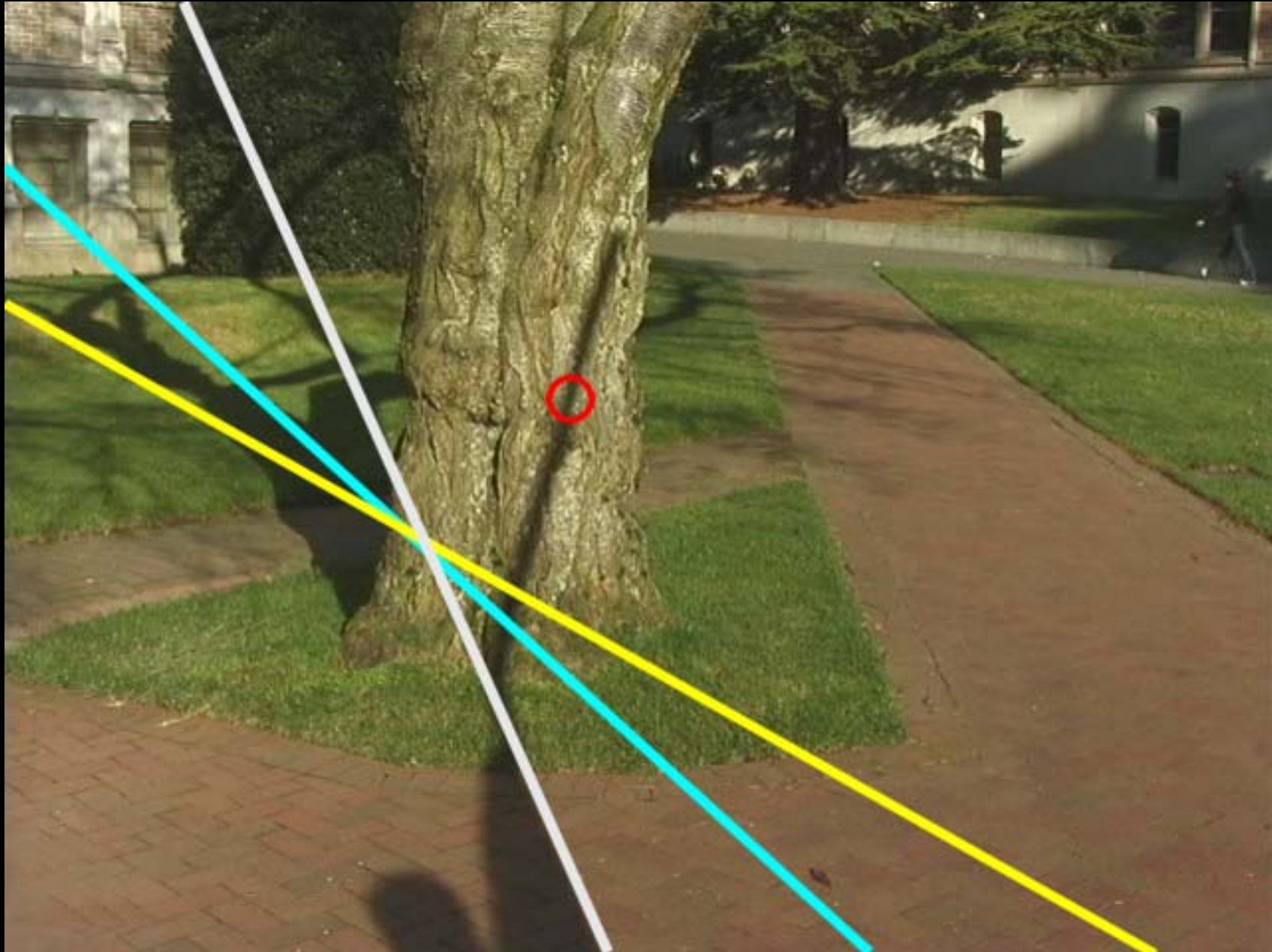


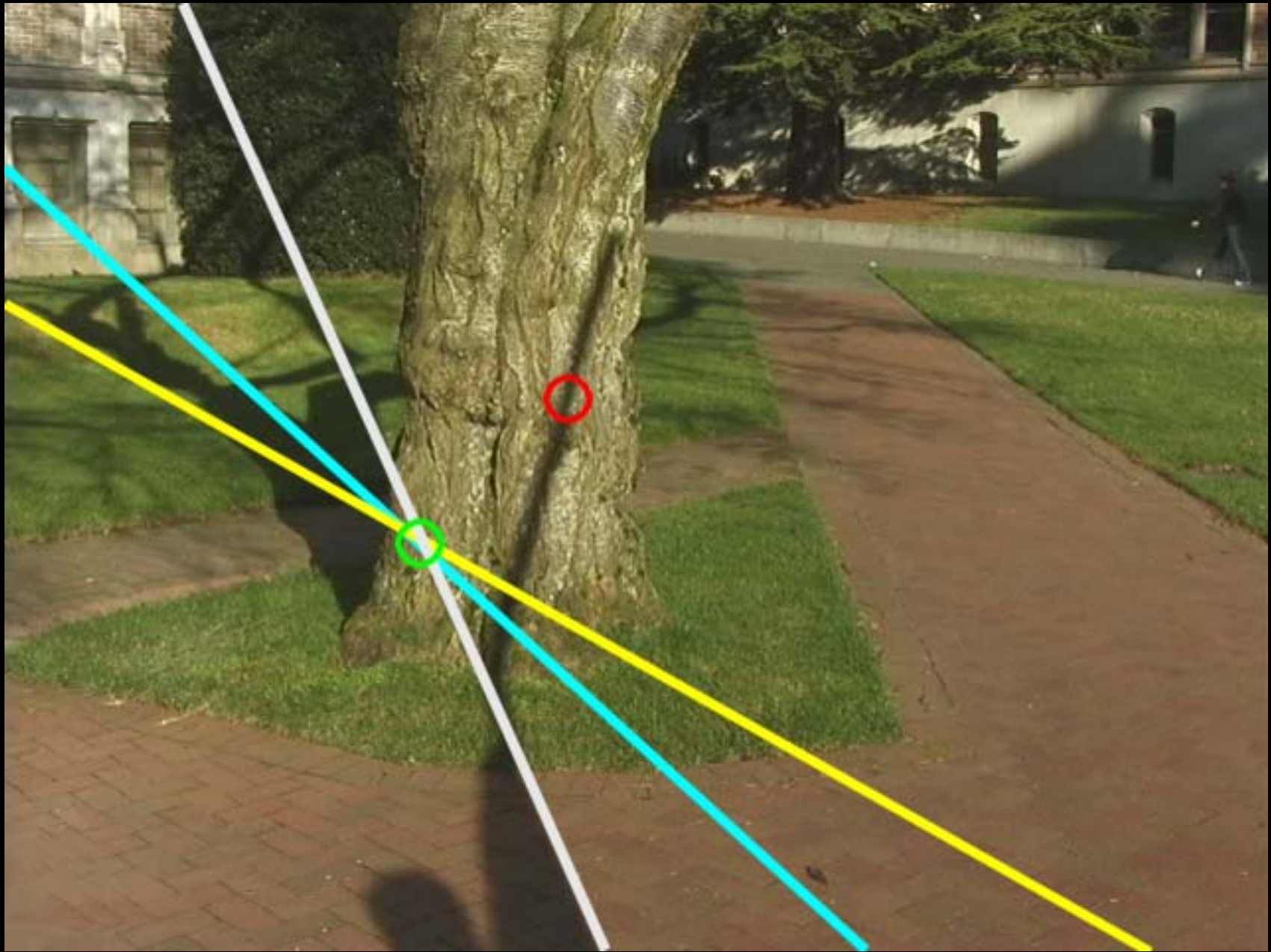


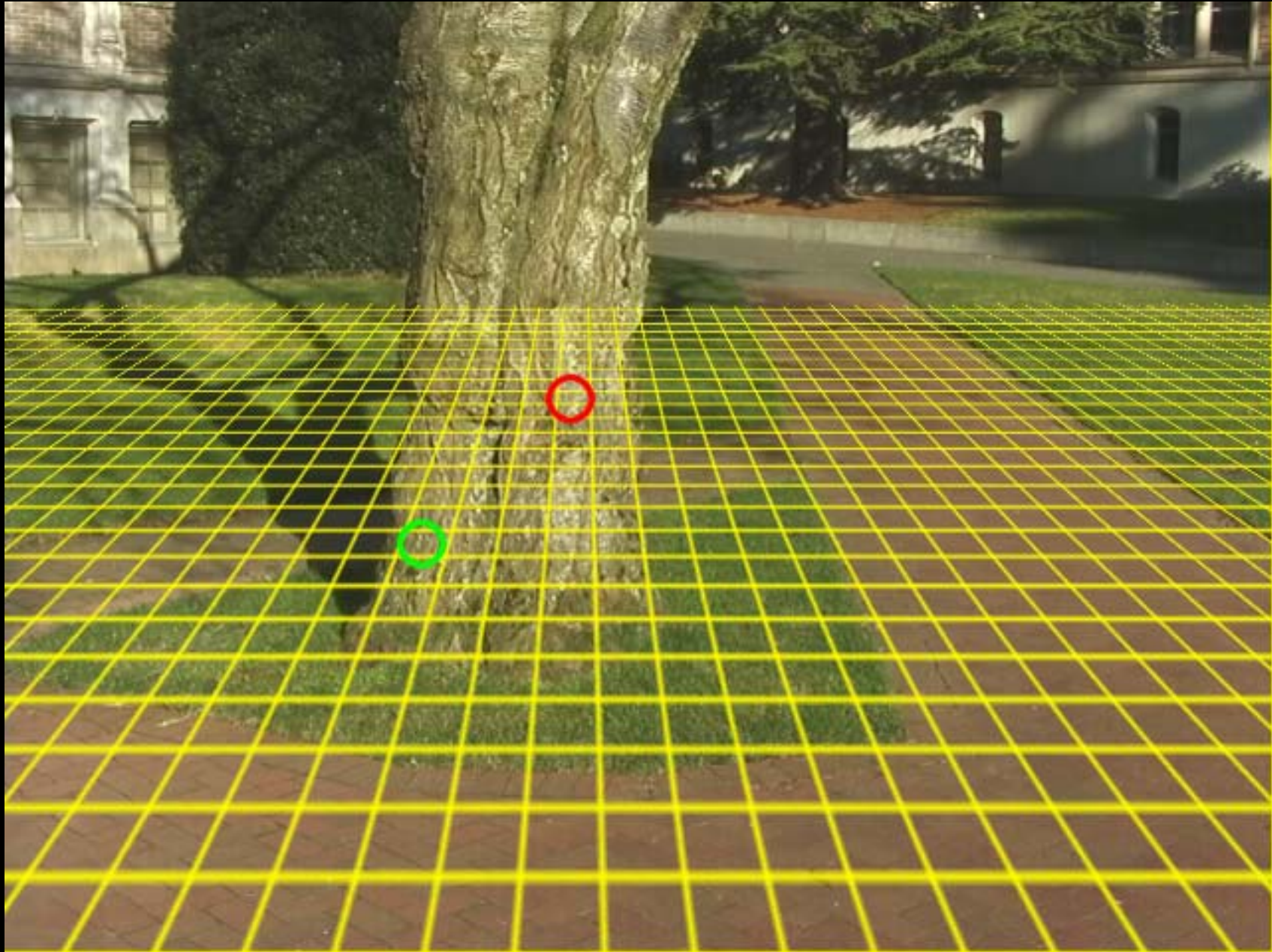


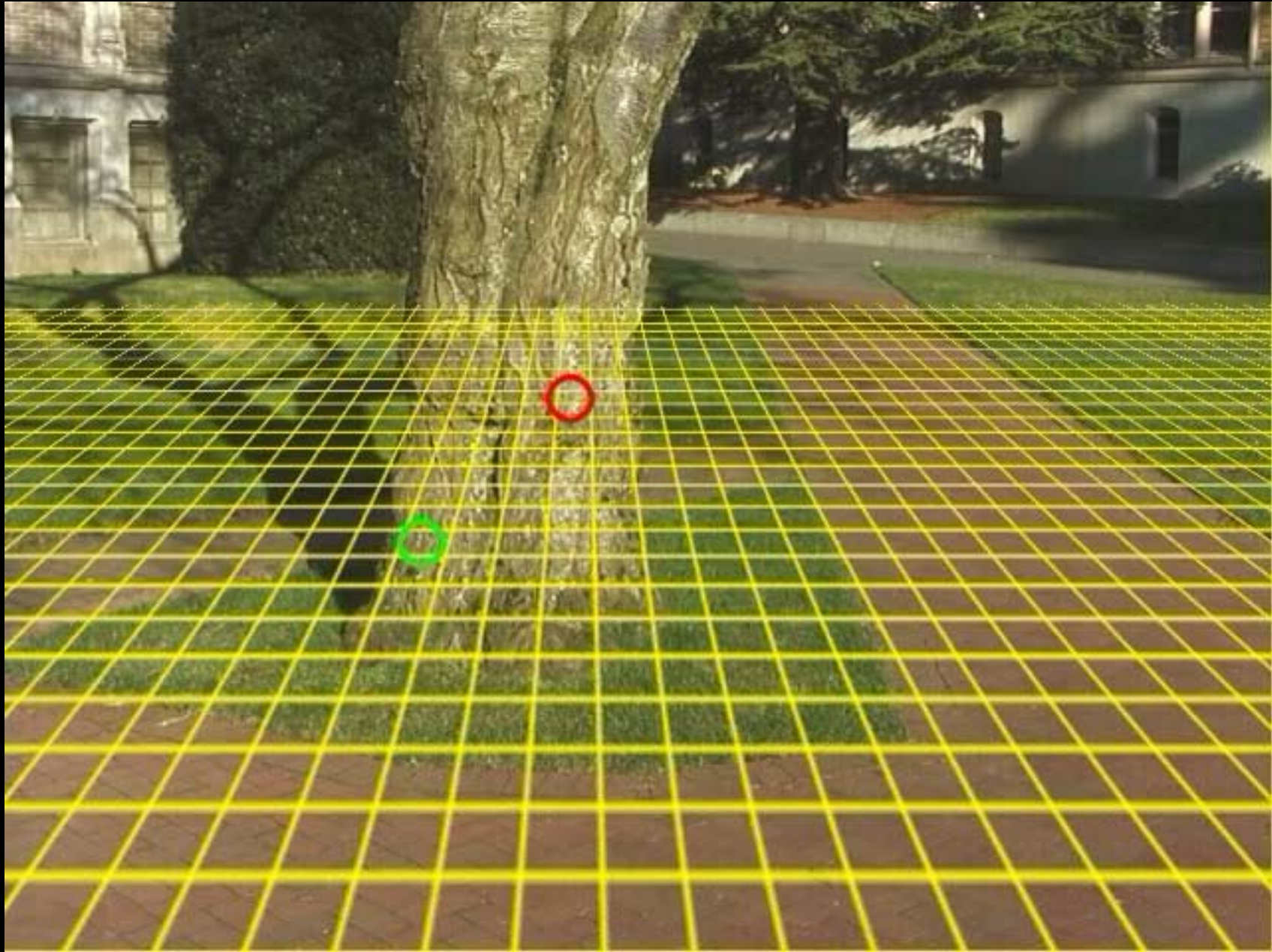


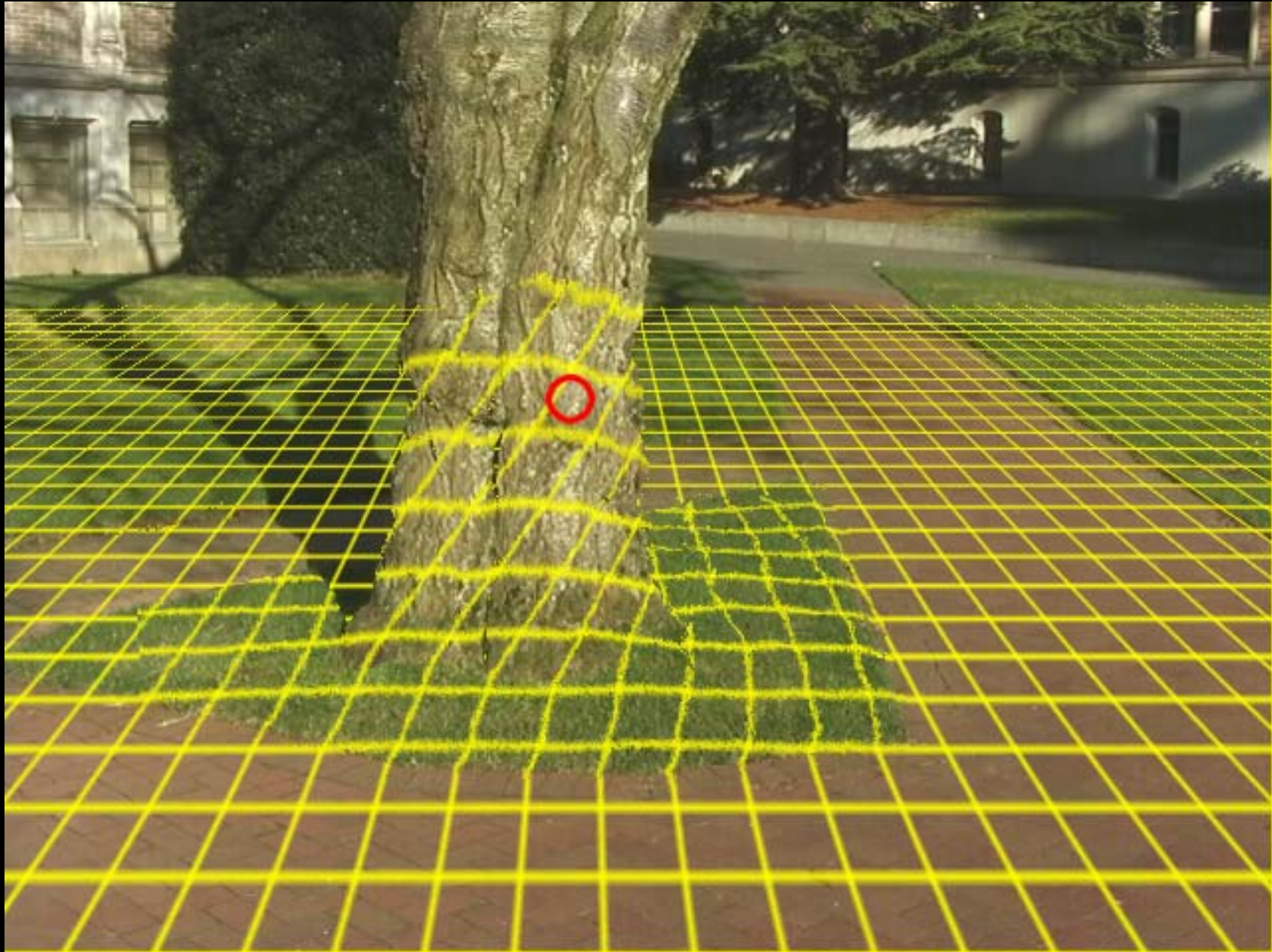








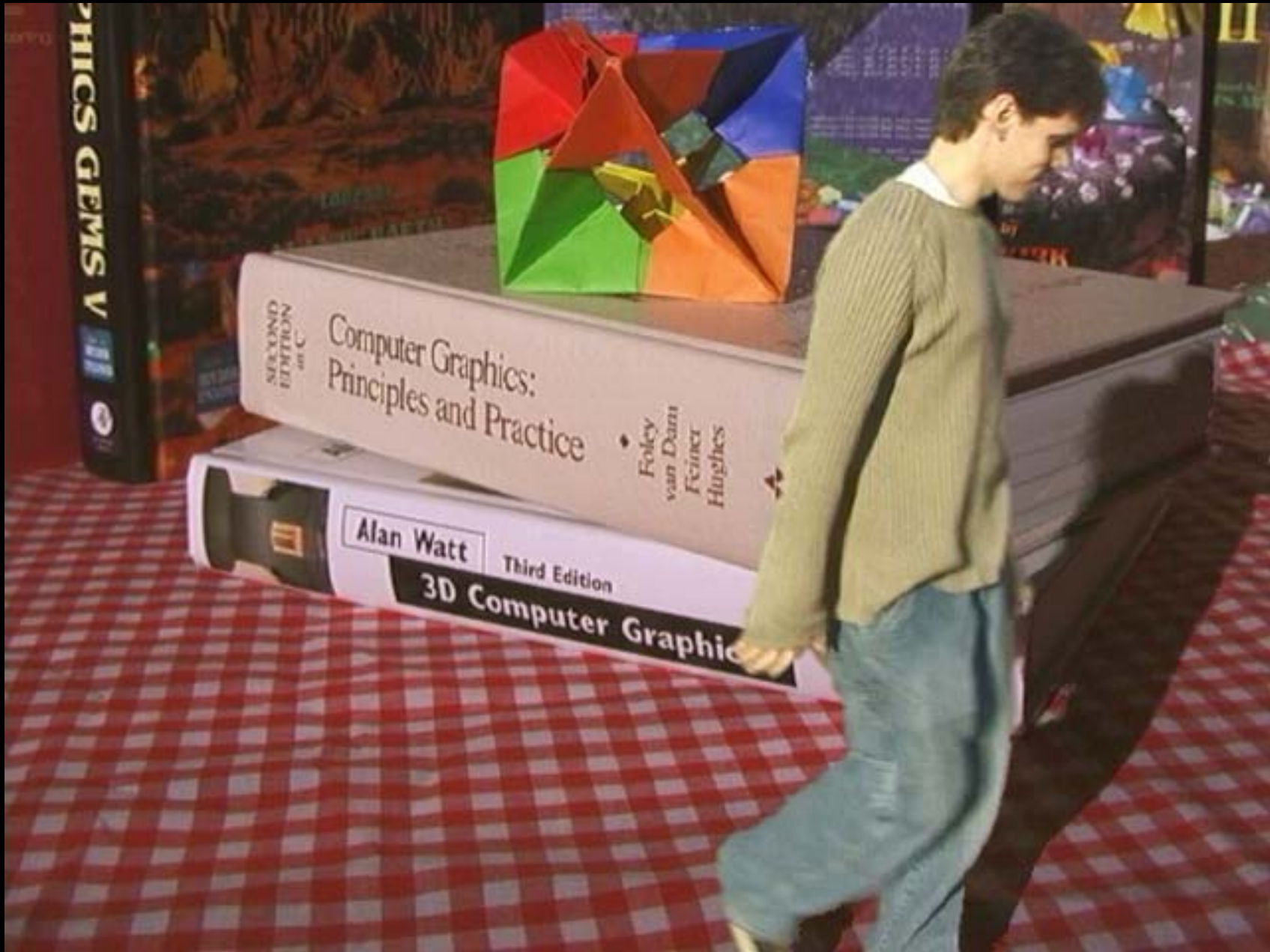


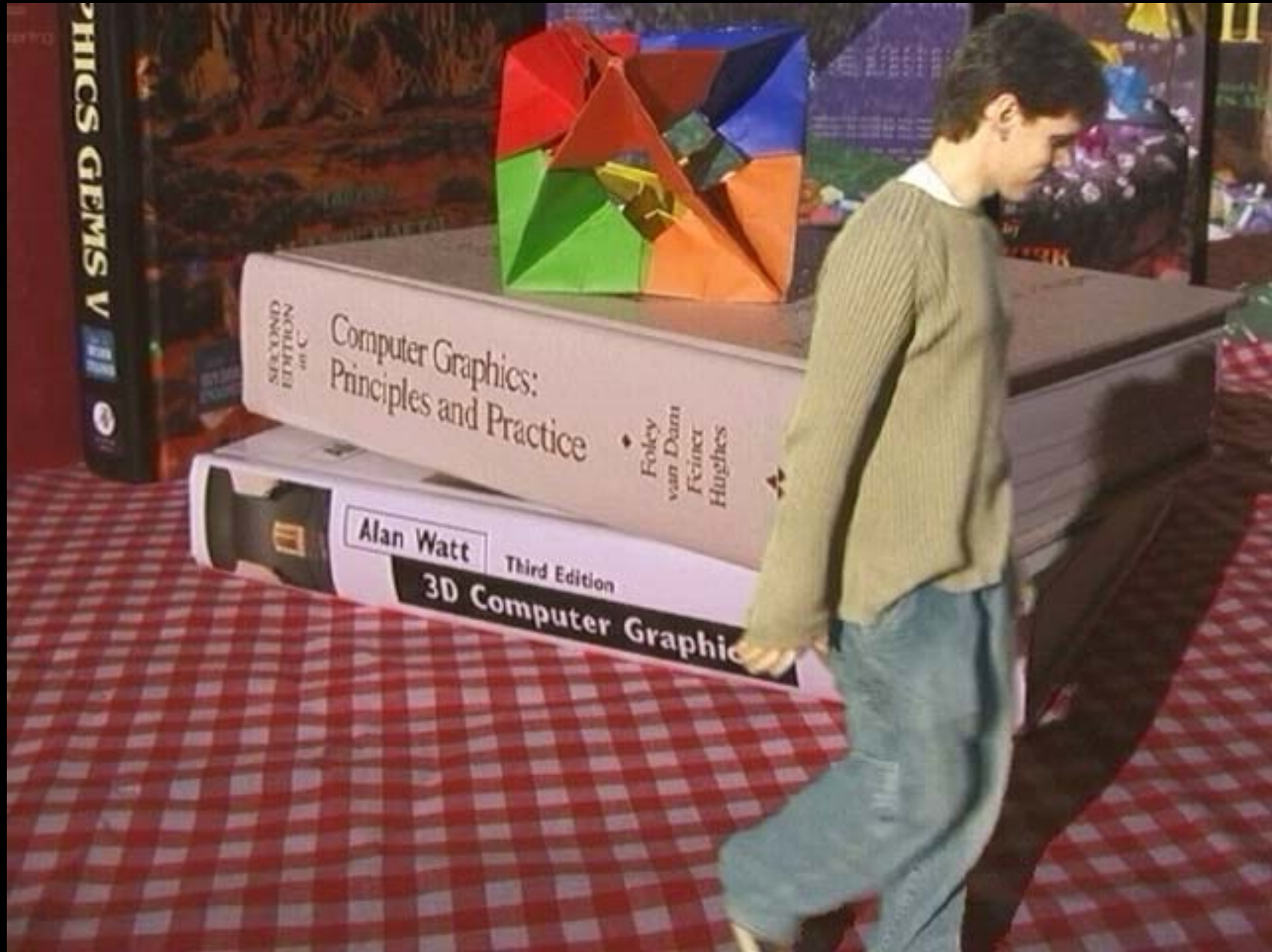












PHYSICS GEMS V

SECOND EDITION
in C

Computer Graphics:
Principles and Practice

Foley
van Dam
Fischer
Hughes

Alan Watt

Third Edition

3D Computer Graphics

Environment matting

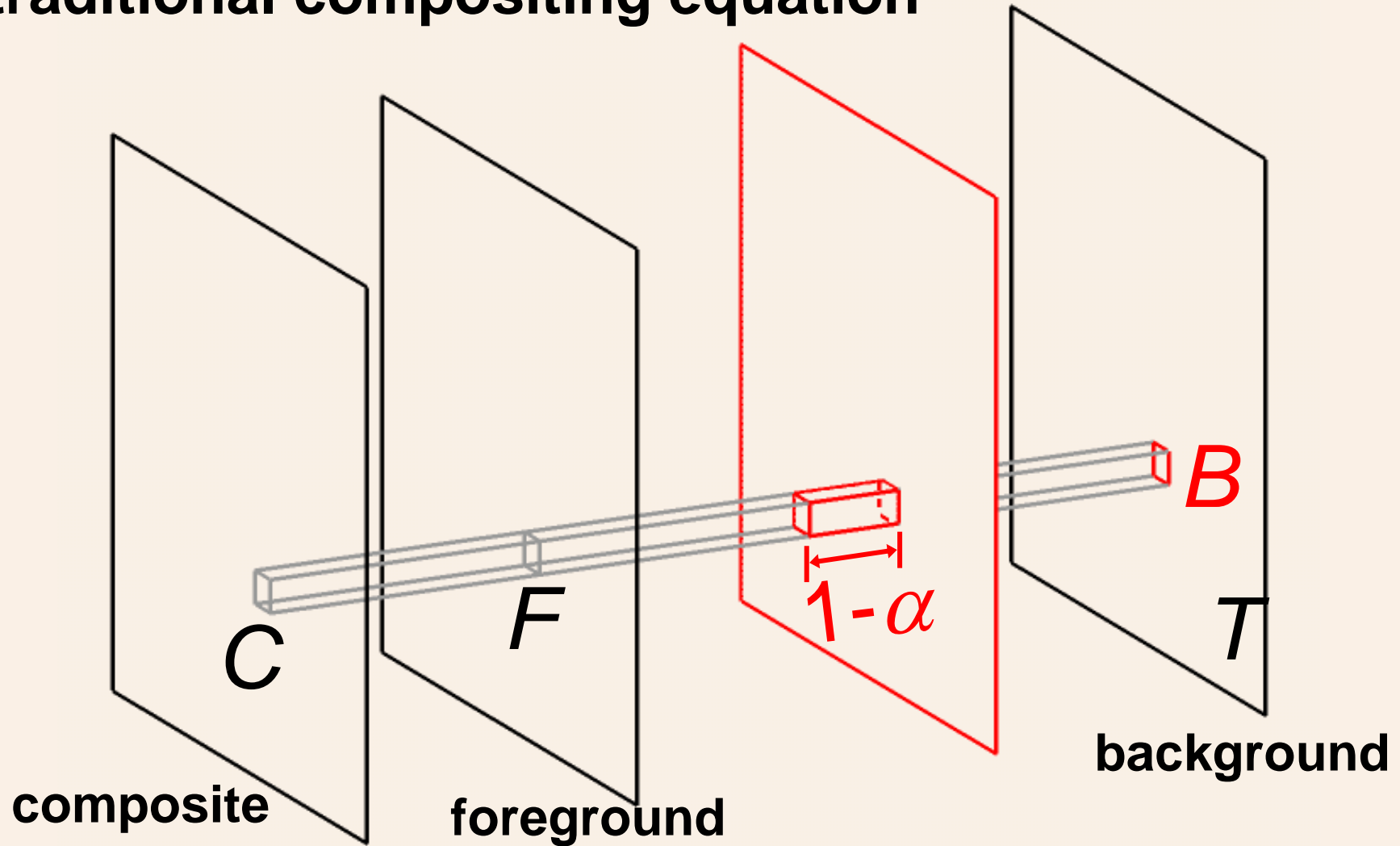
blue screen matting



photograph

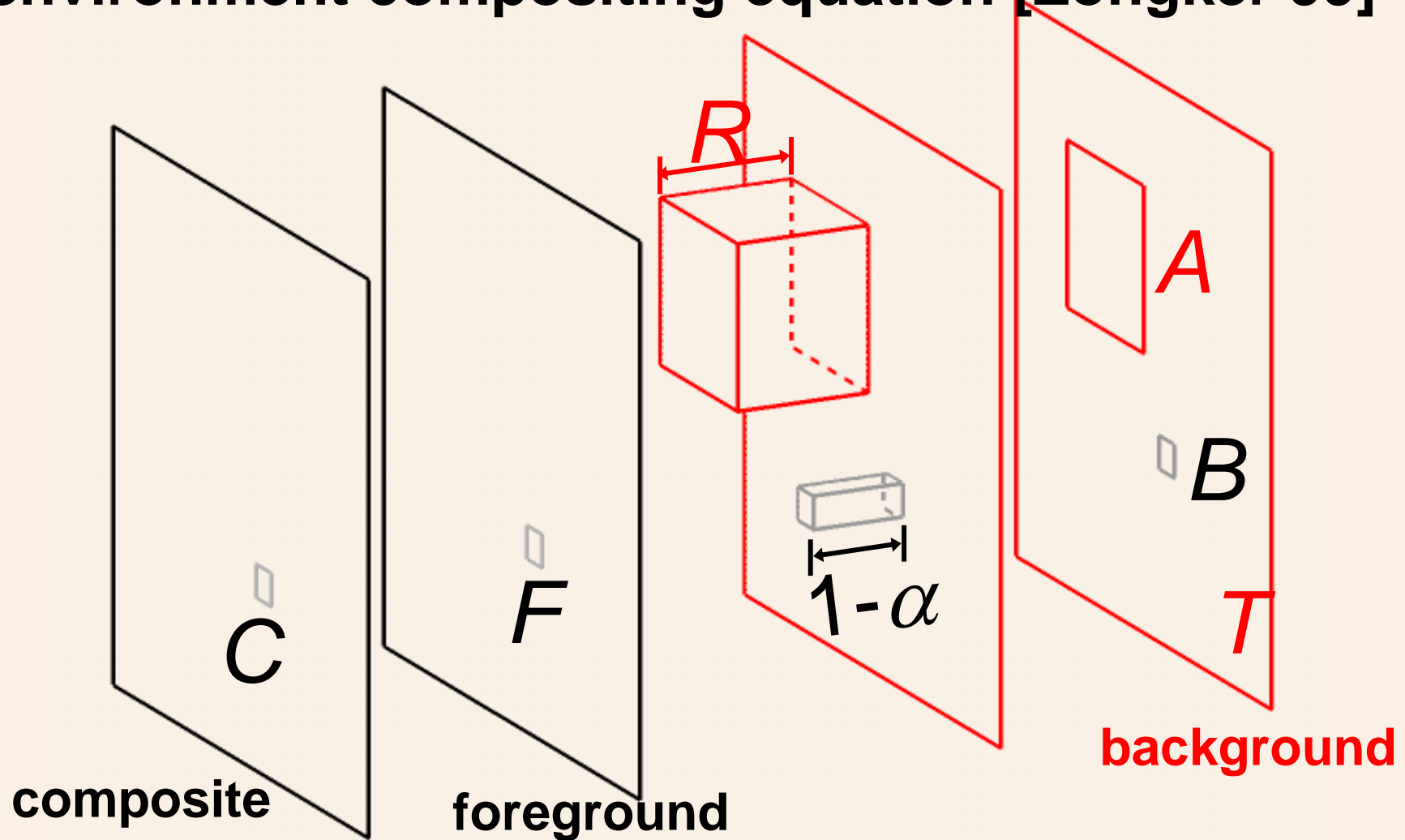


traditional compositing equation



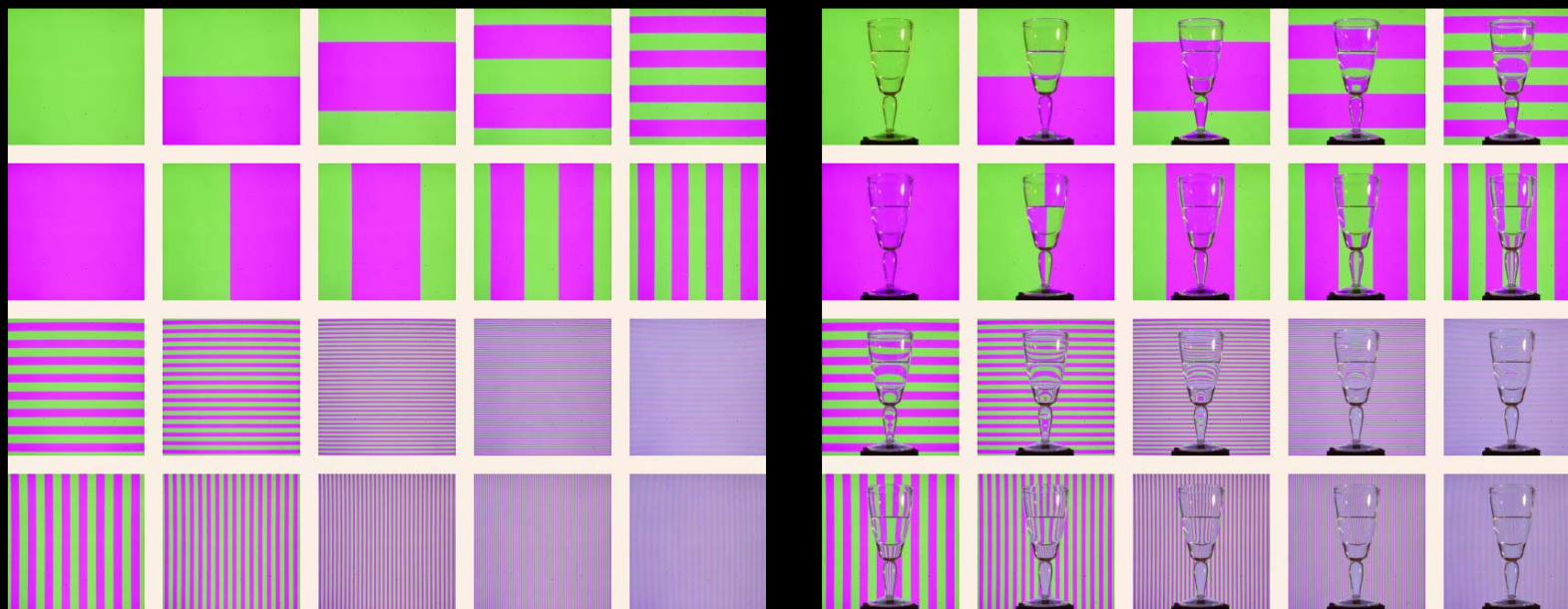
$$C = F + (1-\alpha)B$$

environment compositing equation [Zongker'99]



$$C = F + (1-\alpha)B + R\mathcal{M}(T, A)$$

$O(k)$ images



Environment matting [Zongker'99]

Zongker et al.



photograph



Problem: color dispersion

Zongker et al.

photograph



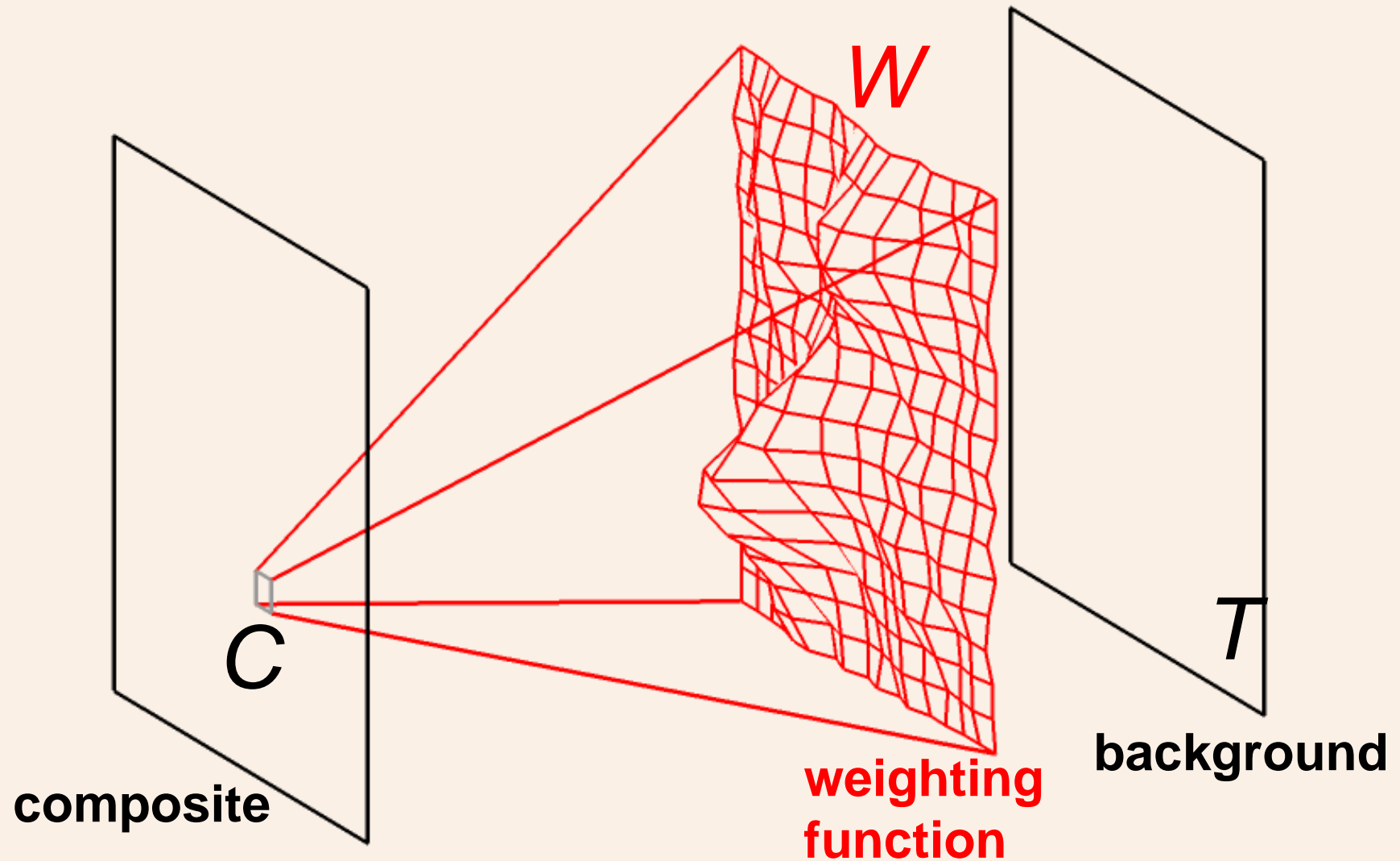
Problem: glossy surface

Zongker et al.

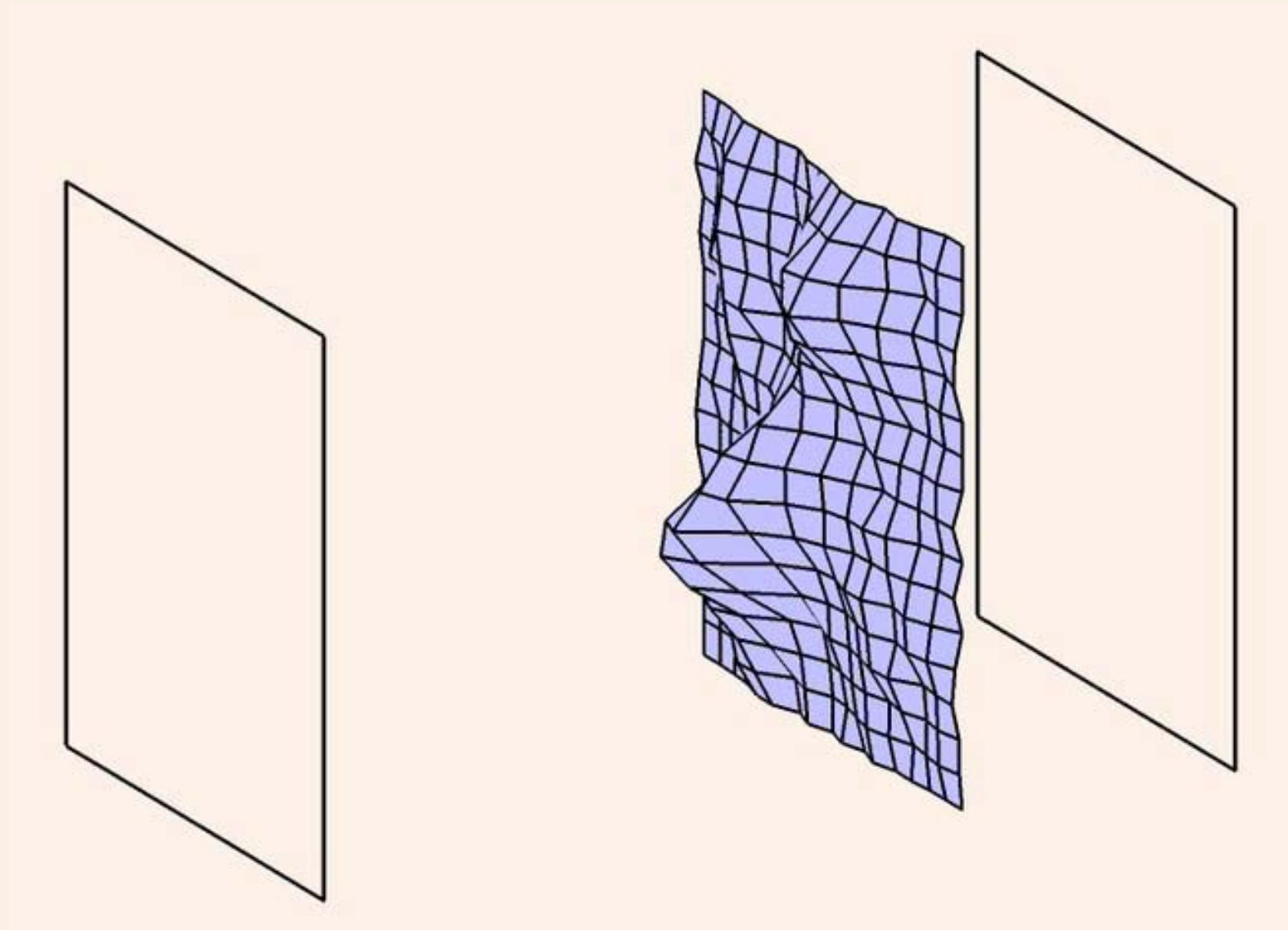
photograph



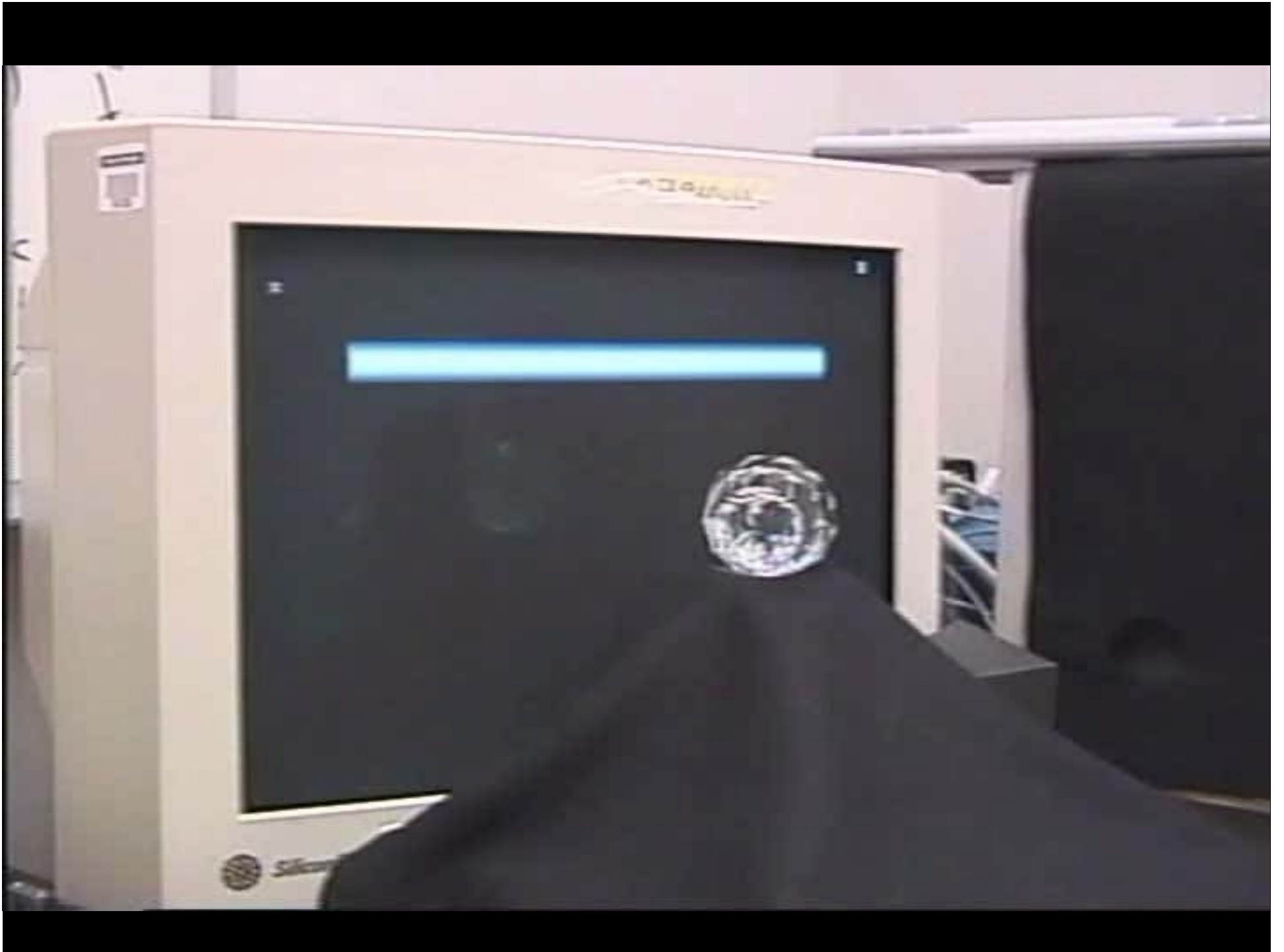
Problem: multiple mappings



$$C = F + \int W T$$



Multimodal oriented Gaussian





high accuracy
algorithm



photograph



Problem: color dispersion

high accuracy
algorithm



photograph



Glossy surface

with
orientation



photograph



Oriented Gaussian

high accuracy
algorithm



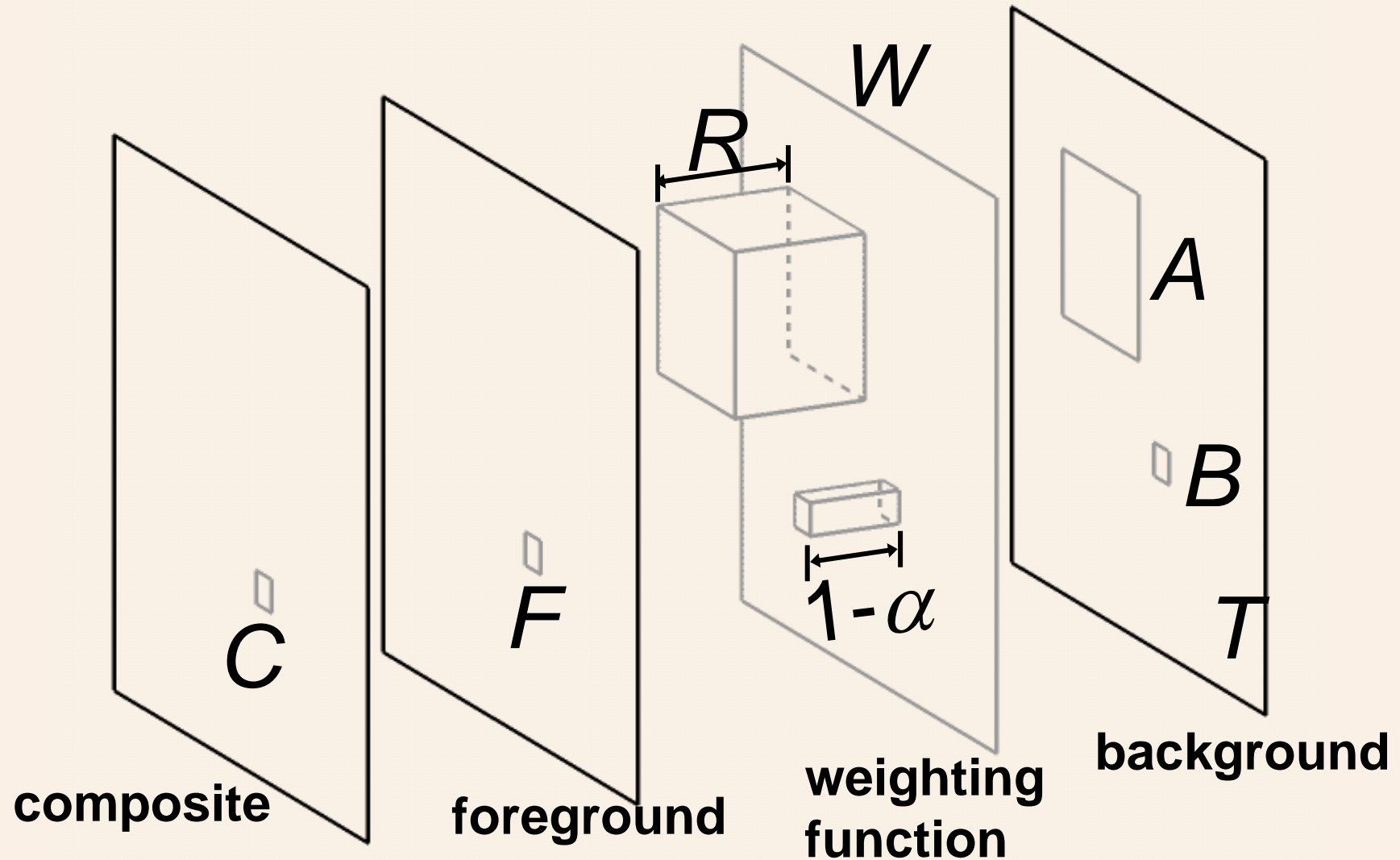
photograph



Problem: multiple mappings



$$C = F + (1 - \alpha)B + R\mathcal{M}(T, A)$$



$$C = F + (1 - \alpha)B + R\mathcal{M}(T, A)$$

3 3 1 3 4

3 observations

11 variables

- A, R
- α
- F

$$C = R\mathcal{M}(T, A)$$

3

3

4

3 observations

7 variables

- A, R

- α

- F

$$C = \rho \mathcal{M}(T, A)$$

3

1

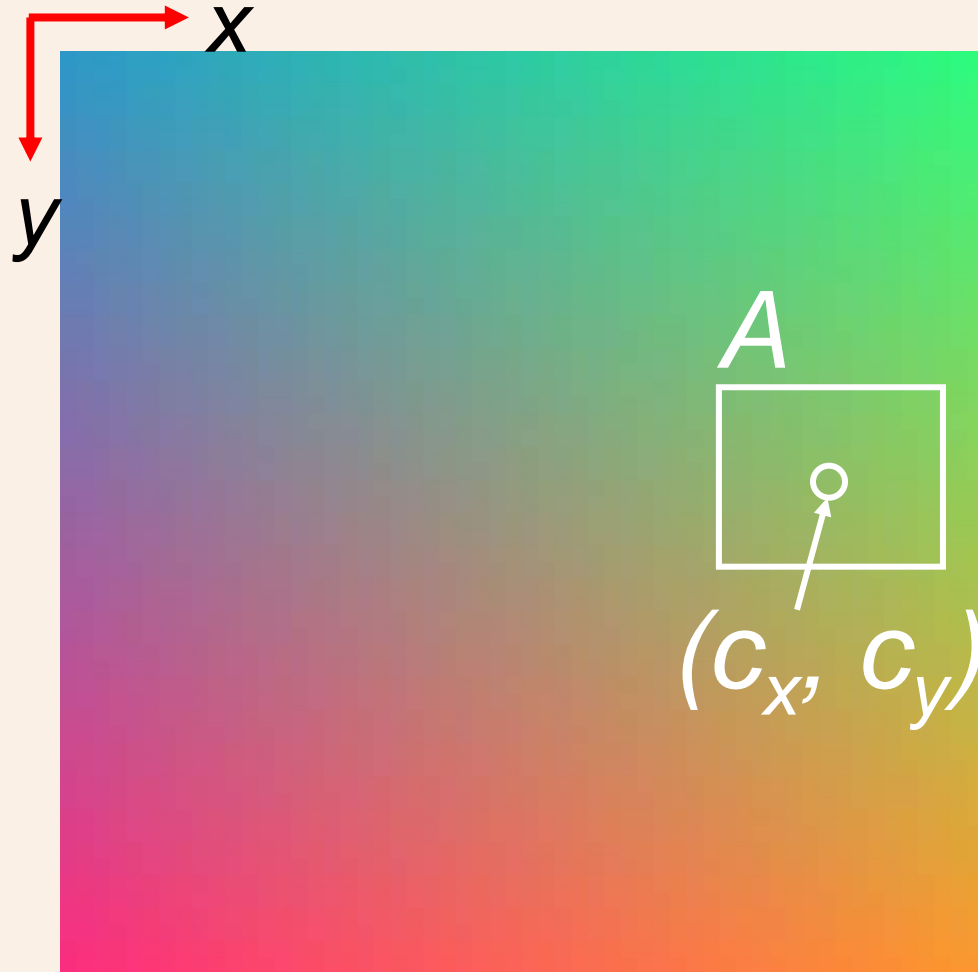
4

3 observations

5 variables

- $A, R \longrightarrow A, \rho$
- α colorless
- F

Stimulus function

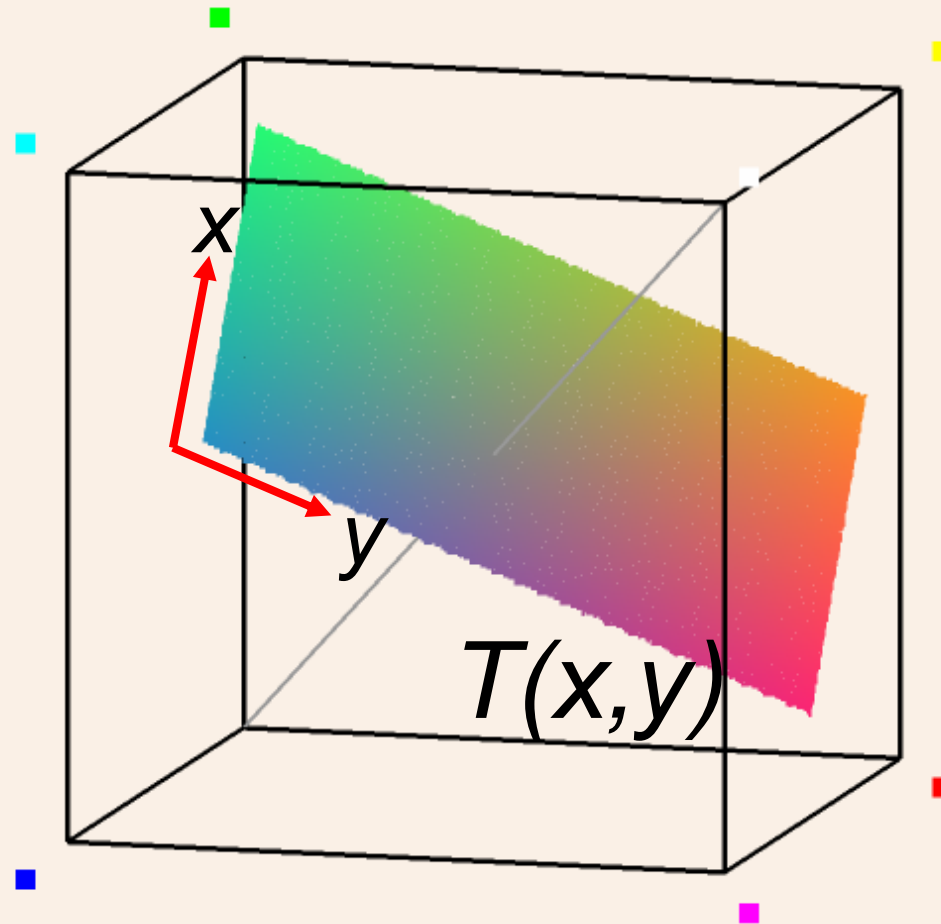


$$\mathcal{M}(T, A) \approx T(c_x, c_y)$$

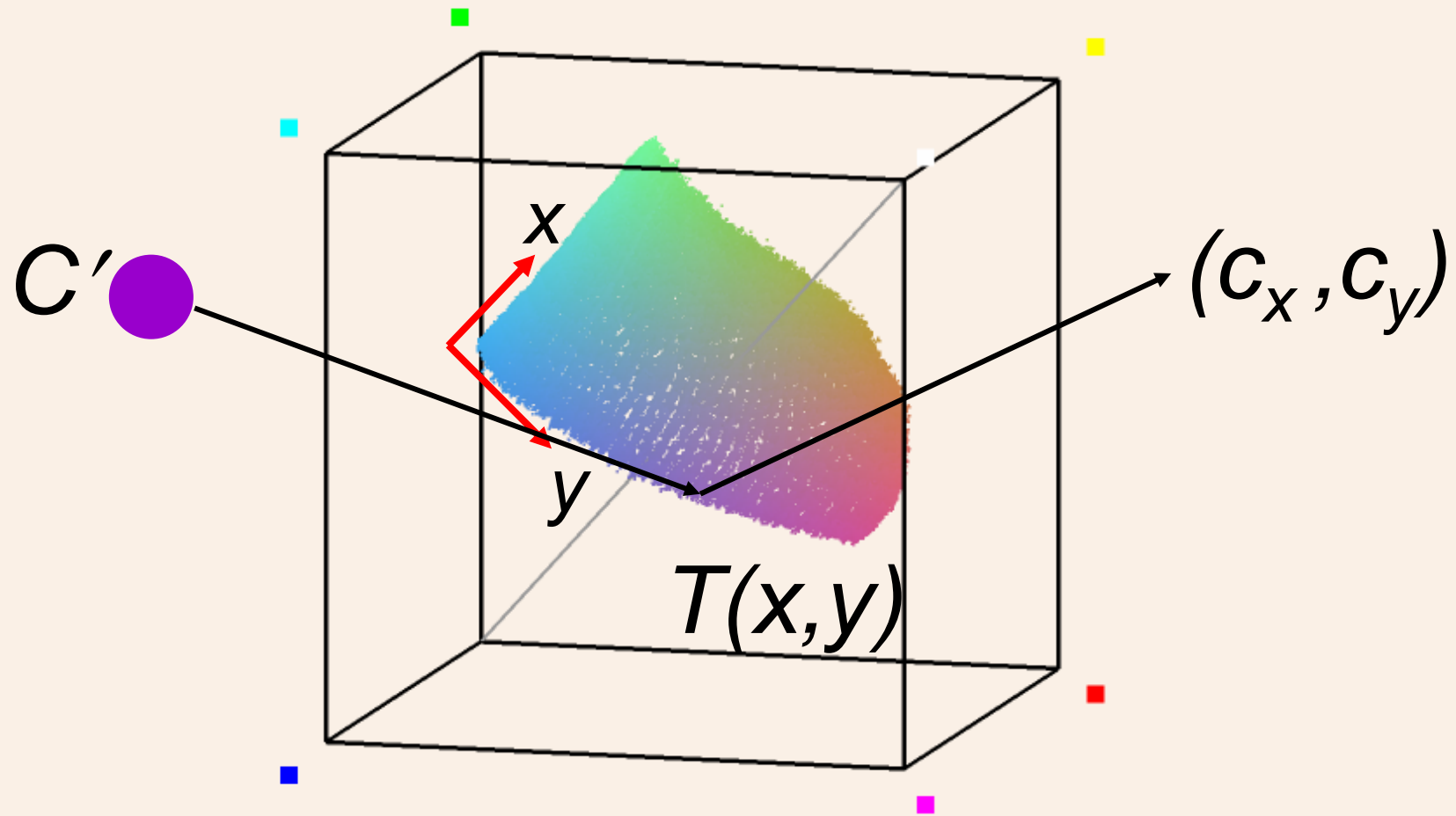


T

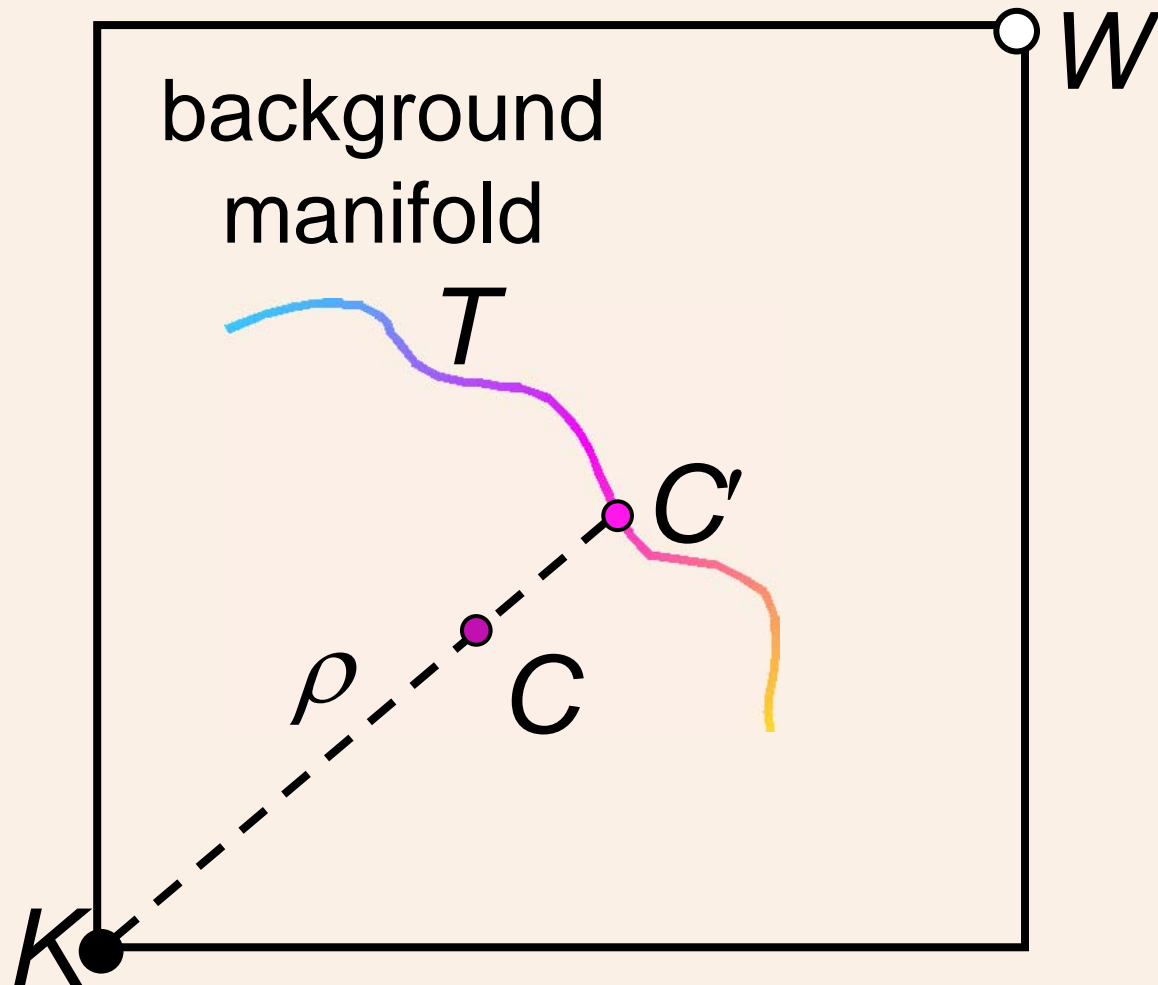
Ideal plane in RGB cube



Calibrated manifold in RGB cube



Estimate c_x, c_y and ρ



$$C' \rightarrow (c_x, c_y)$$

$$\rho = \frac{\|KC\|}{\|KC'\|}$$

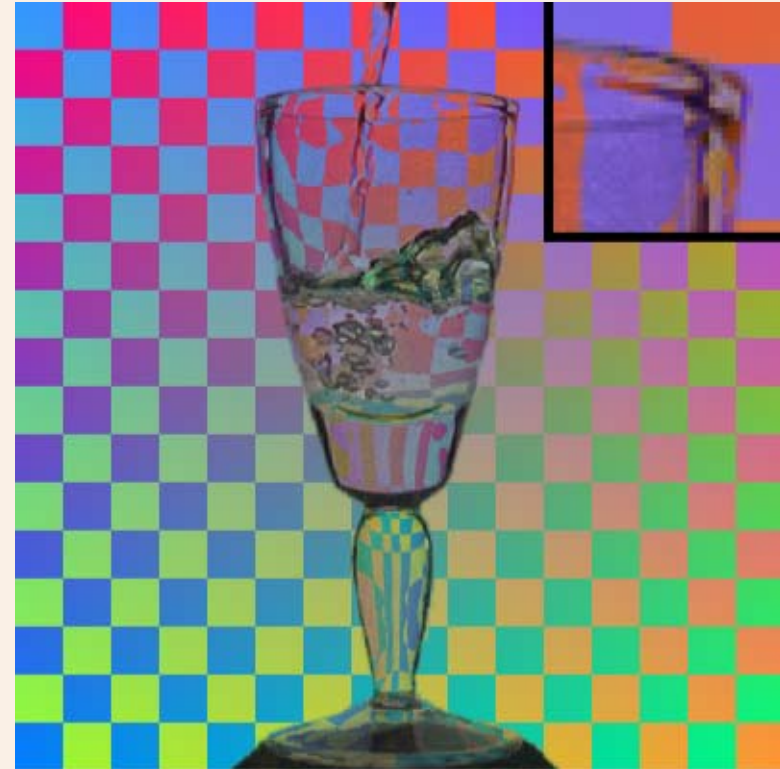
Problem: noisy matte



Edge-preserving filtering



without filtering



with filtering

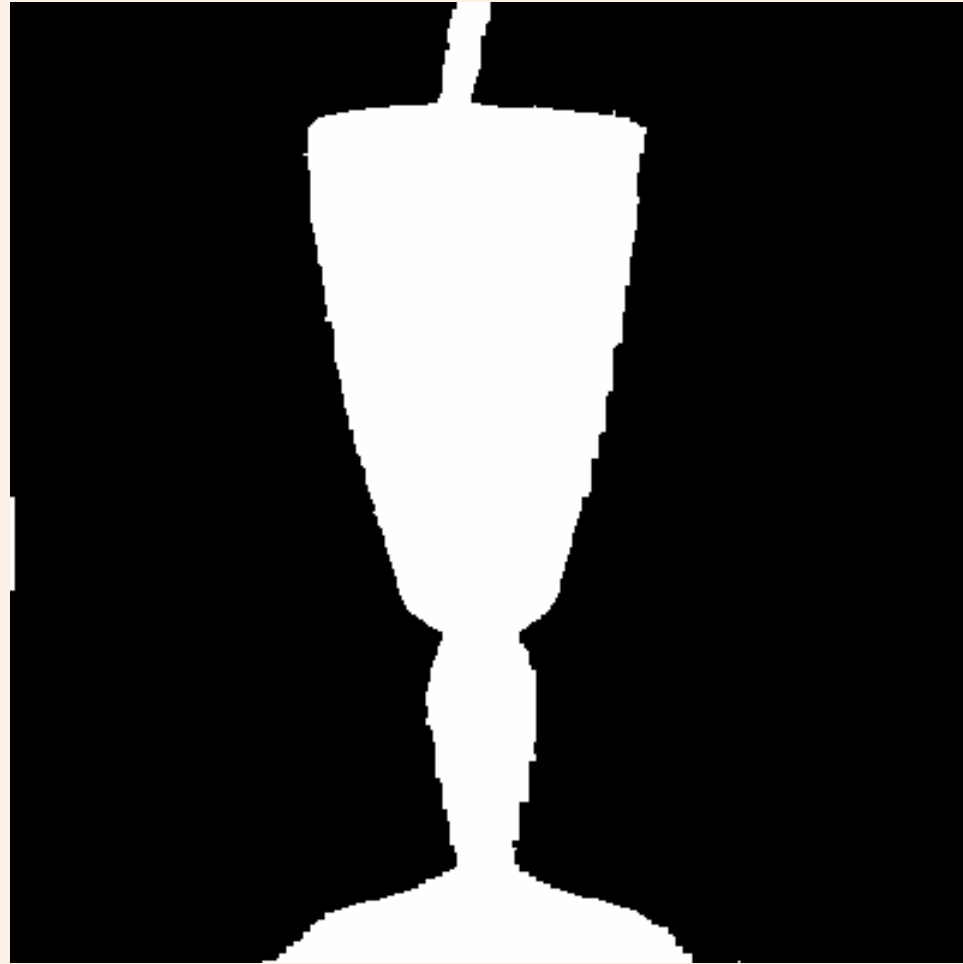
Input image



Difference thresholding



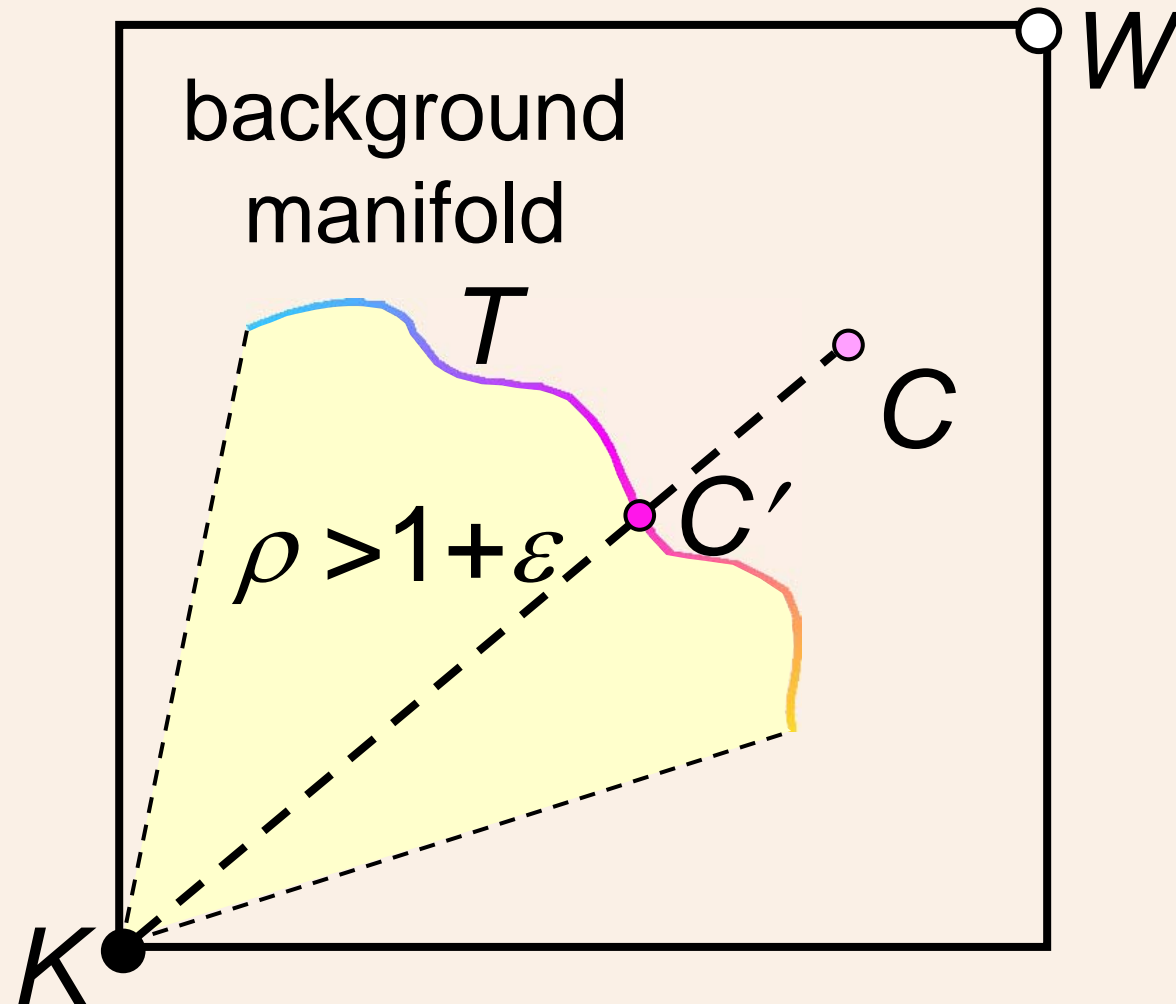
Morphological operation



Feathering

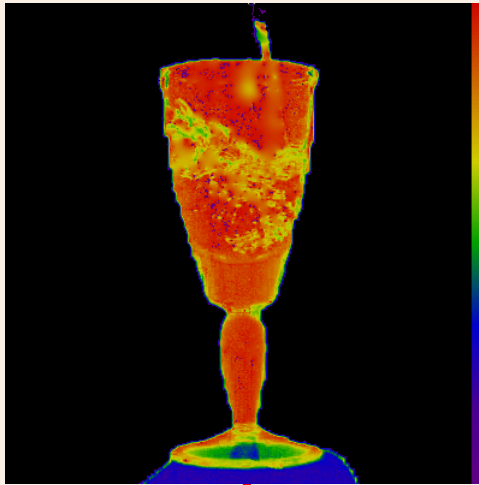
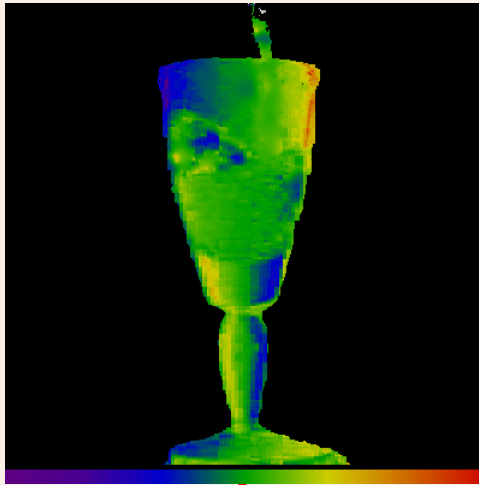
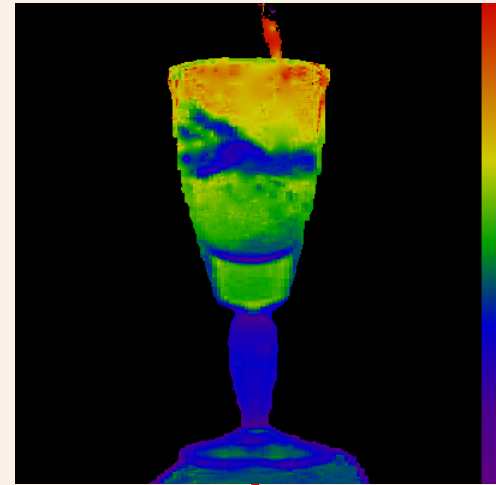


Heuristics for specular highlights

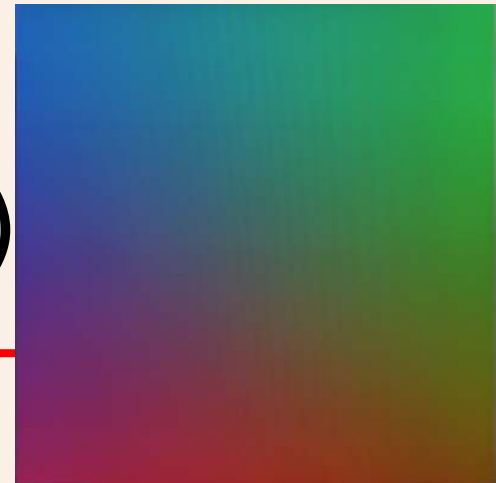


Heuristics for specular highlights



ρ  c_x  c_y 

$$C = \rho T(c_x, c_y)$$



Heuristics for specular highlights



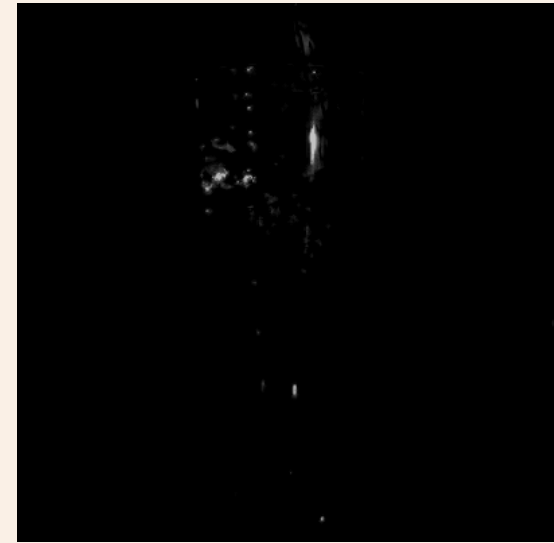
input

-



estimation

=



**foreground
(highlights)**

Composite with highlights



3369 52264



| | compositing model | matting method |
|--------------------------|--------------------------------|-------------------------------|
| color blending | $C = \alpha F + (1 - \alpha)B$ | blue-screen Bayesian |
| shadow | $C = \beta S + (1 - \beta)L$ | Shadow matting |
| refraction reflection | $C = F + \int WB$ | High-accuracy env. matting |