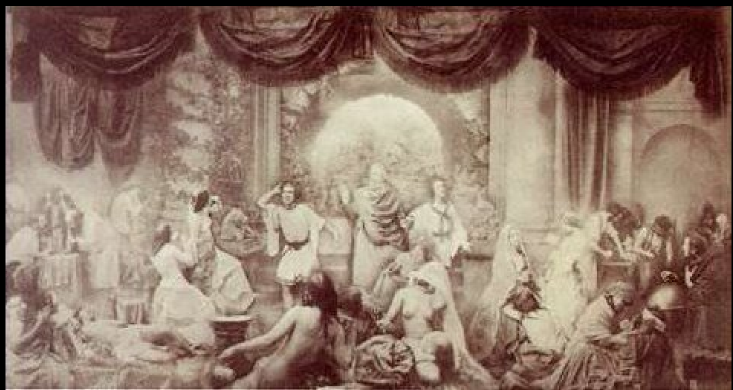
Matting and Compositing

Digital Visual Effects, Spring 2007
Yung-Yu Chuang
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.

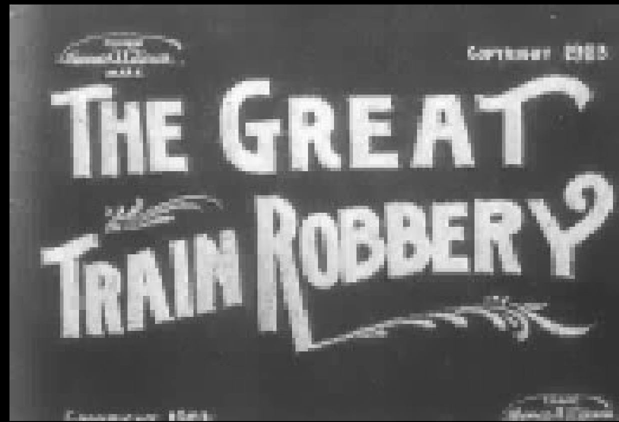
Photographic compositions

Lang Ching-shan

Use of mattes for compositing

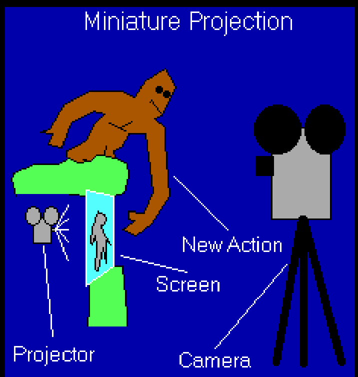
The Great Train Robbery (1903) matte shot

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 composting

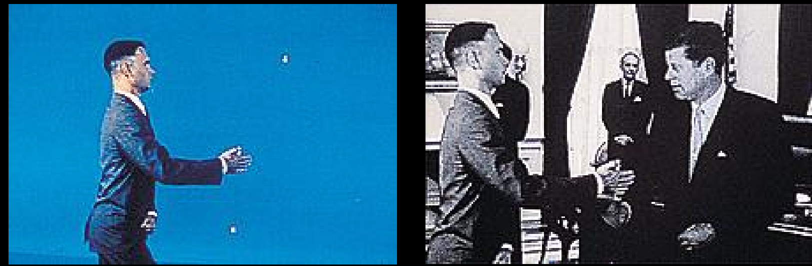
King Kong (1933)

Jurassic Park III (2001)

Optical compositing

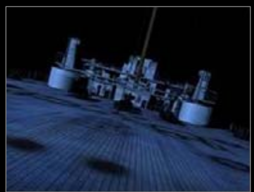
Blue-screen matting,
digital composition,
digital matte painting

Digital matting: bluescreen matting



Forrest Gump (1994)

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



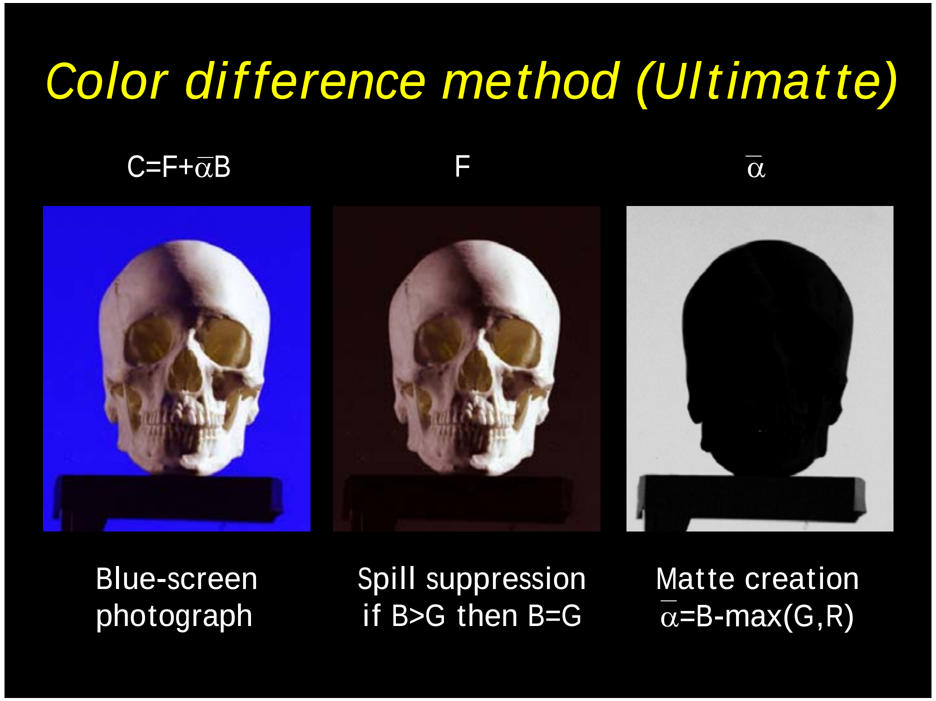
Titanic

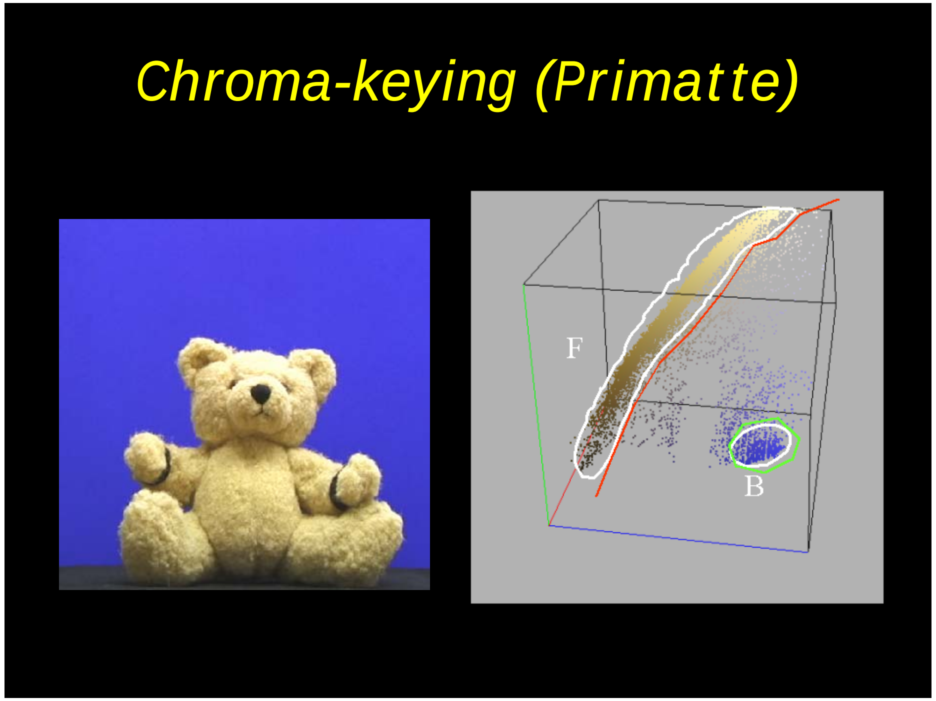
Matting and Compositing

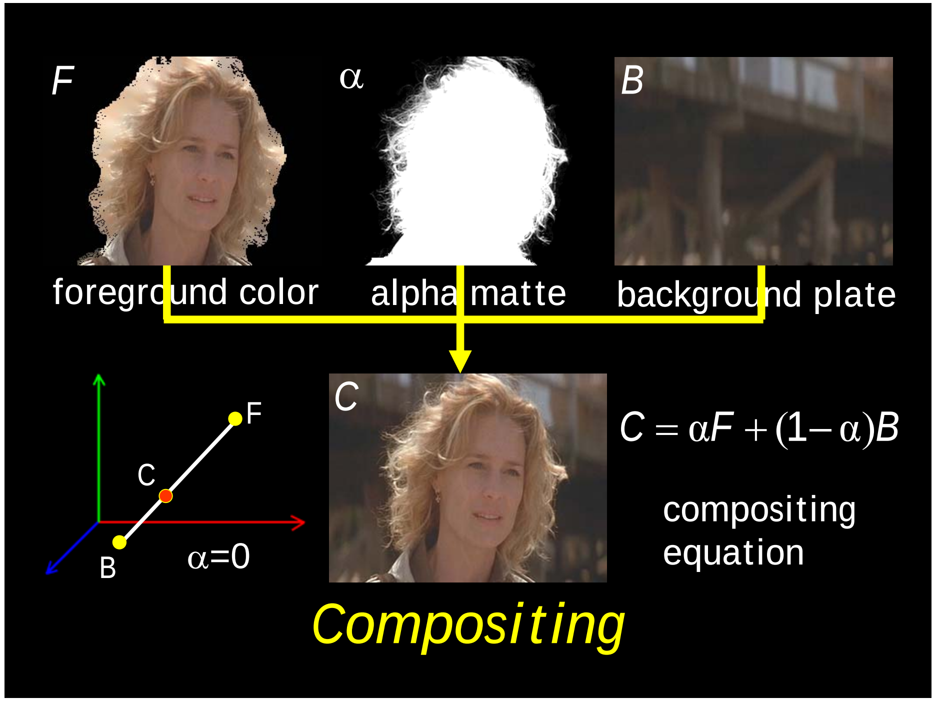
background
replacement

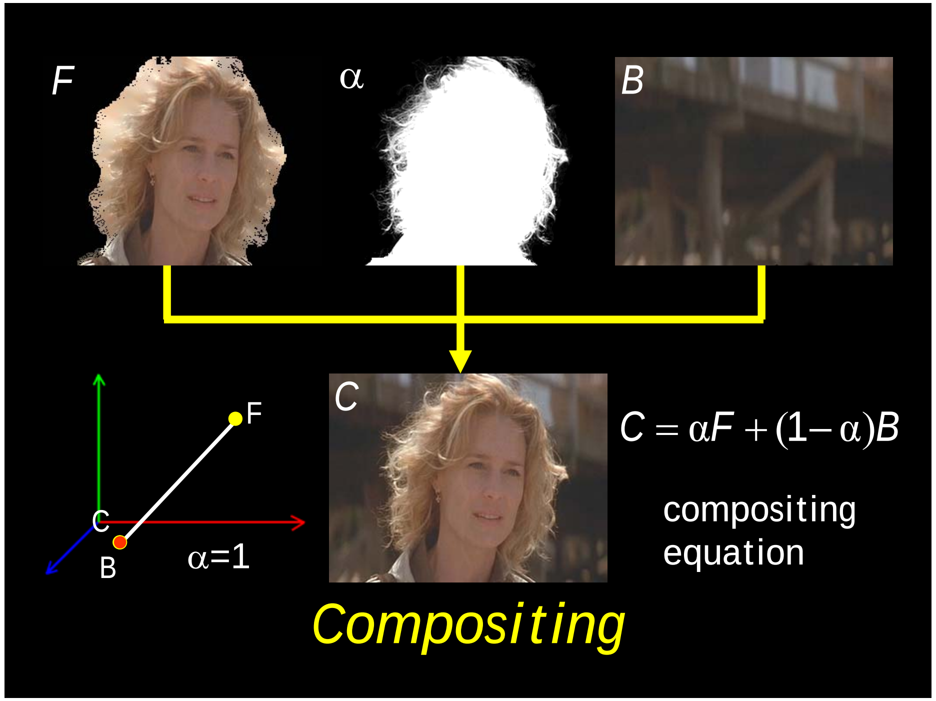
background
editing

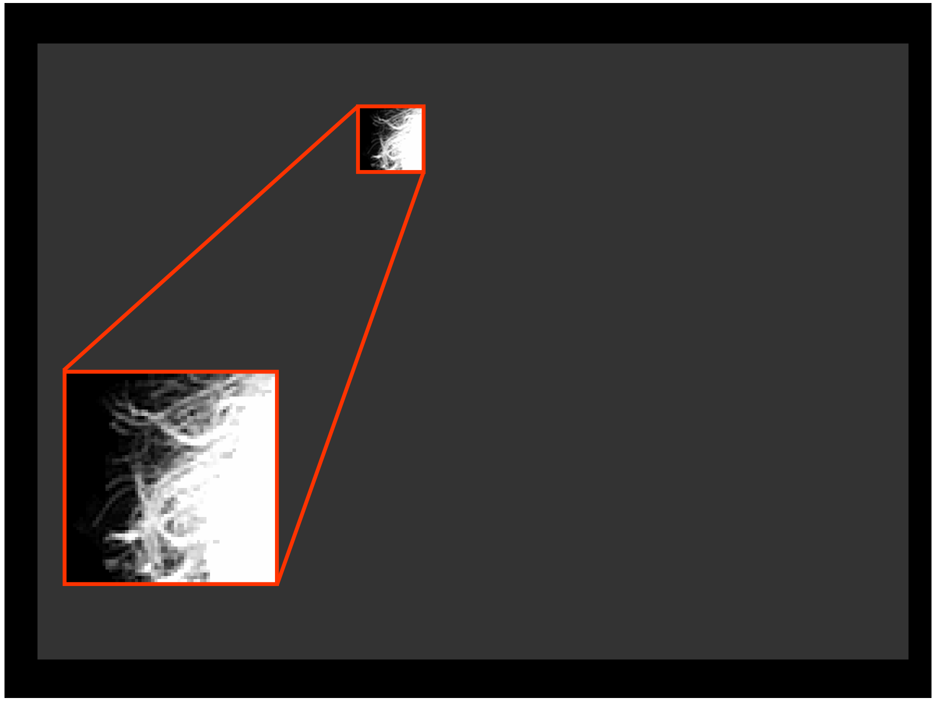
Matting and Compositing

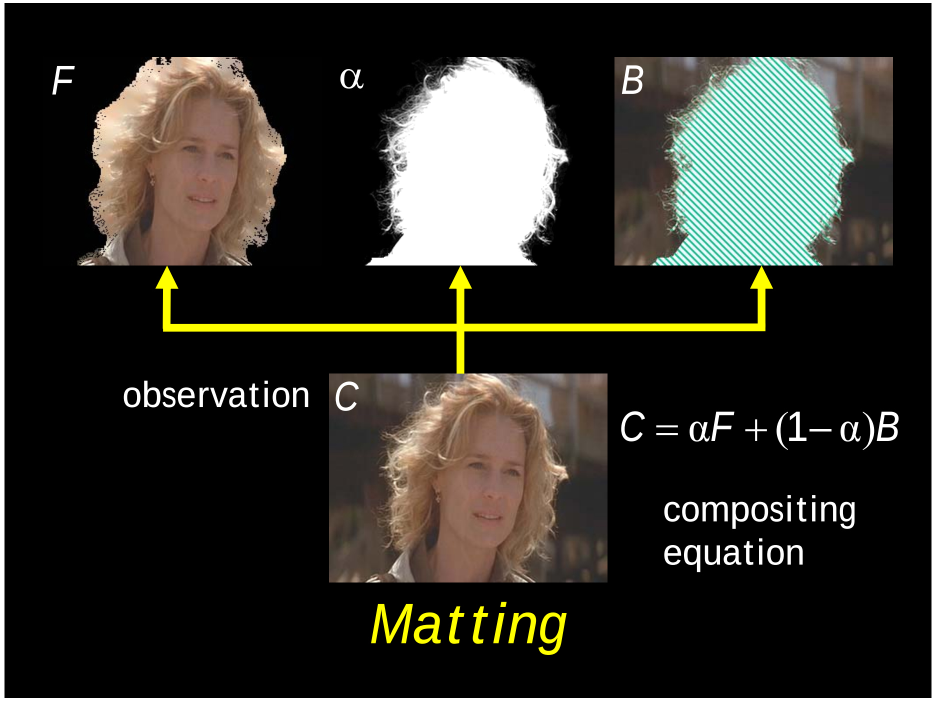

Color difference method (Ultimatte)
C=F+ᾱB
F
ᾱ
Blue-screen photograph
Spill suppression if B>G then B=G
Matte creation ᾱ=B-max(G,R)

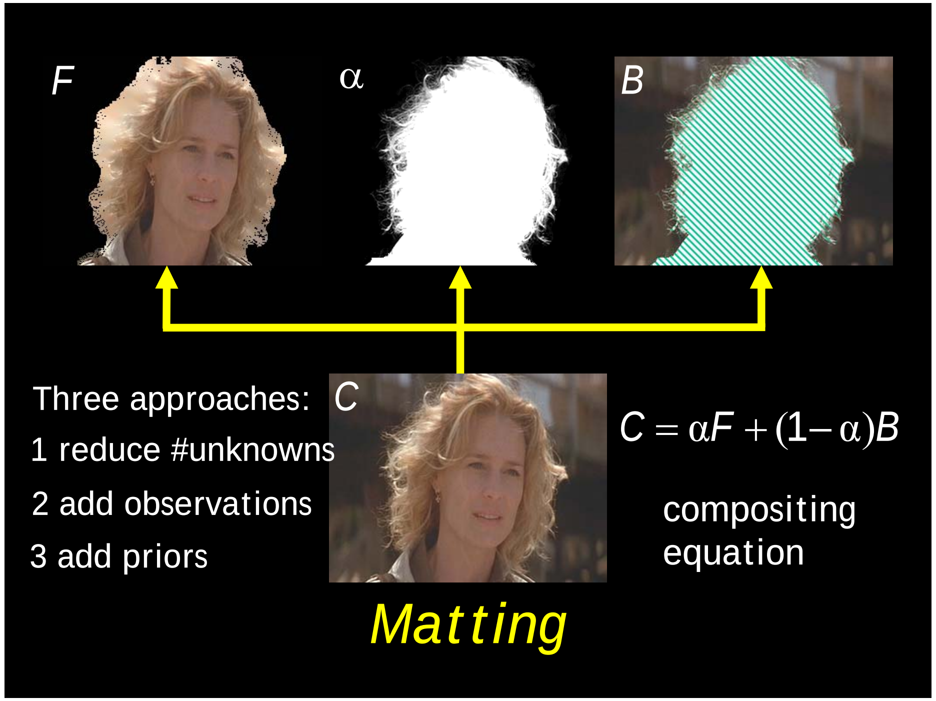

Chroma-keying (Primatte)
F
B

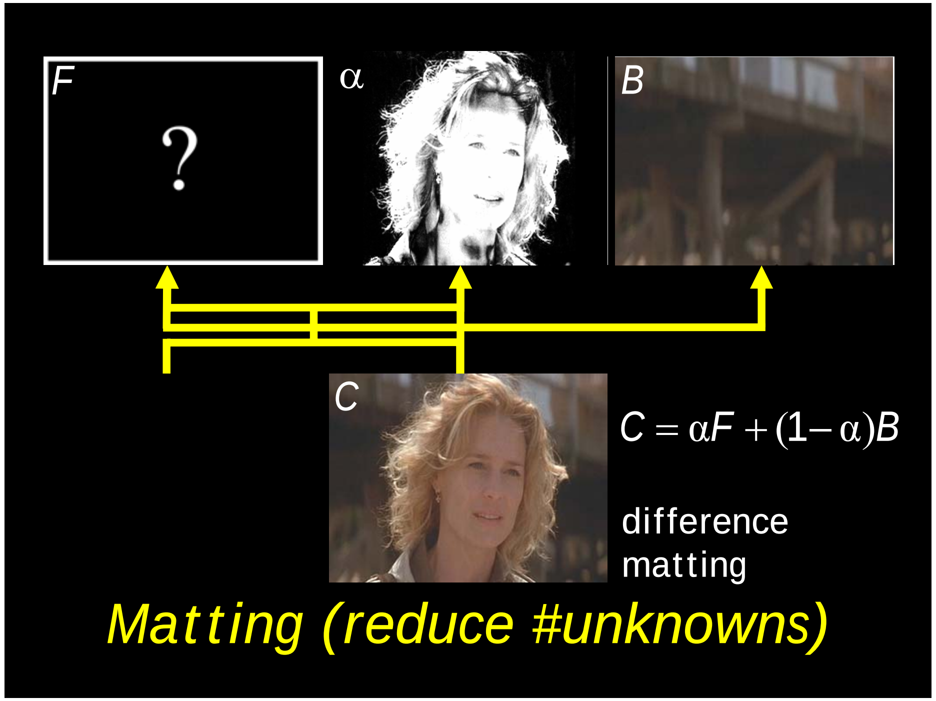

F
α
B
foreground color
alpha matte
background plate
C
F
C
B
α=0
$C = \alpha F + (1-\alpha)B$
compositing equation
Compositing

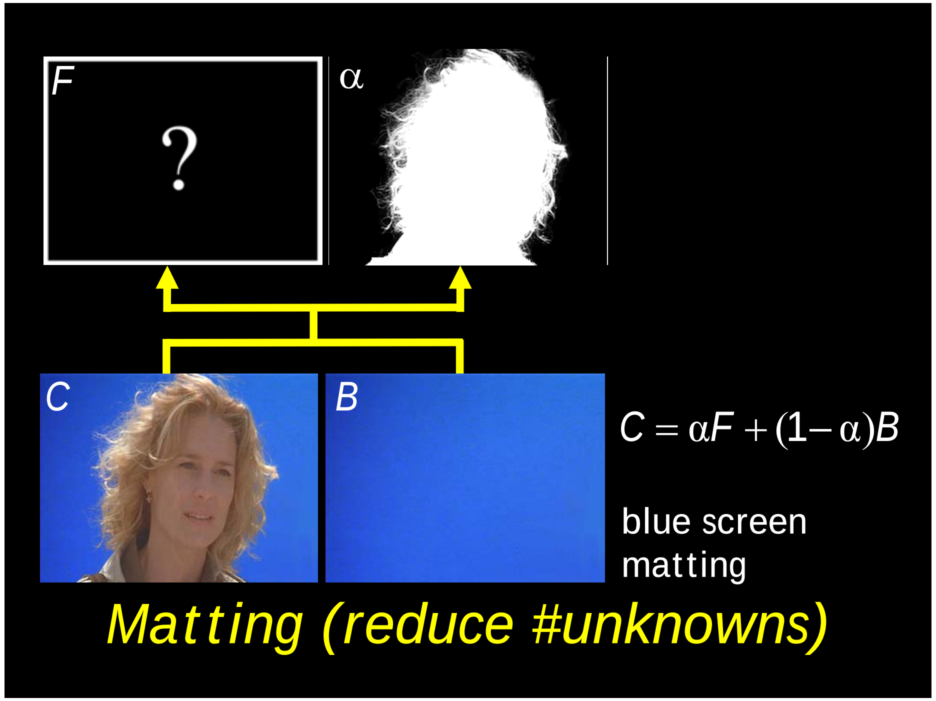

F
α
B
F
C
B
α=1
C
$C = \alpha F + (1-\alpha)B$
compositing equation
Compositing

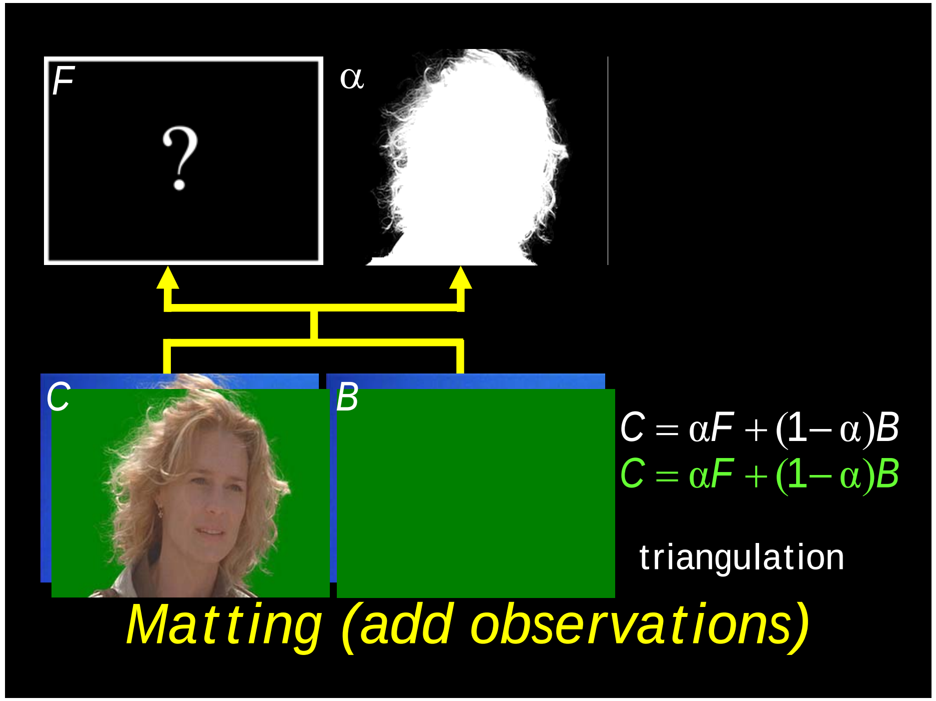


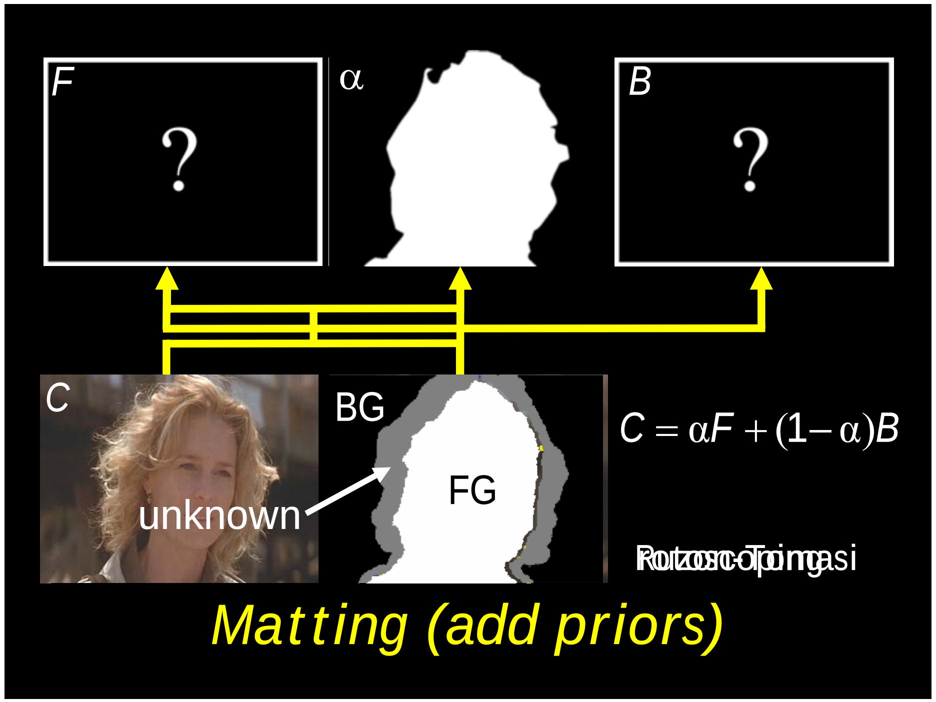

F
α
B
observation
C
C = αF + (1− α)B
compositing equation
Matting


F
α
B
Three approaches:
1 reduce #unknowns
2 add observations
3 add priors
C
C = αF + (1− α)B
compositing equation
Matting


F
?
α
B
C
C = αF + (1− α)B
difference matting
Matting (reduce #unknowns)


F
?
α
C
B
$C = \alpha F + (1-\alpha)B$
blue screen matting
Matting (reduce #unknowns)


F
?
α
C
B
$C = \alpha F + (1-\alpha)B$
$C = \alpha F + (1-\alpha)B$
triangulation
Matting (add observations)


F
?
α
B
?
C
unknown
BG
FG
$C = \alpha F + (1-\alpha)B$
Ruzon-Tomasi
Rotoscoping
Matting (add priors)


Bayesian image matting

posterior probability

likelihood

priors

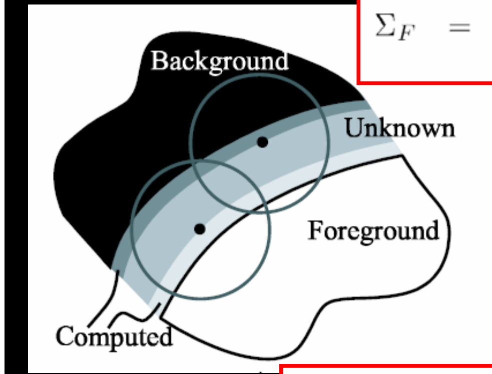
$$\arg\max_{F,B,\alpha} P(F,B,\alpha\,|\,C) = \arg\max_{F,B,\alpha} P(C\,|\,F,B,\alpha)\,P(F)\,P(B)\,P(\alpha)\,/\,P(C)$$

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

Bayesian framework

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

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



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

Priors

repeat

1. fix alpha

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

2. fix F and B

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

until converge

Optimization

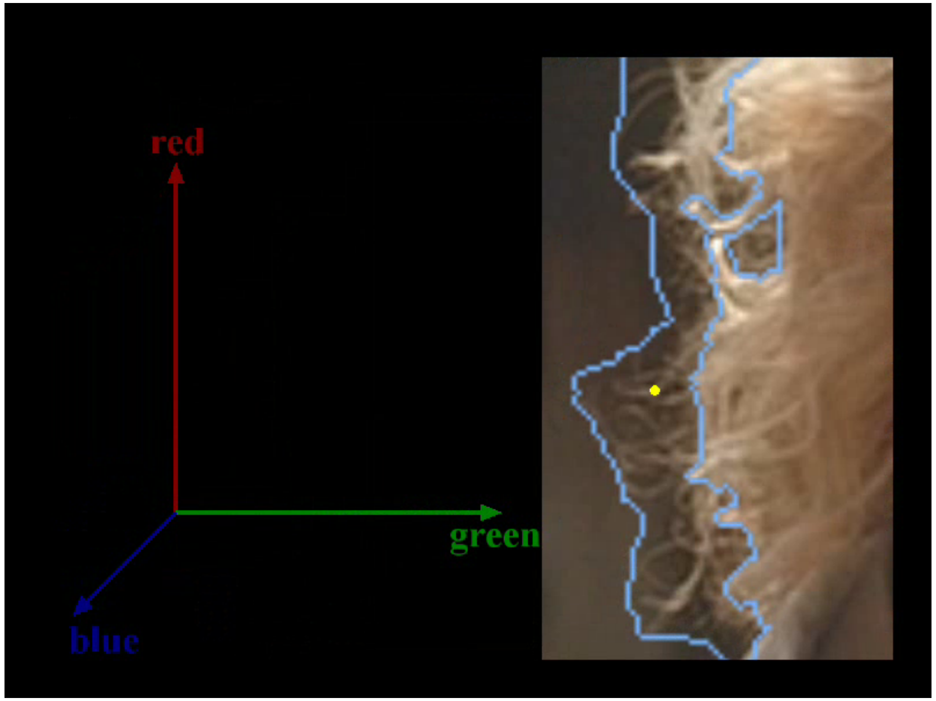
Bayesian image matting

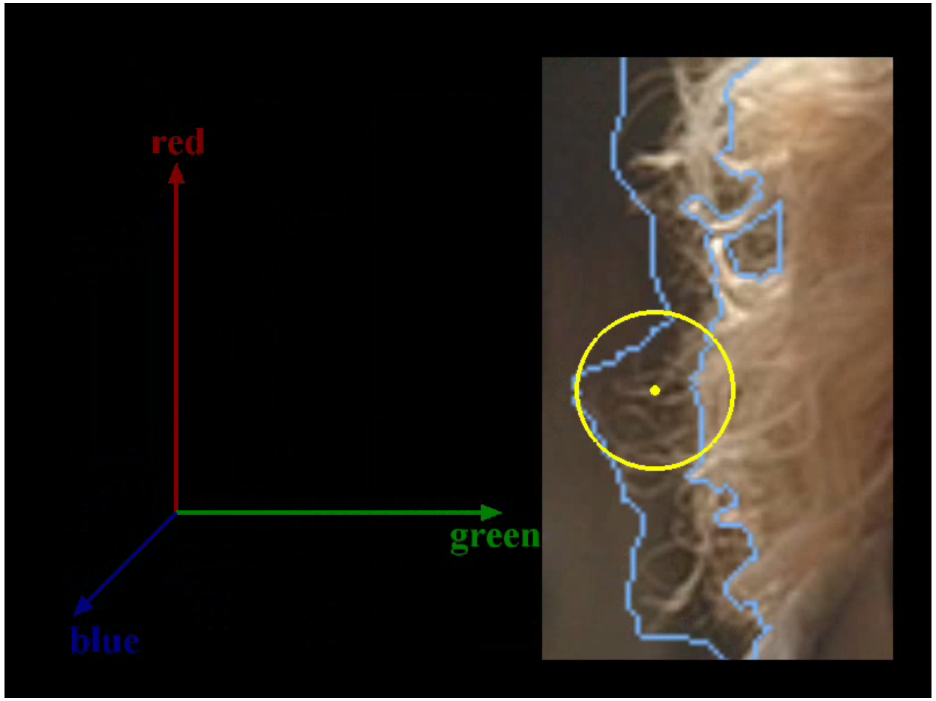
Bayesian image matting

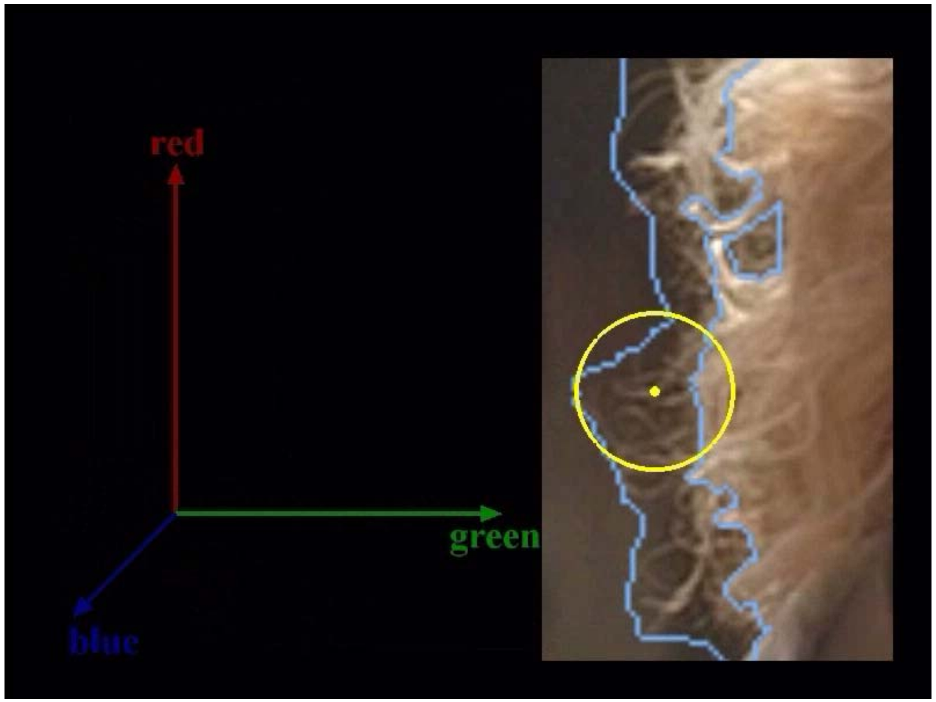
Bayesian image matting

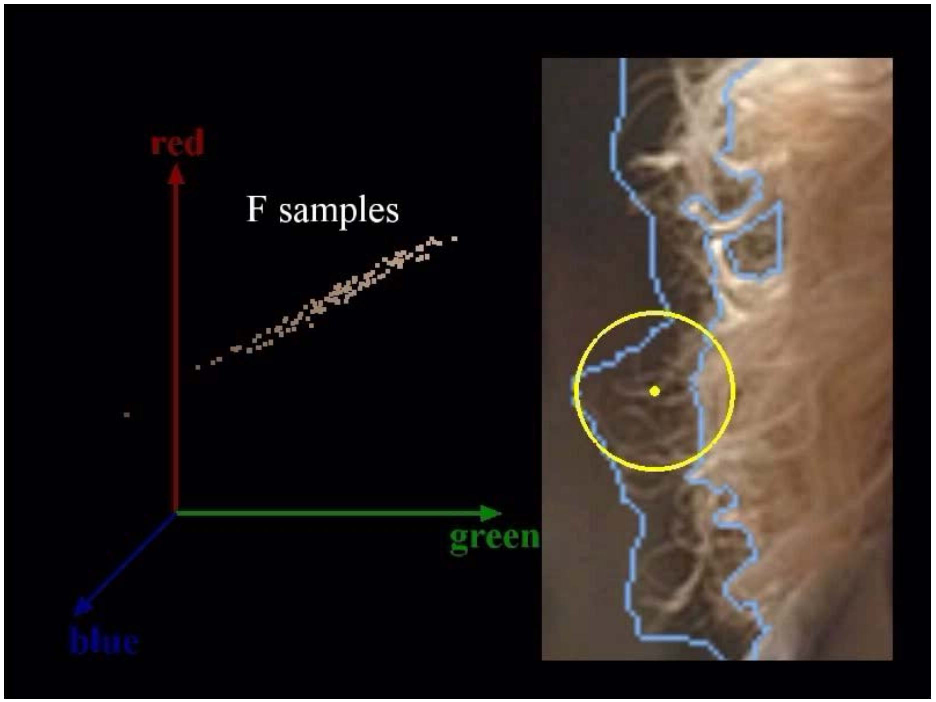
Bayesian image matting

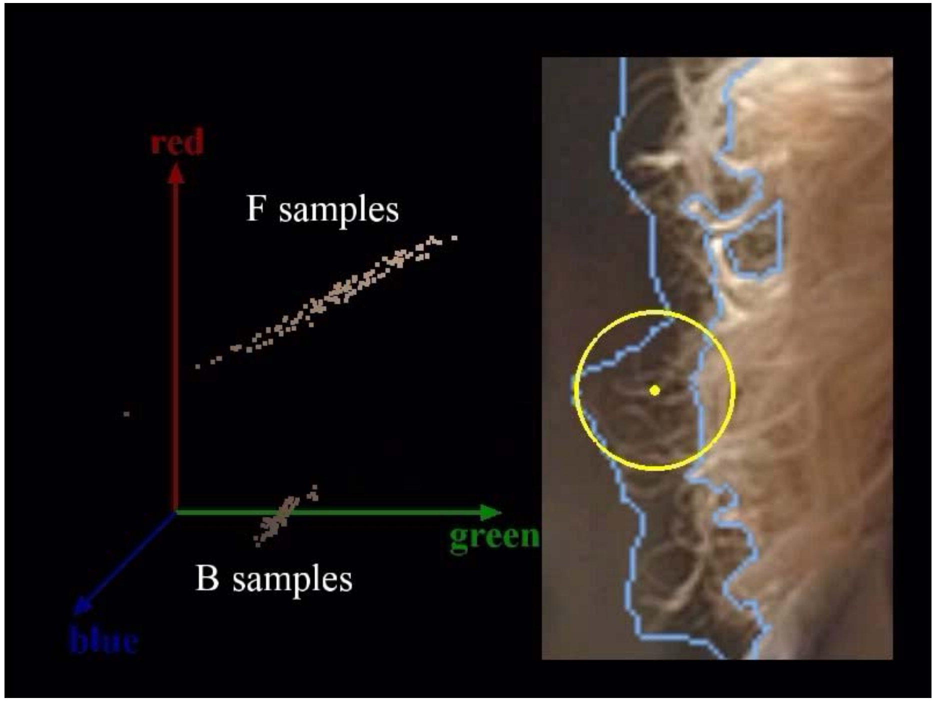
Bayesian image matting

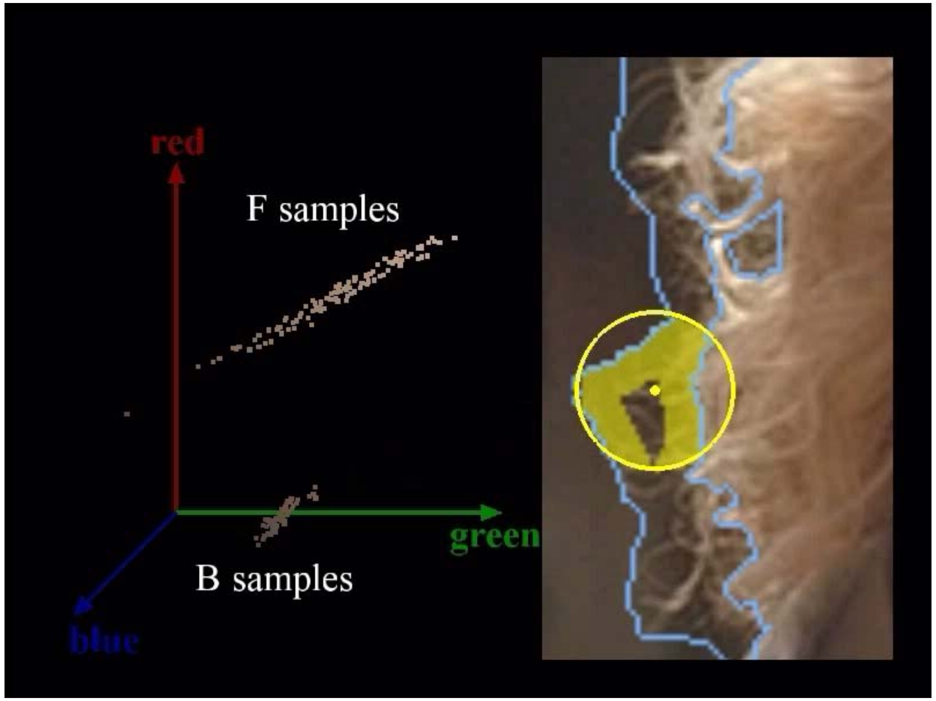

red
green
blue

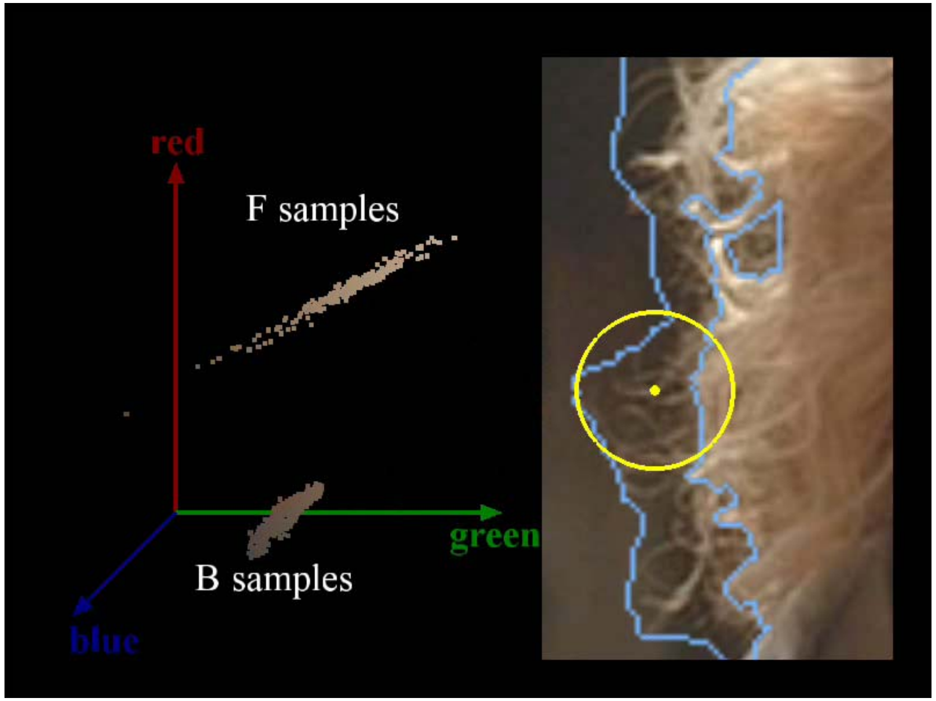

red
green
blue

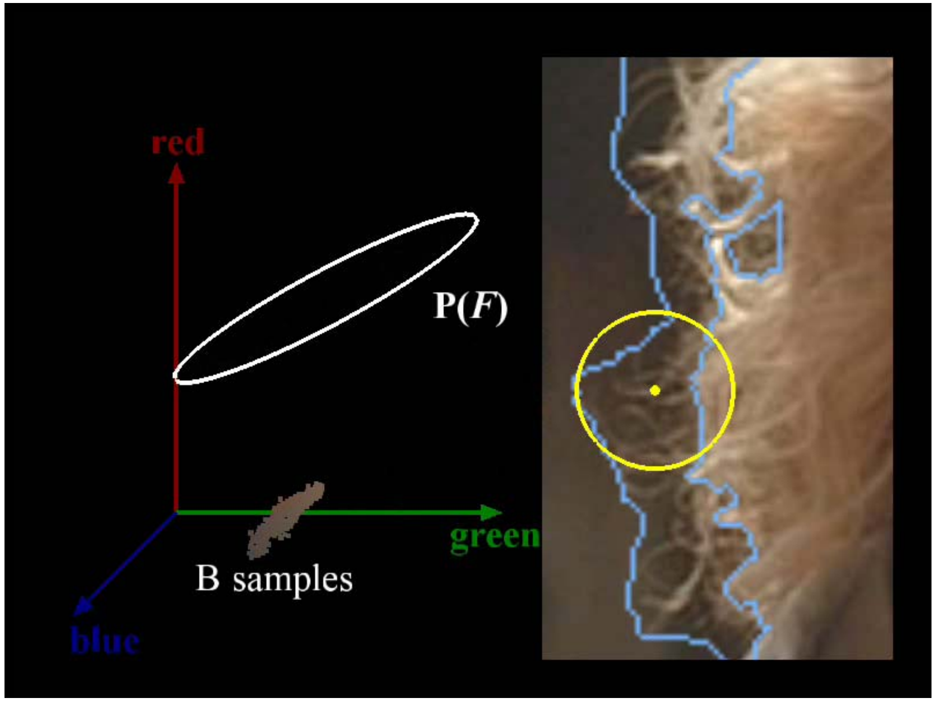

red
green
blue

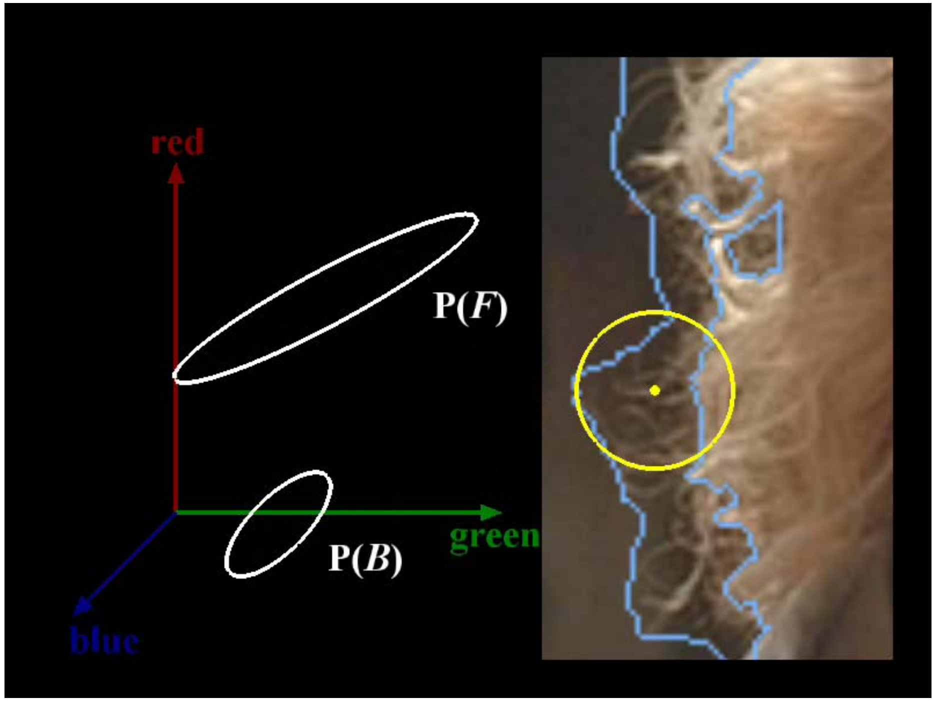

F samples
red
green
blue

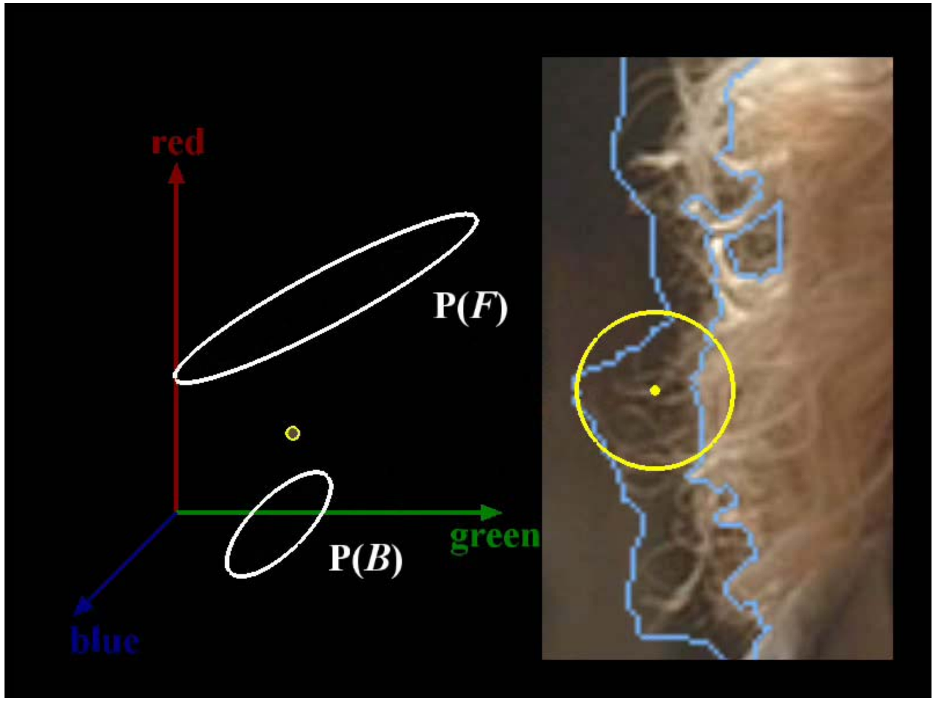

red
F samples
green
B samples
blue

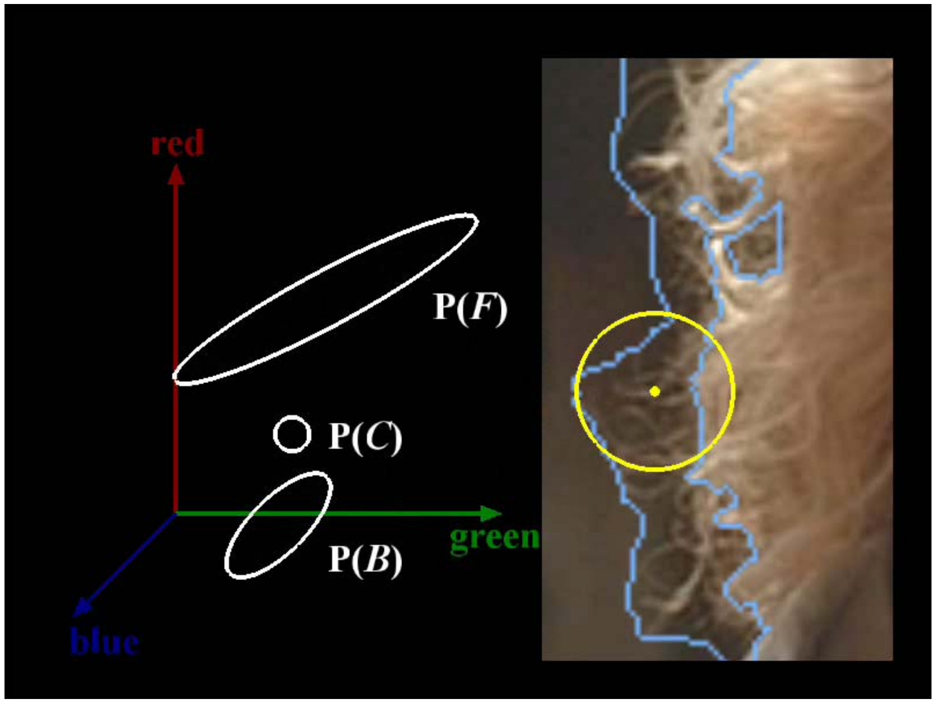

red
F samples
green
B samples
blue

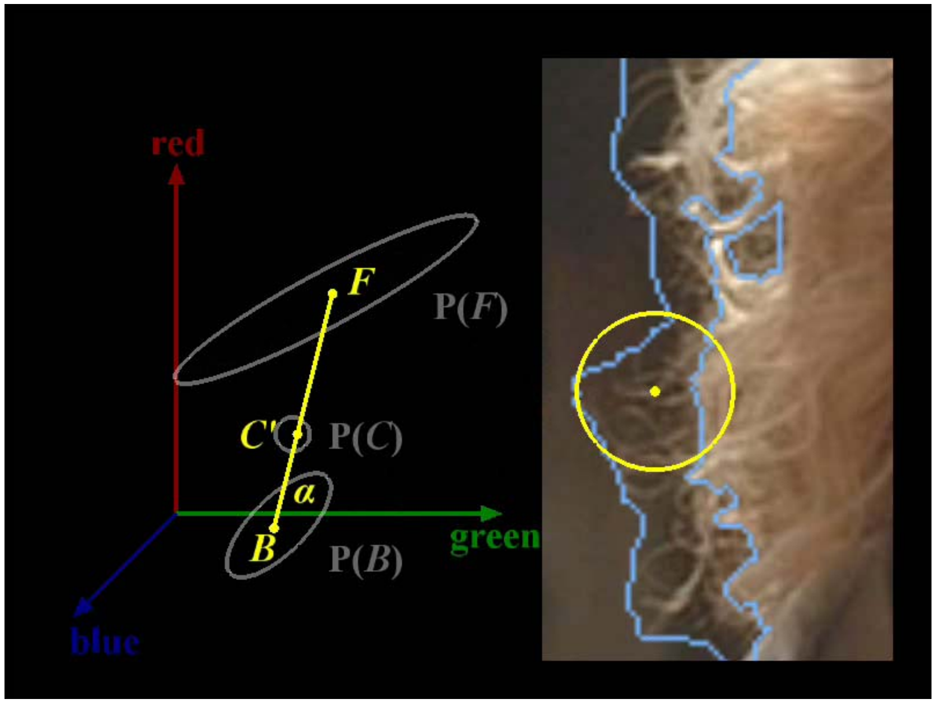

red
F samples
green
B samples
blue


red
P(F)
green
B samples
blue


red
P(F)
P(B)
green
blue


red
P(F)
P(B)
green
blue

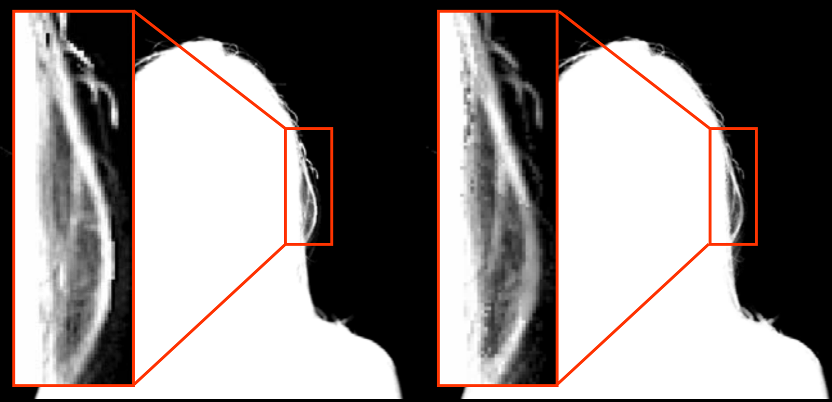

red
P(F)
P(C)
P(B)
green
blue


red
F
P(F)
C'
P(C)
α
B
P(B)
green
blue

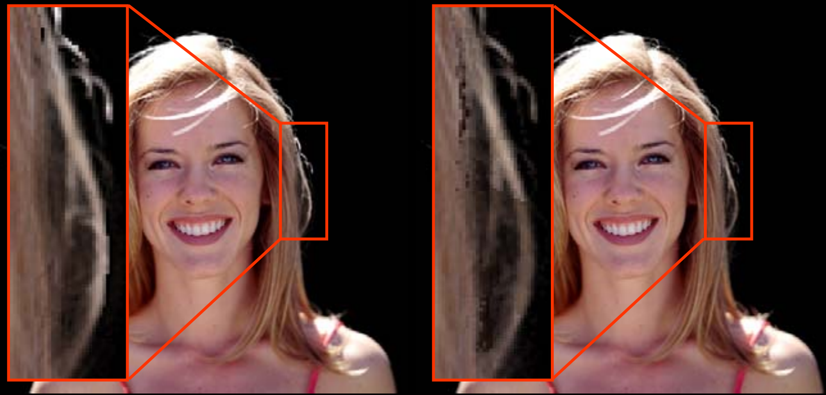
Results

Results

Comparisons

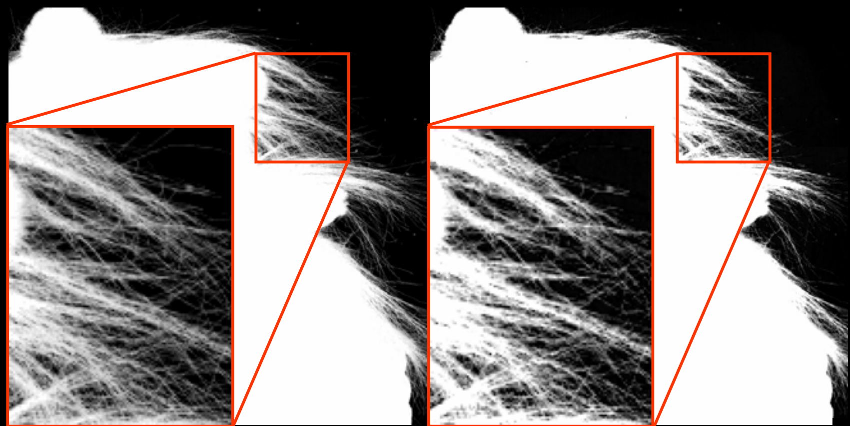


Comparisons



Comparisons

Comparisons



Comparisons

Comparisons

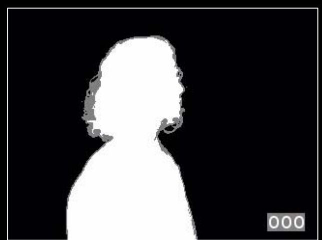
Video matting

input video

Video matting

input video

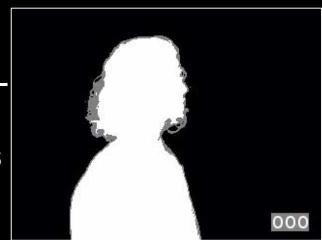
input key trimaps



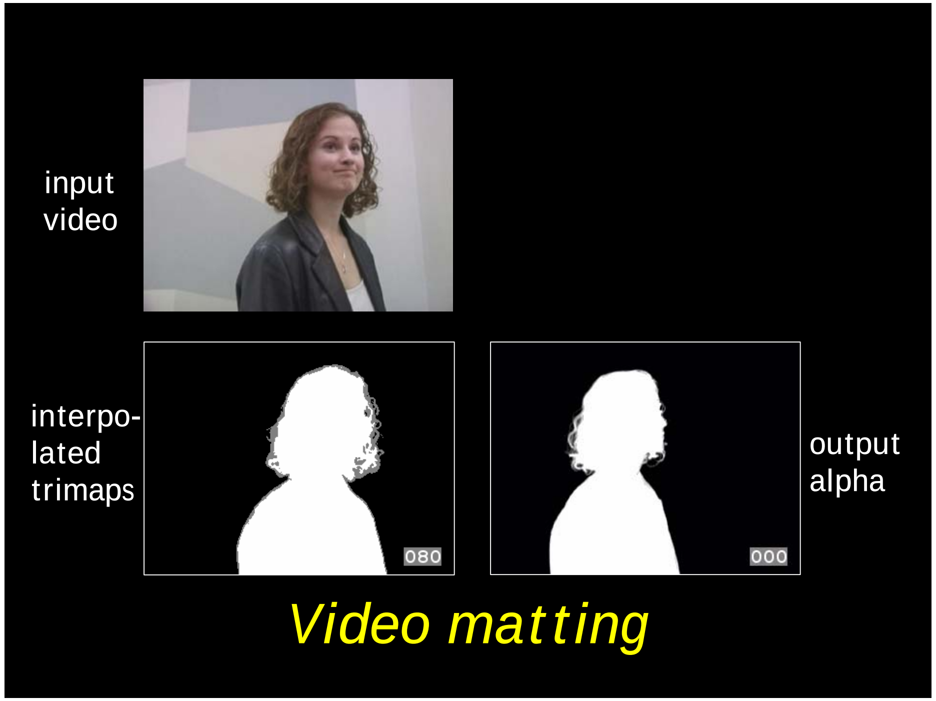
Video matting

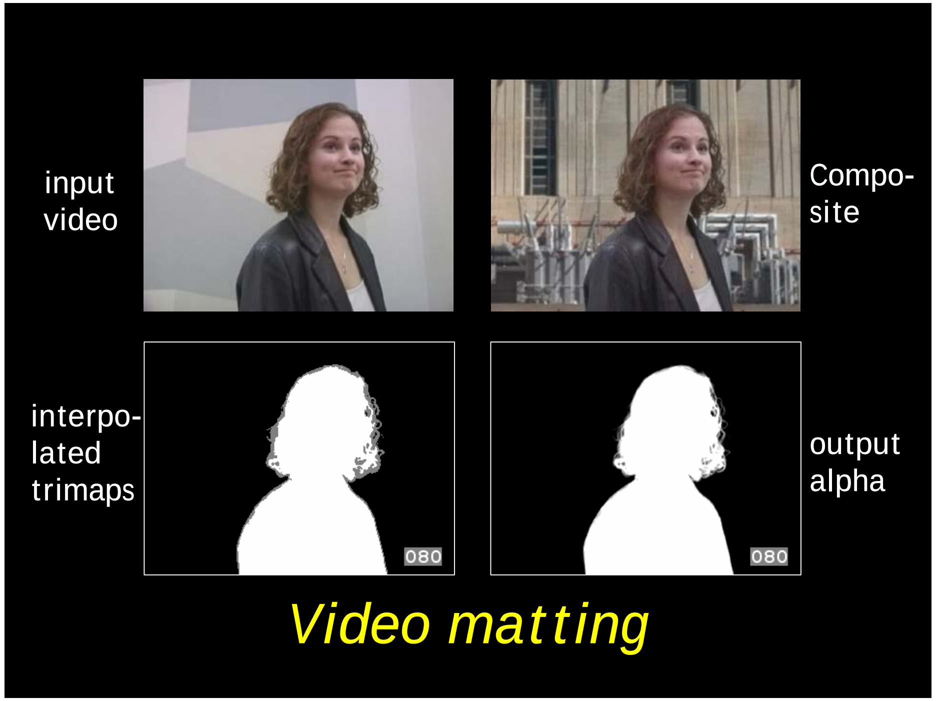
input video

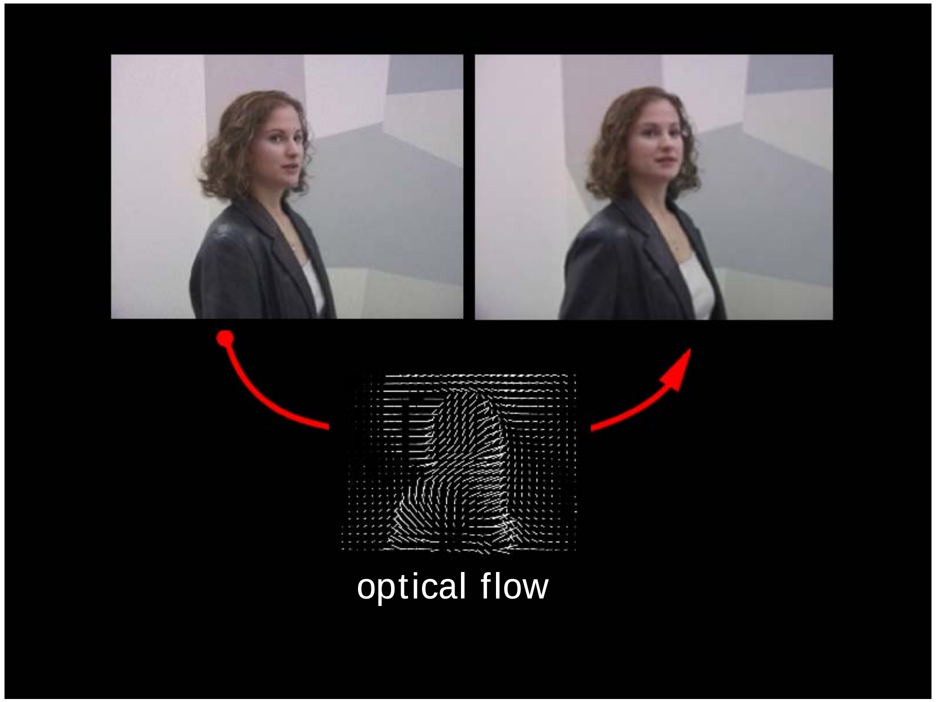
interpo-lated trimaps

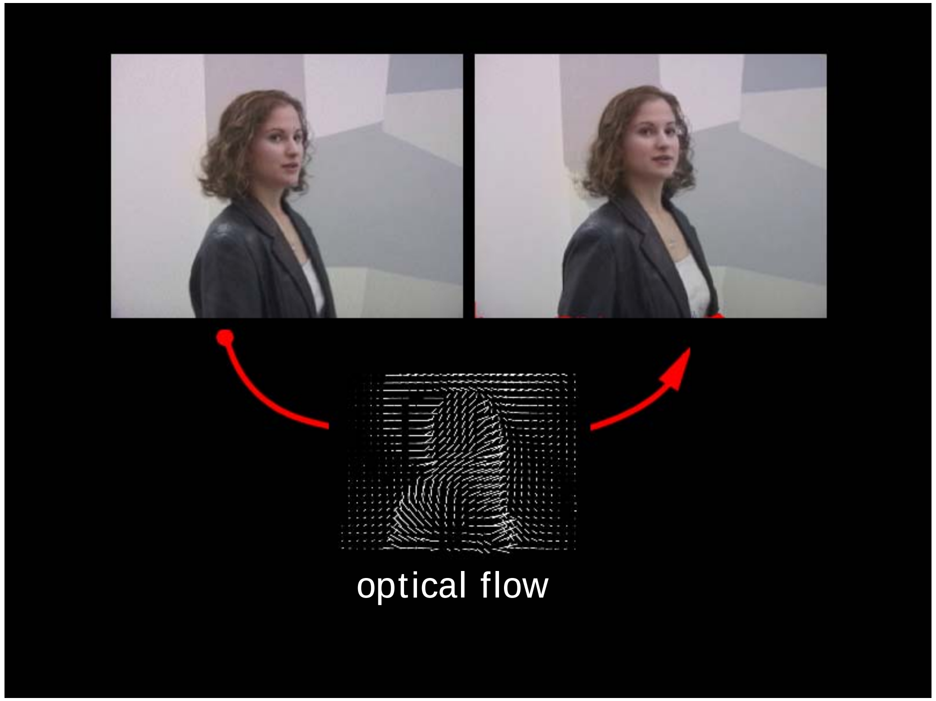


Video matting


input
video
interpo-
lated
trimaps
080
000
output
alpha
Video matting

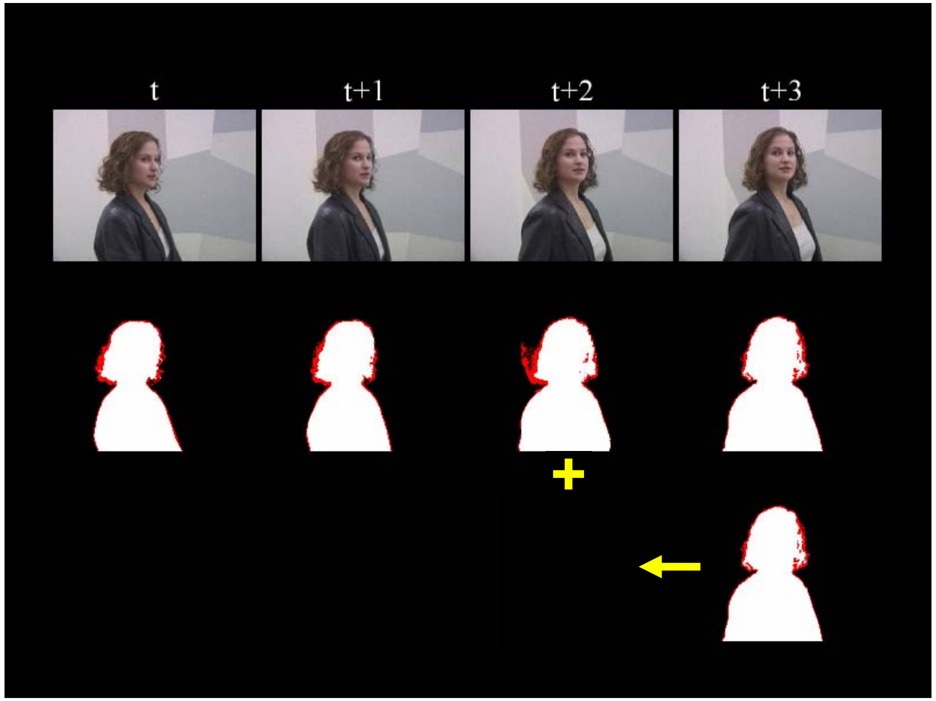

input
video
Compo-
site
interpo-
lated
trimaps
080
080
output
alpha
Video matting


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

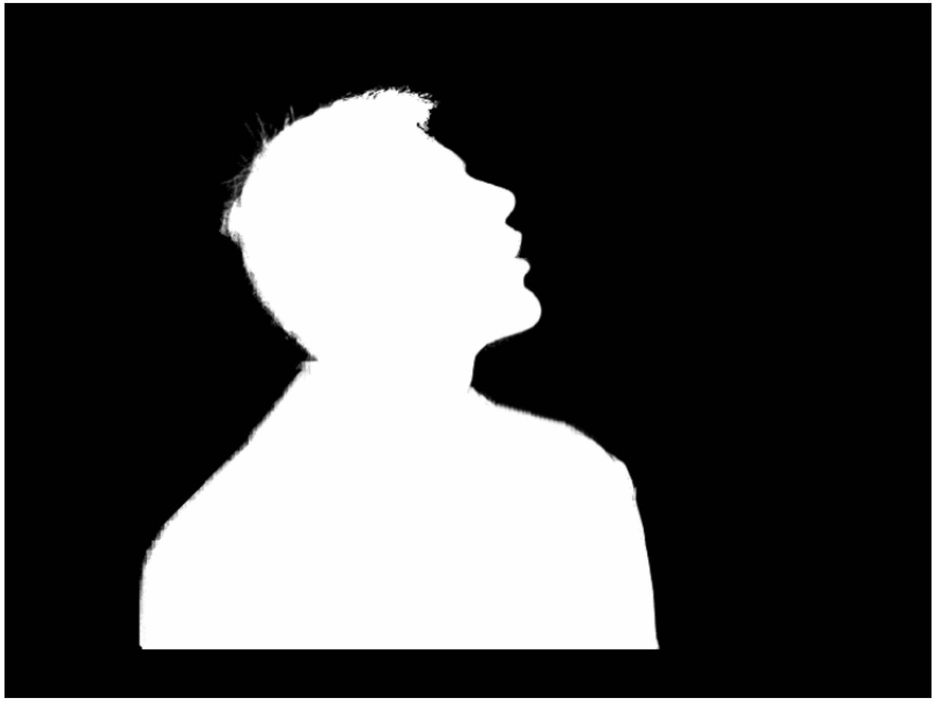
Alpha matte

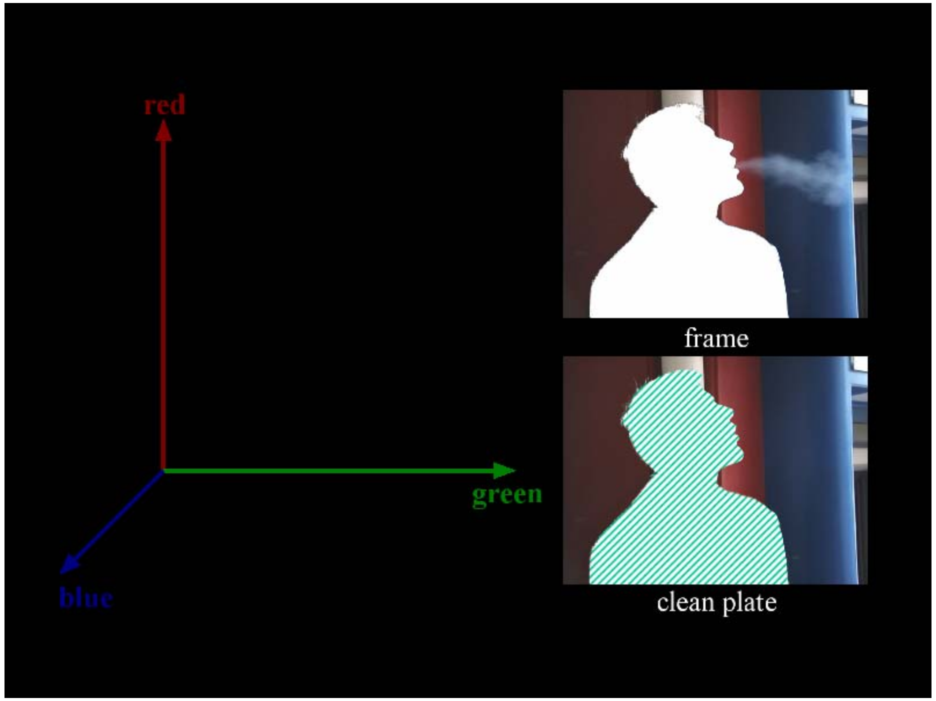
without background

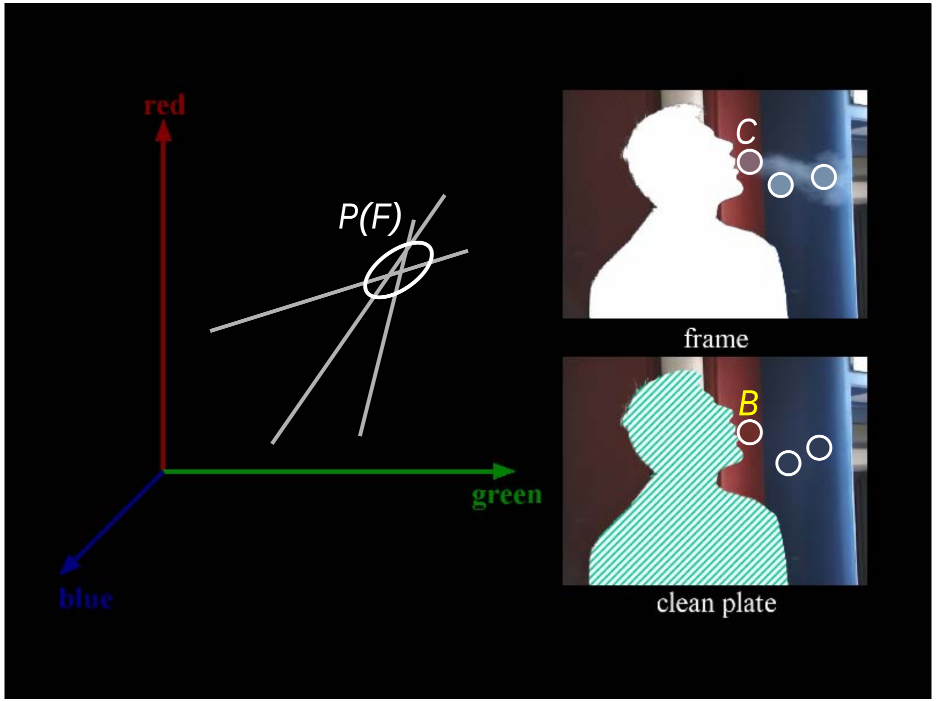
with background

Comparison


input
composite




red
green
blue
frame
clean plate


red
P(F)
green
blue
C
frame
B
clean plate

More on matting

Recent progresses on matting

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

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

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

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

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

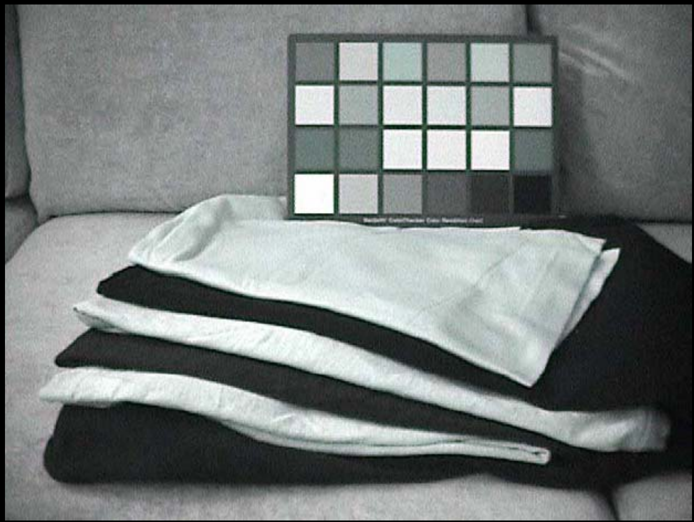
Poisson matting

Poisson matting

Two-camera matting methods

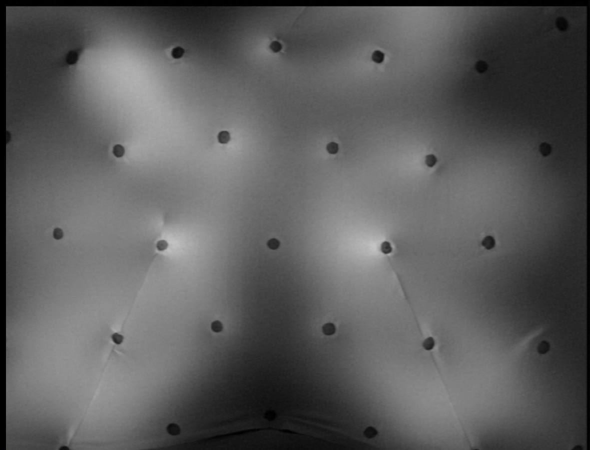
- Invisible lights
  - Polarized lights
  - Infrared
- Thermo-key
- Depth Keying (ZCam)

Invisible lights (Infared)



Invisible lights (Infared)

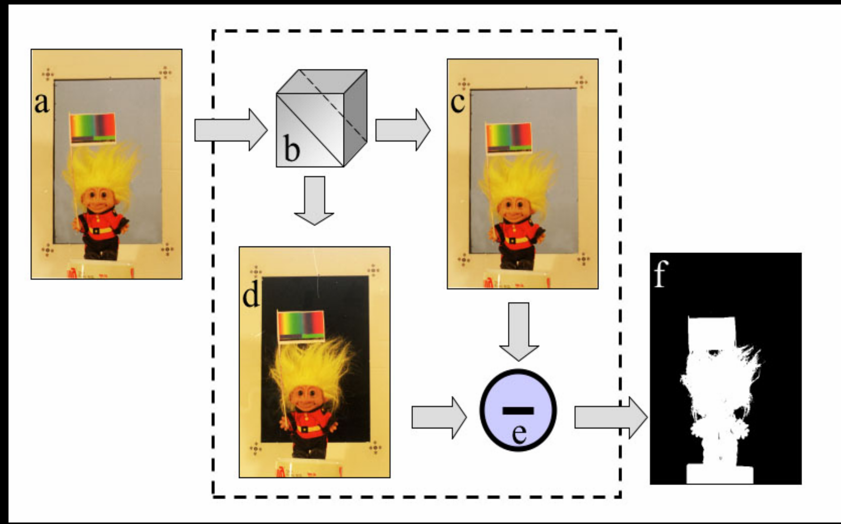
Invisible lights (Infared)



Invisible lights (Infared)

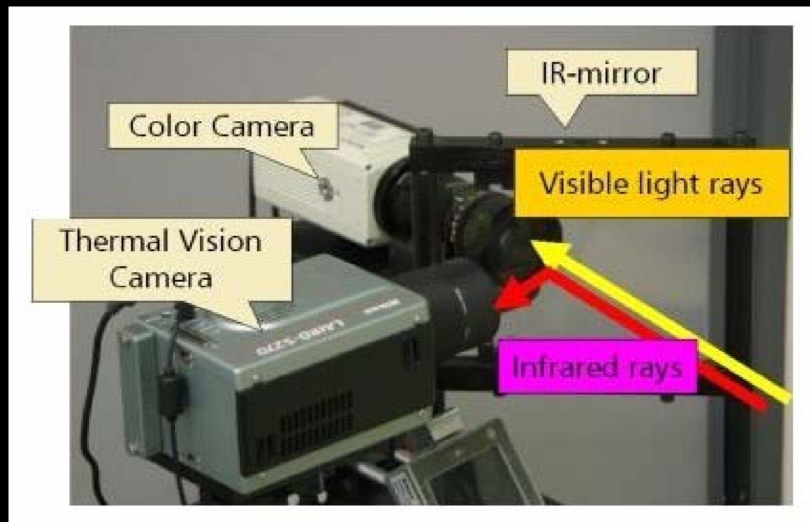
Invisible lights (Infared)

Invisible lights (Infared)

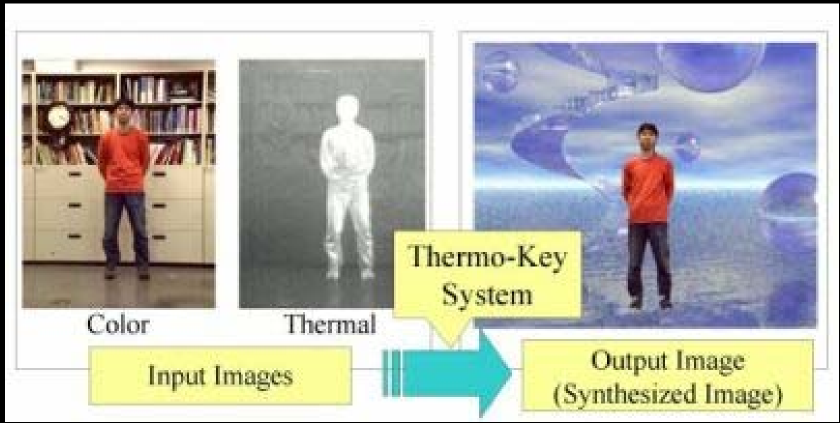


Invisible lights (Polarized)

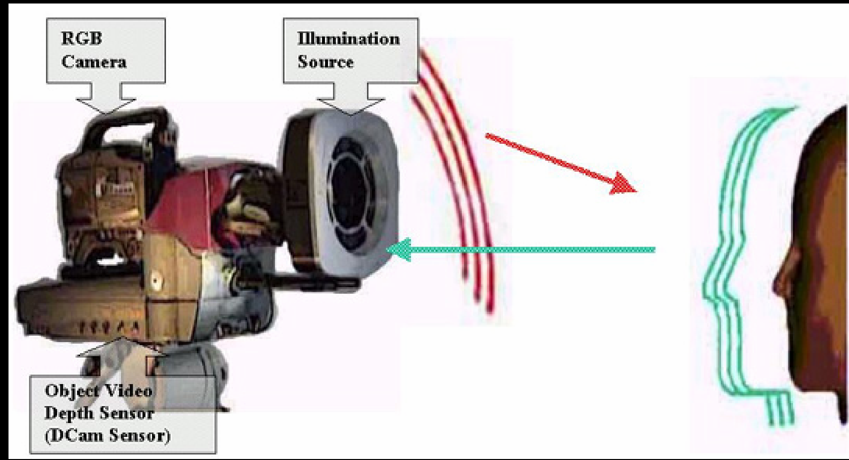
Invisible lights (Polarized)



Thermo-Key



Thermo-Key



ZCam

ZCam

Flash matting

$$
\begin{aligned}
I &= \alpha F + (1-\alpha)B, \\
I^f &= \alpha F^f + (1-\alpha)B^f,
\end{aligned}
$$

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.

$$
\begin{aligned}
& \arg\max_{\alpha, F'} L(\alpha, F' \mid I') \\
= & \arg\max_{\alpha, F'} \{L(I'|\alpha, F') + L(F') + L(\alpha)\}
\end{aligned}
$$

$$L(I'|\alpha, F') = -||I' - \alpha F'||/\sigma_{I'}^2$$

$$L(F') = -(F' - \overline{F'})^T \Sigma_{F'}^{-1} (F' - \overline{F'})$$

Flash matting

Foreground flash matting

$$
\begin{aligned}
I &= \alpha F + (1-\alpha)B \\
I' &= \alpha F'
\end{aligned}
$$

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

Joint Bayesian flash matting

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

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

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

Joint Bayesian flash matting

flash

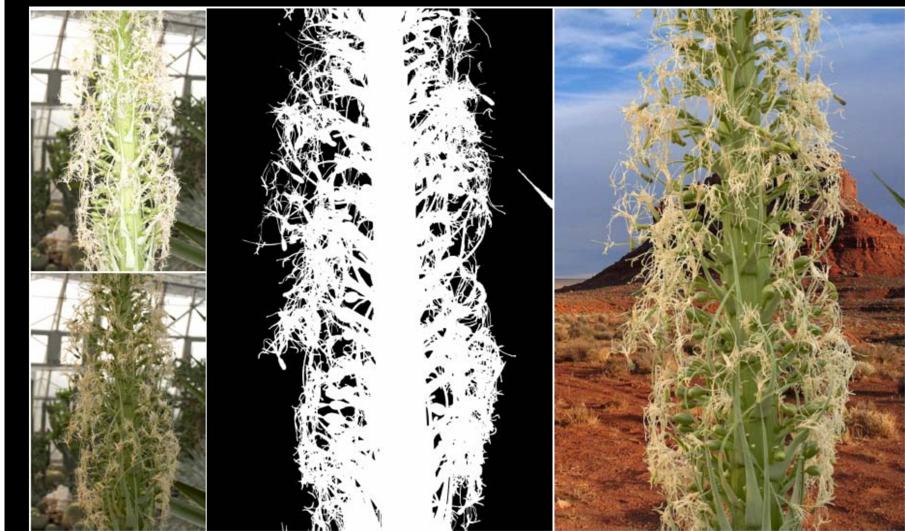
no flash

Comparison

foreground flash matting

ioint Bayesian flash matting

Comparison



Flash matting

Shadow matting
and composting

source scene

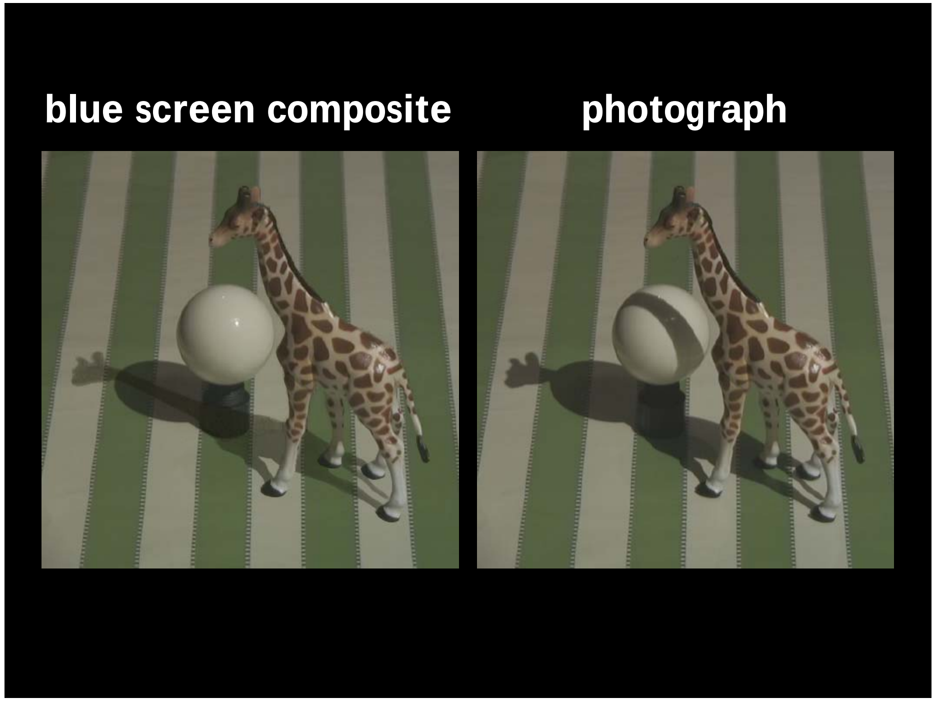
target background

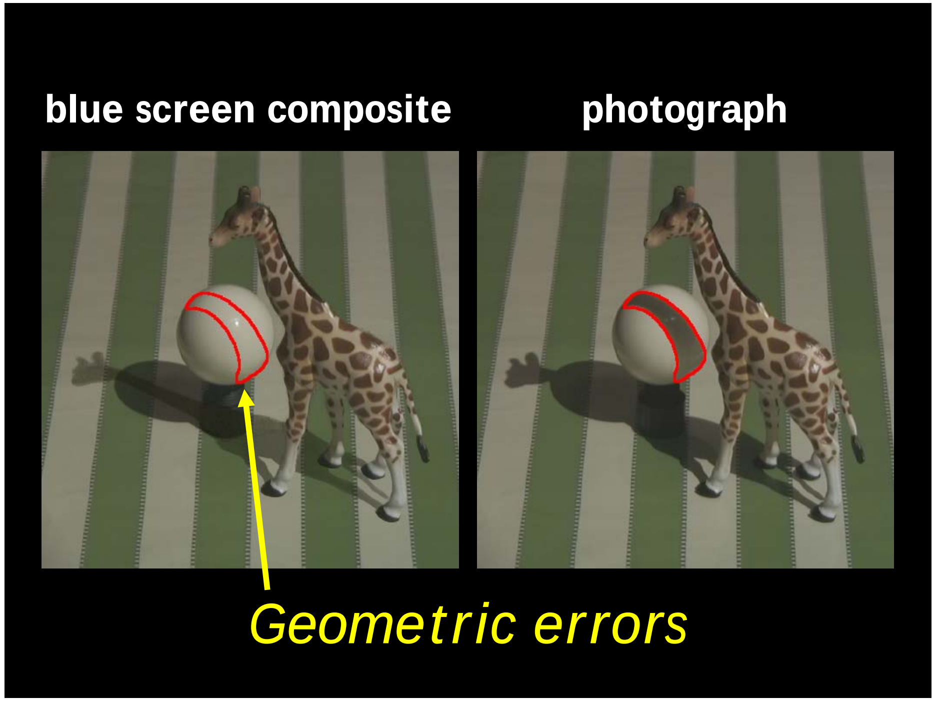
blue screen image

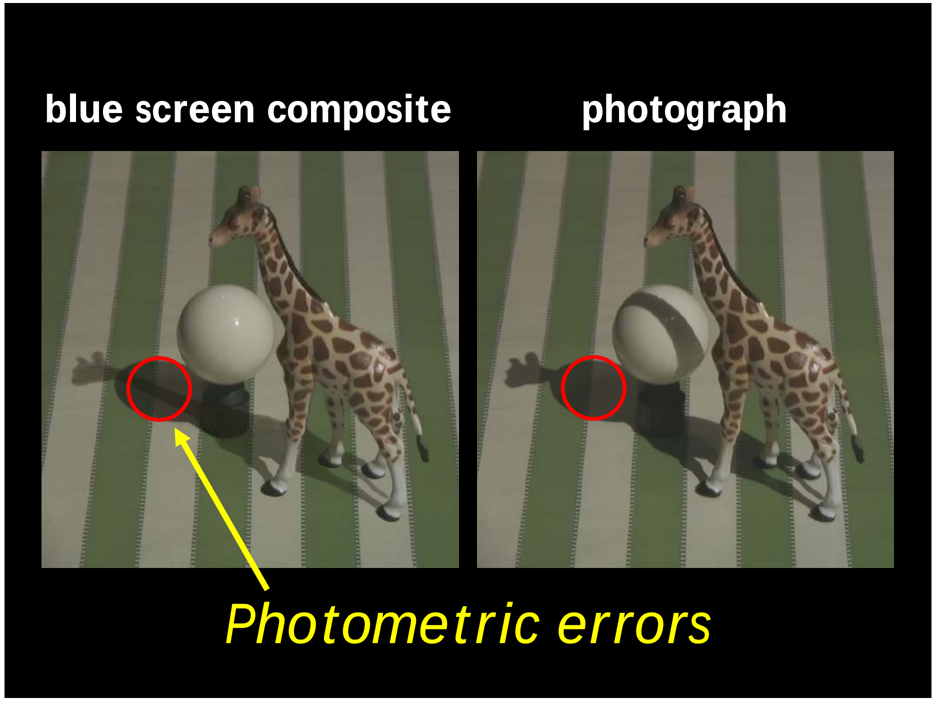
target background

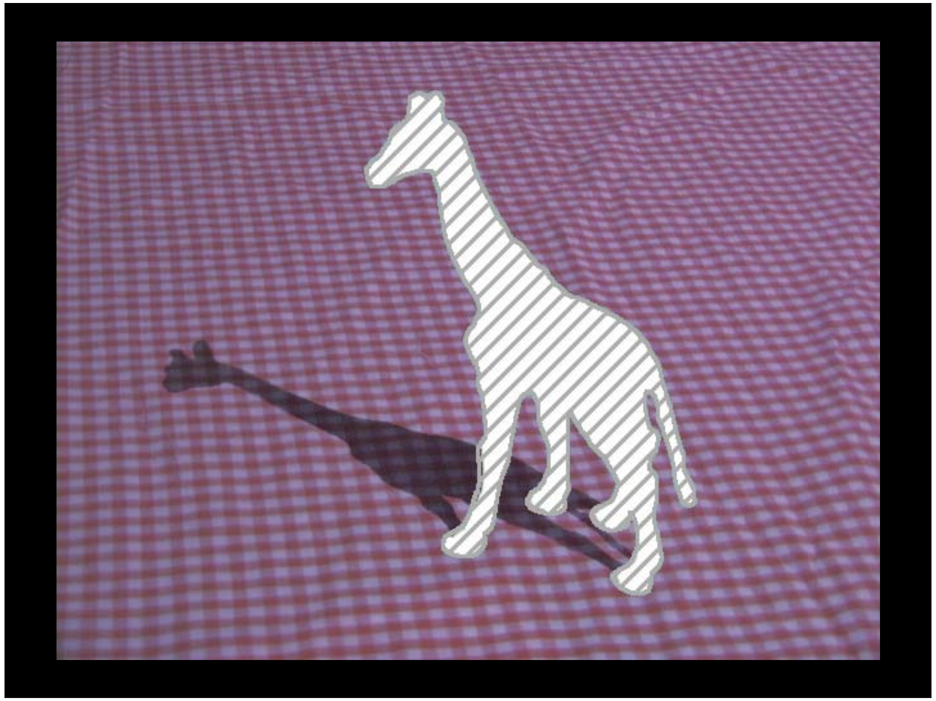
blue screen composite

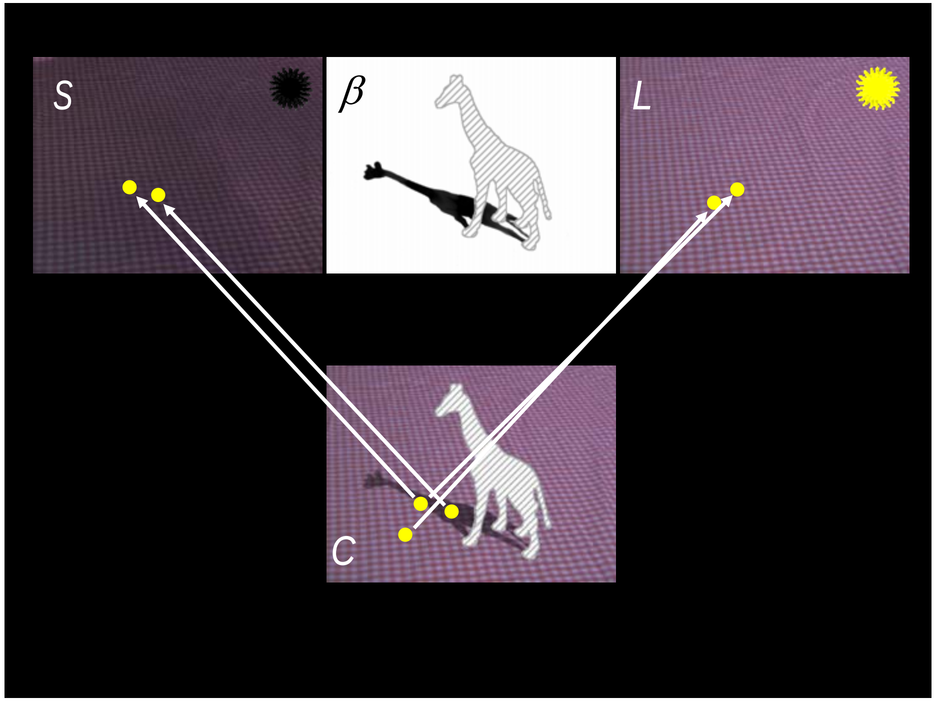
target background

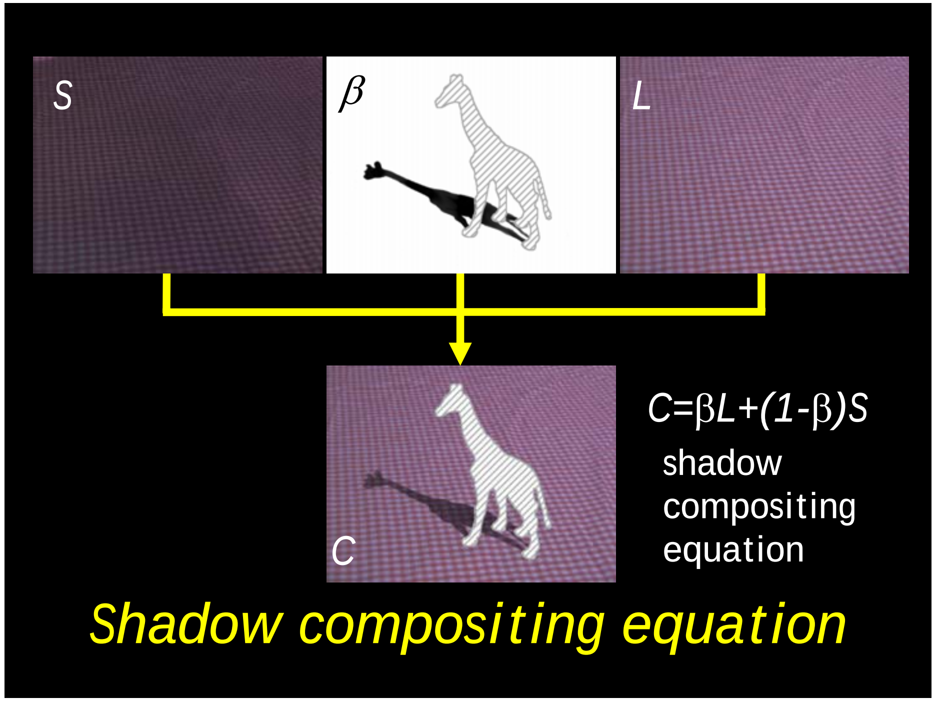

blue screen composite
photograph

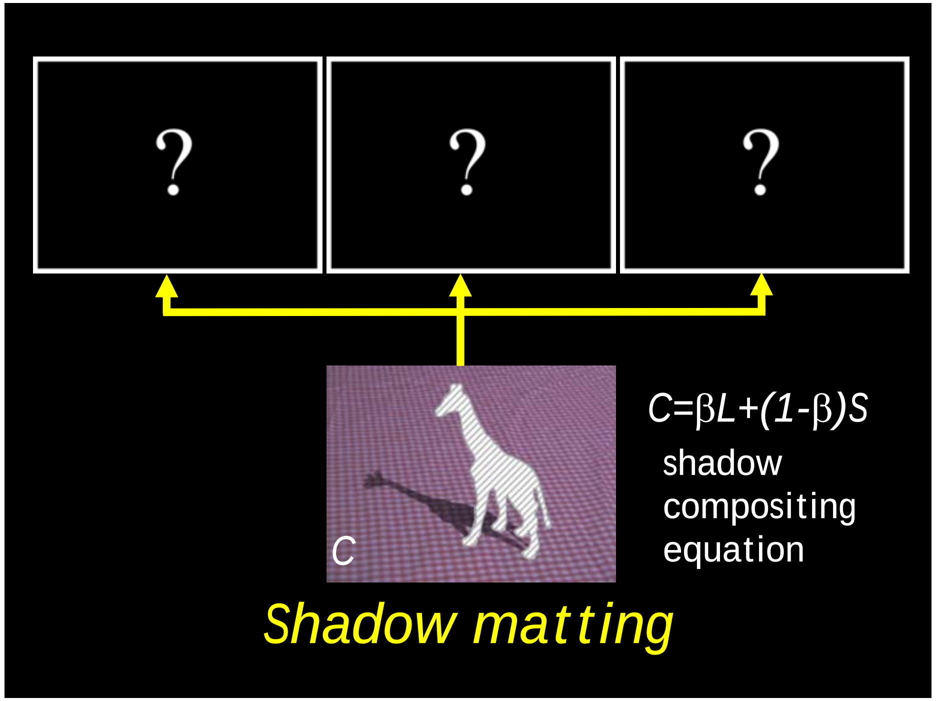

blue screen composite
photograph
Geometric errors

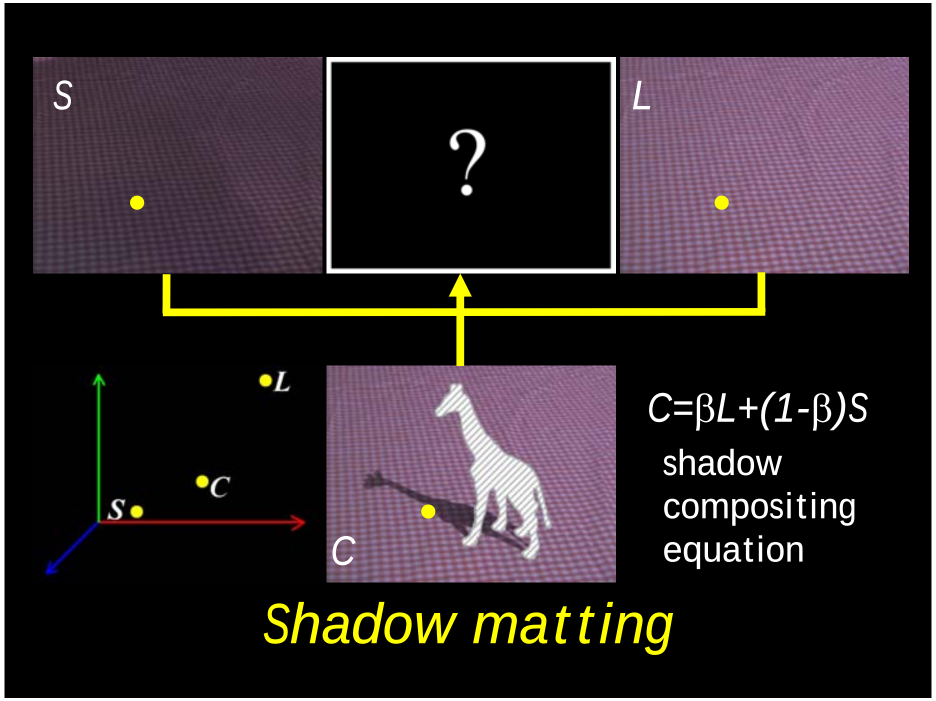

blue screen composite
photograph
Photometric errors

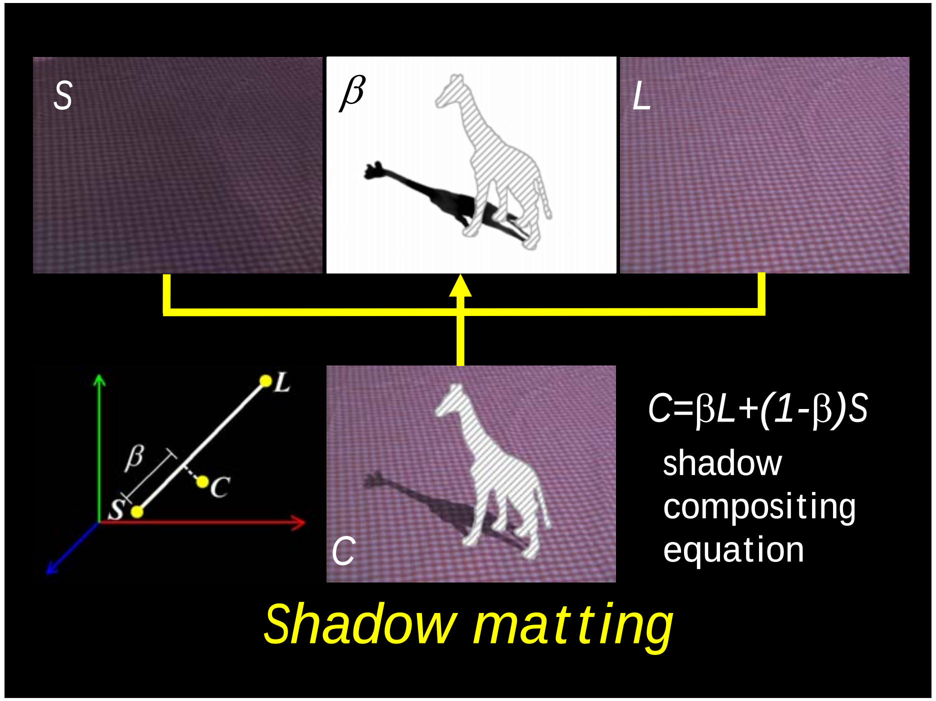


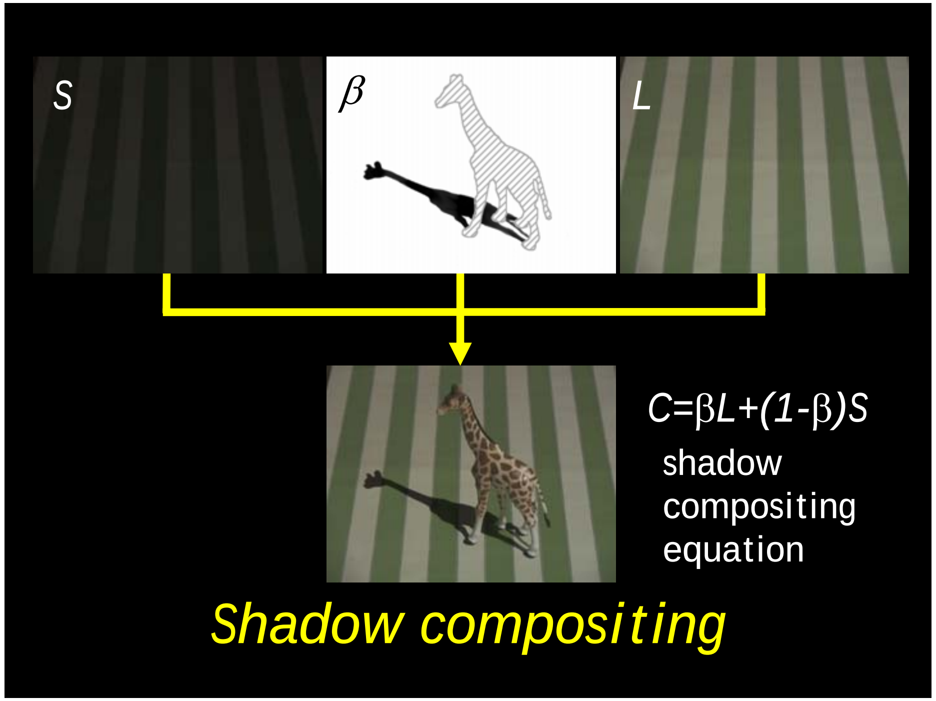

S
β
L
C

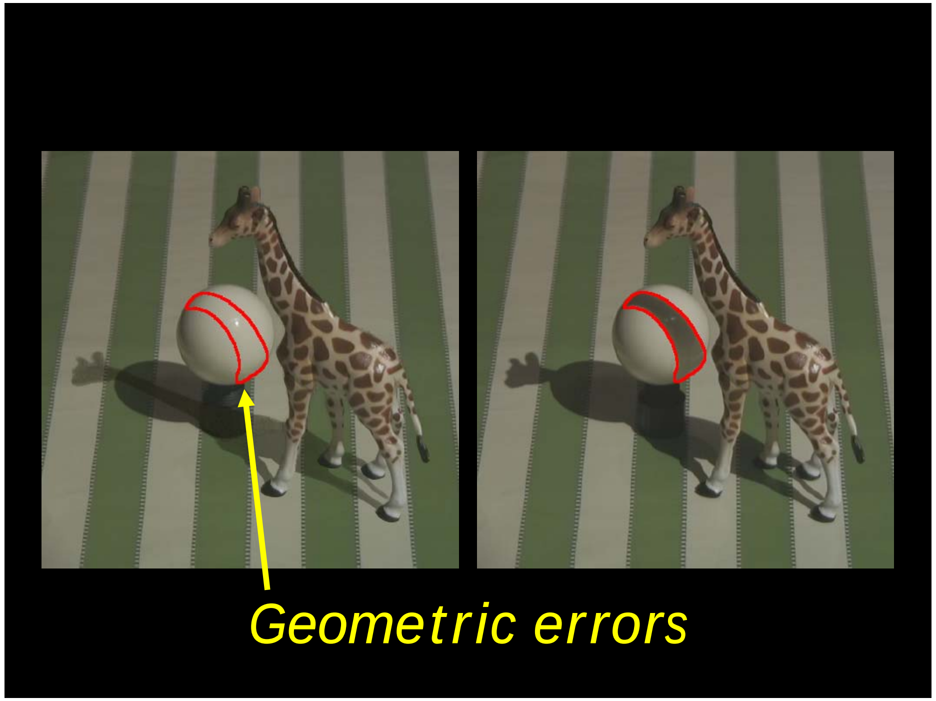

S
β
L
C
C=βL+(1-β)S
shadow compositing equation
Shadow compositing equation

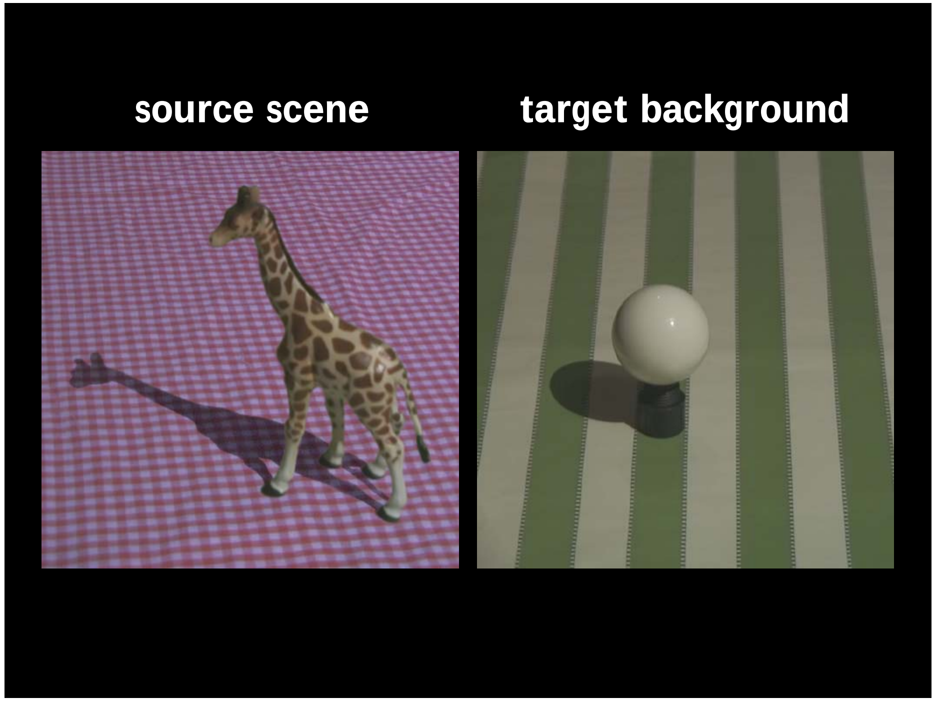

?
?
?
C
C=βL+(1-β)S
shadow compositing equation
Shadow matting

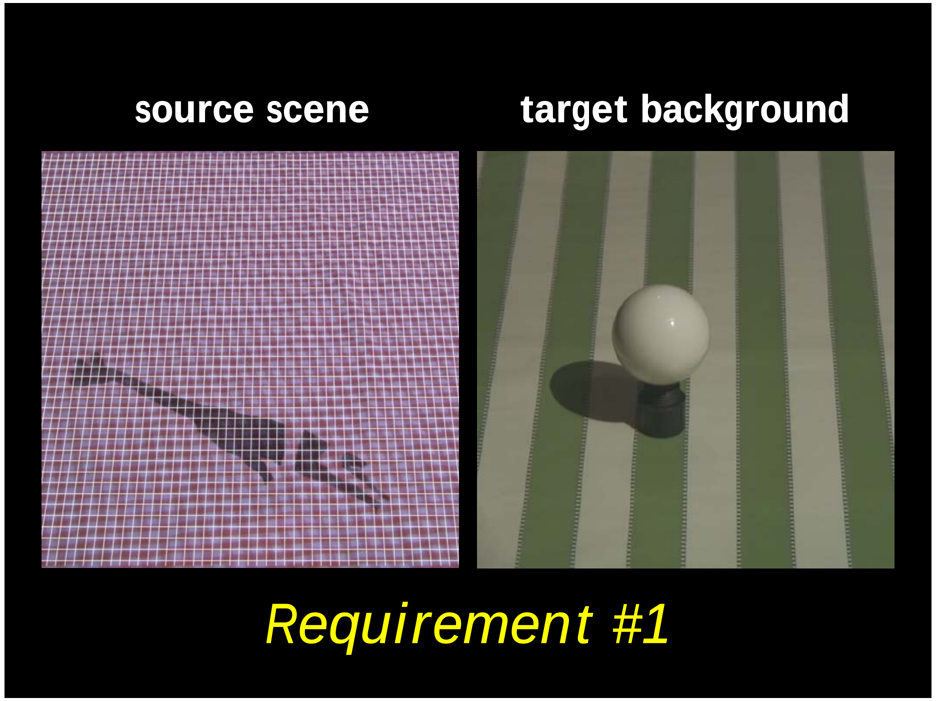

S
?
L
L
C
S
C
C=βL+(1-β)S
shadow
compositing
equation
Shadow matting

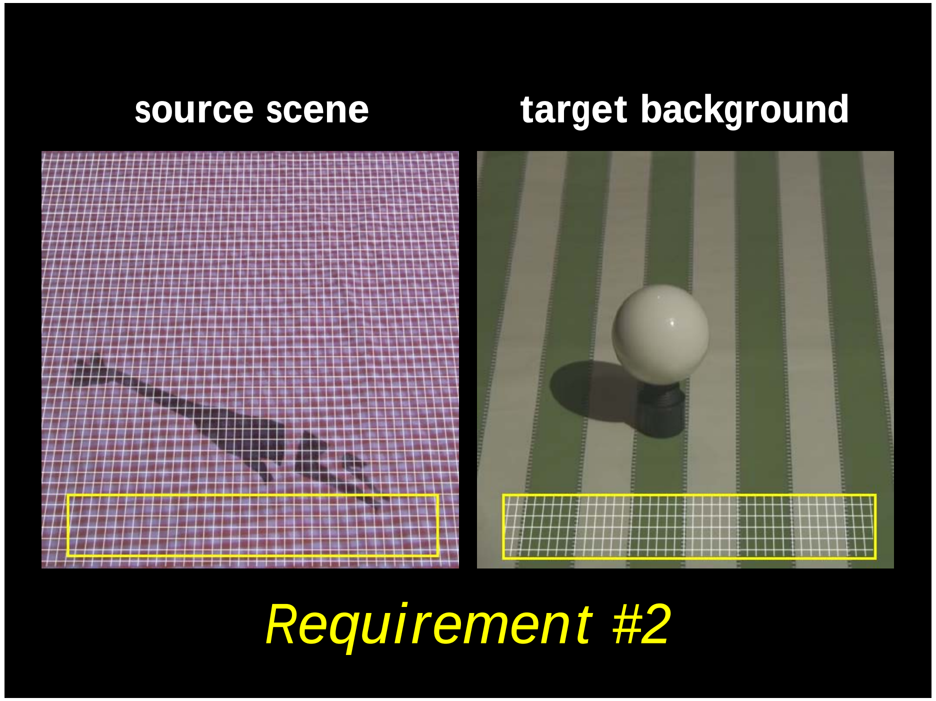

S
β
L
L
β
C
S
C
C=βL+(1-β)S
shadow
compositing
equation
Shadow matting

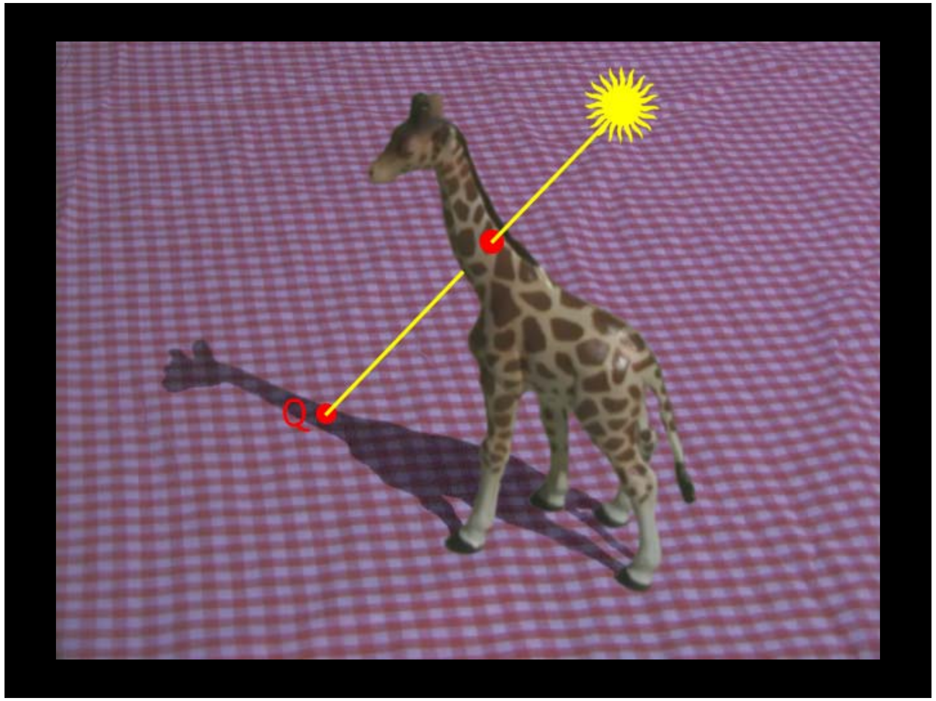

S
β
L
C=βL+(1-β)S
shadow
compositing
equation
Shadow compositing

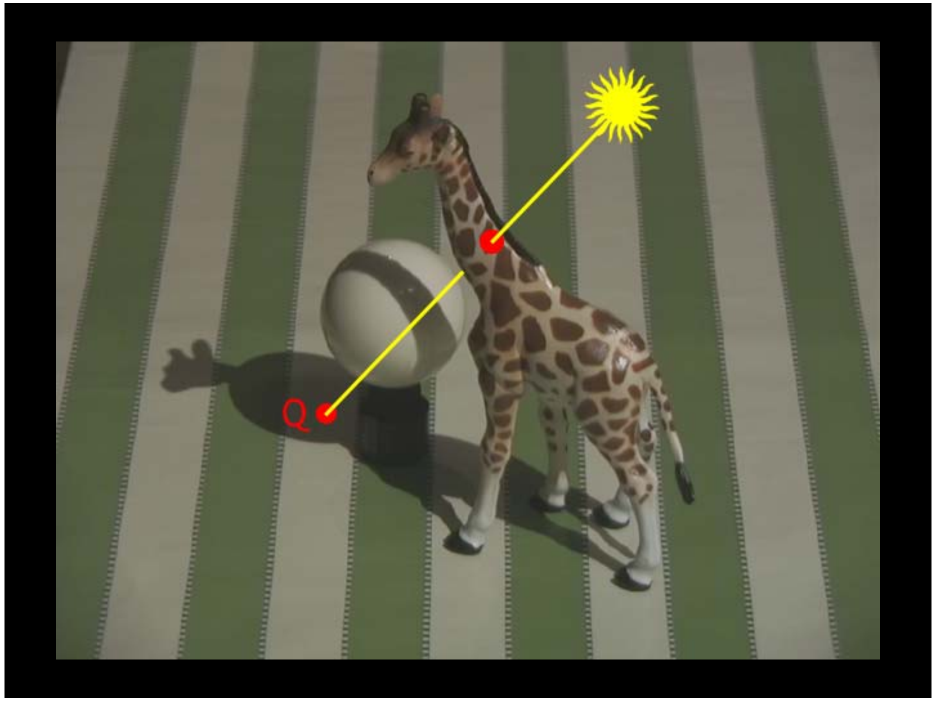

Geometric errors

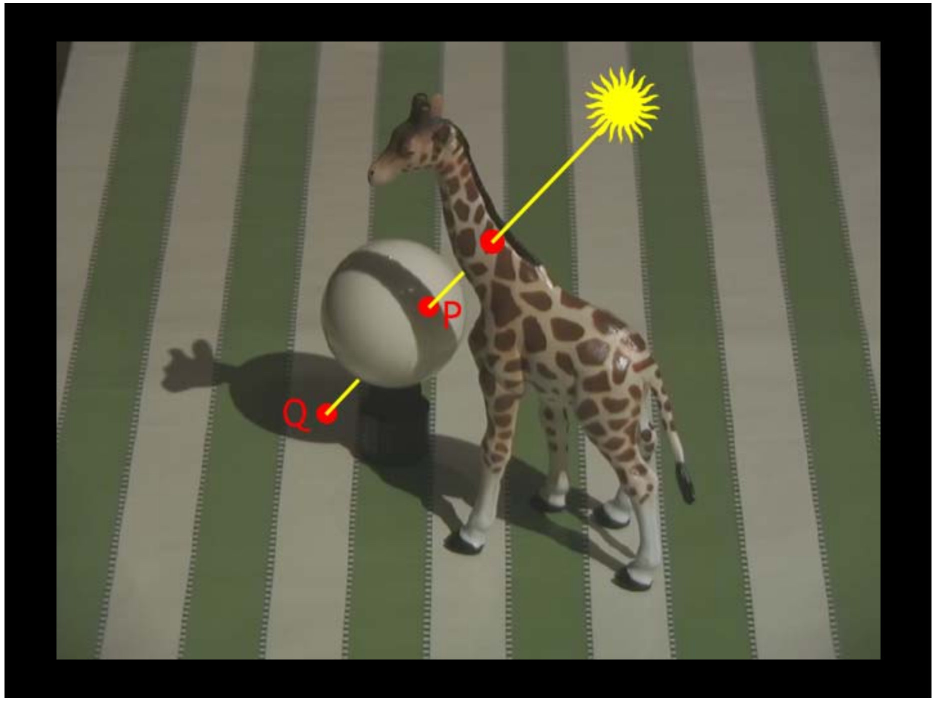

source scene
target background

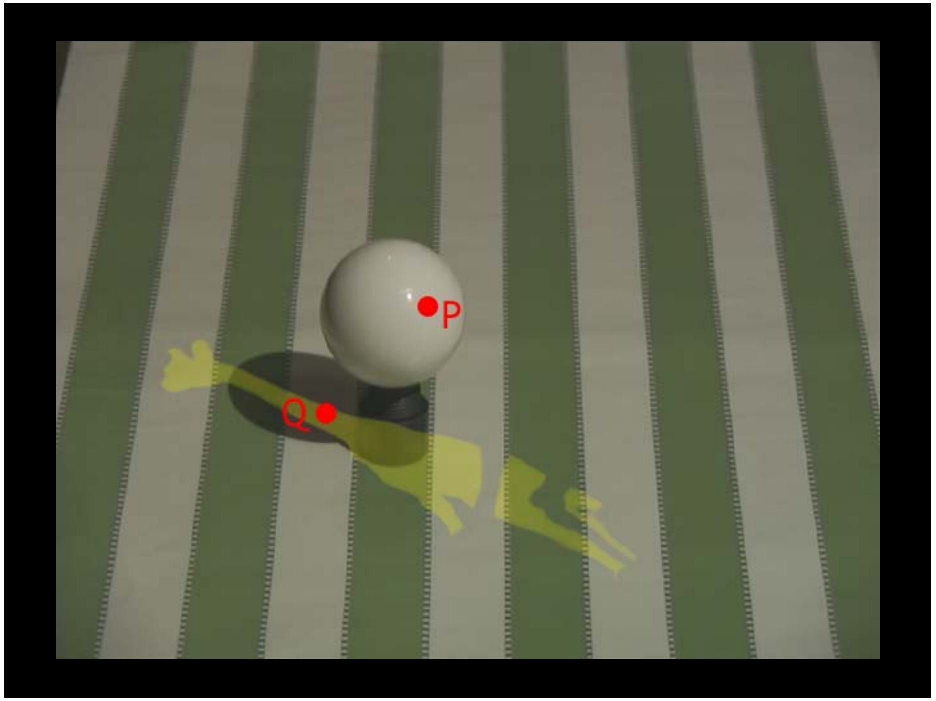
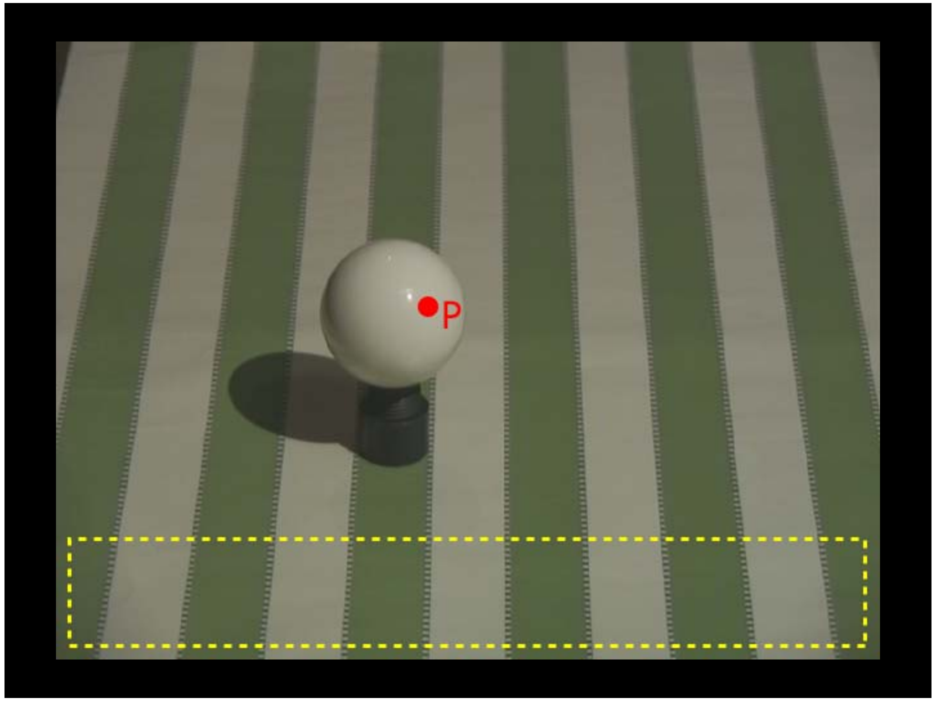
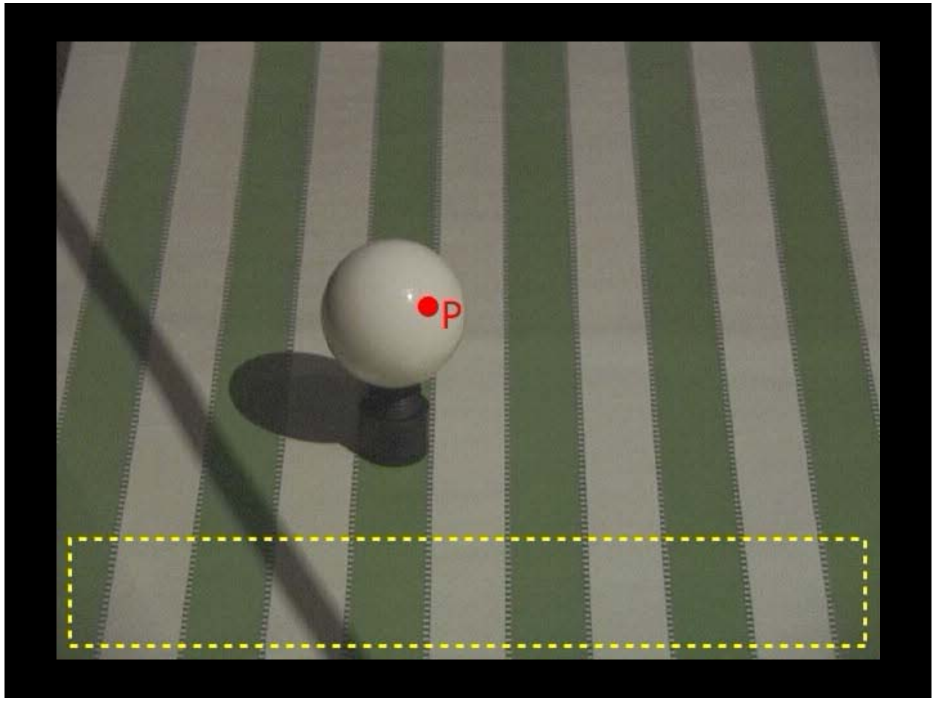
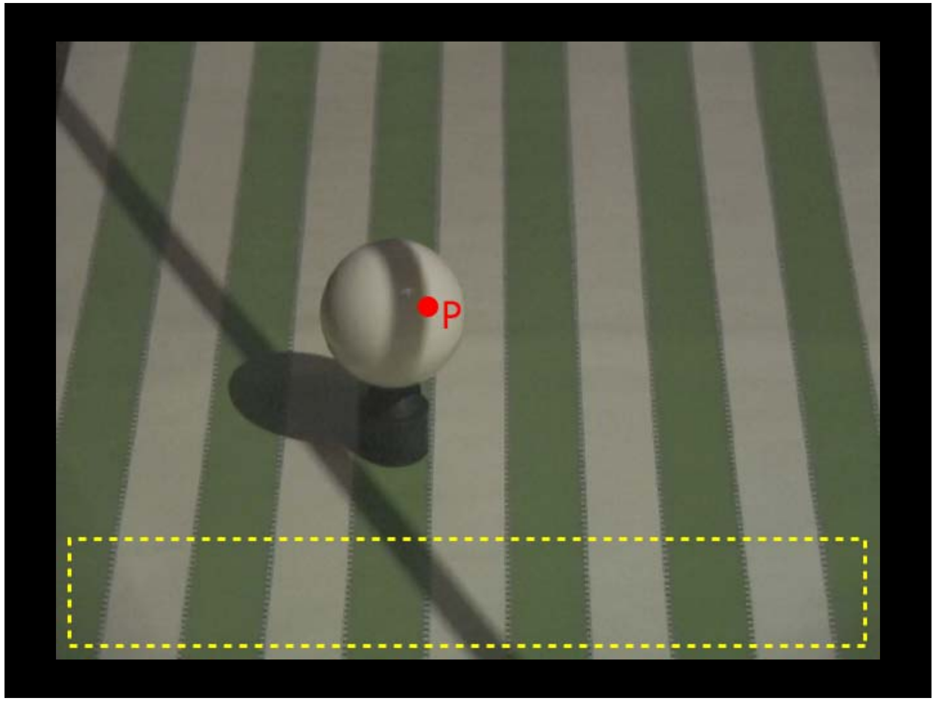

source scene
target background
Requirement #1

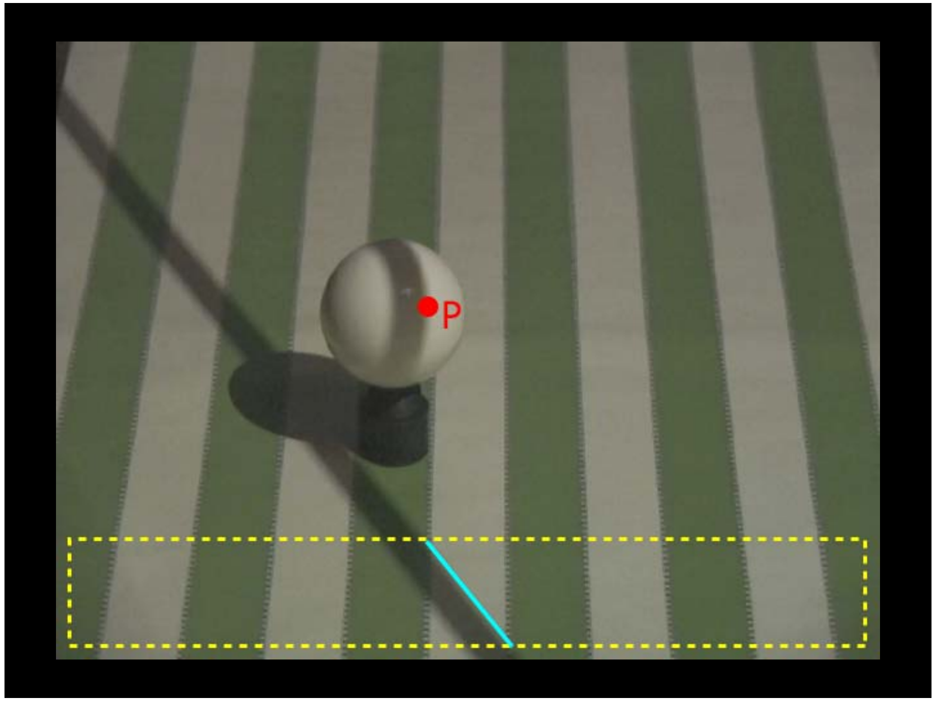

source scene
target background
Requirement #2

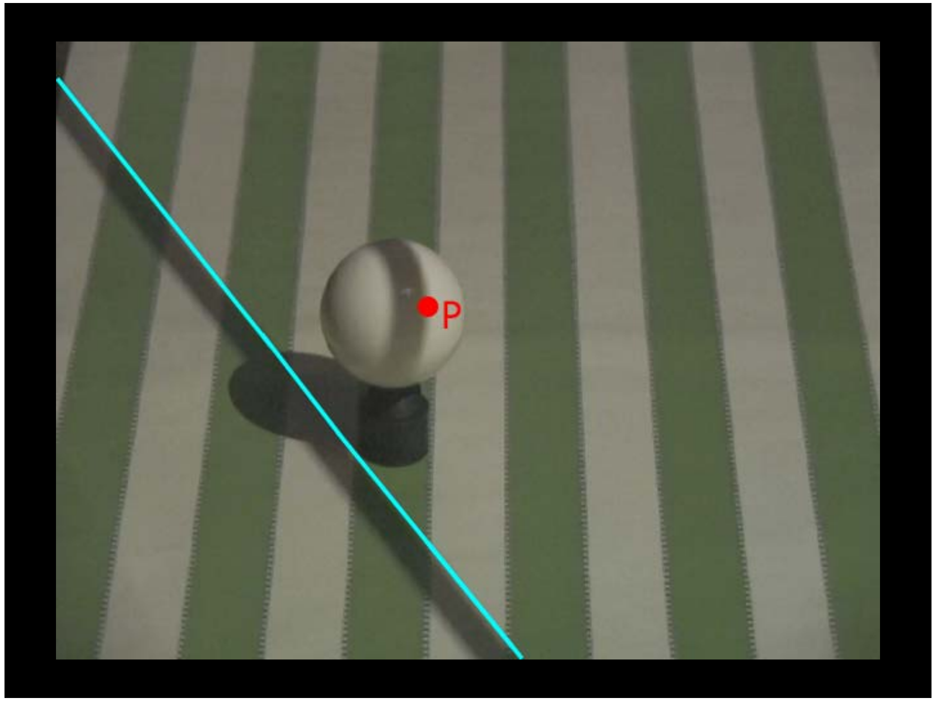

Q

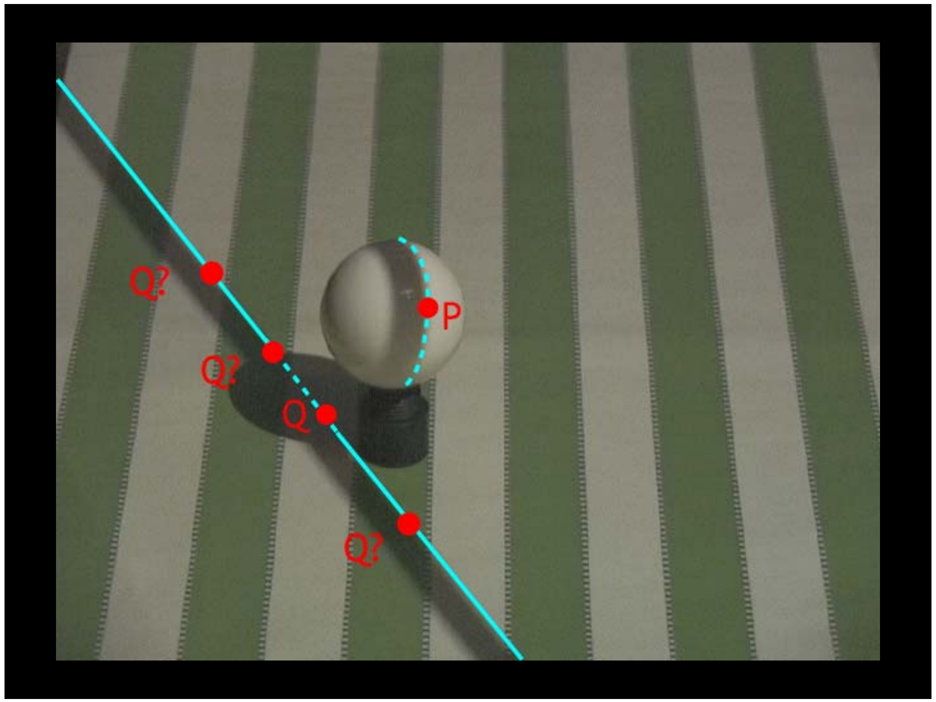

Q

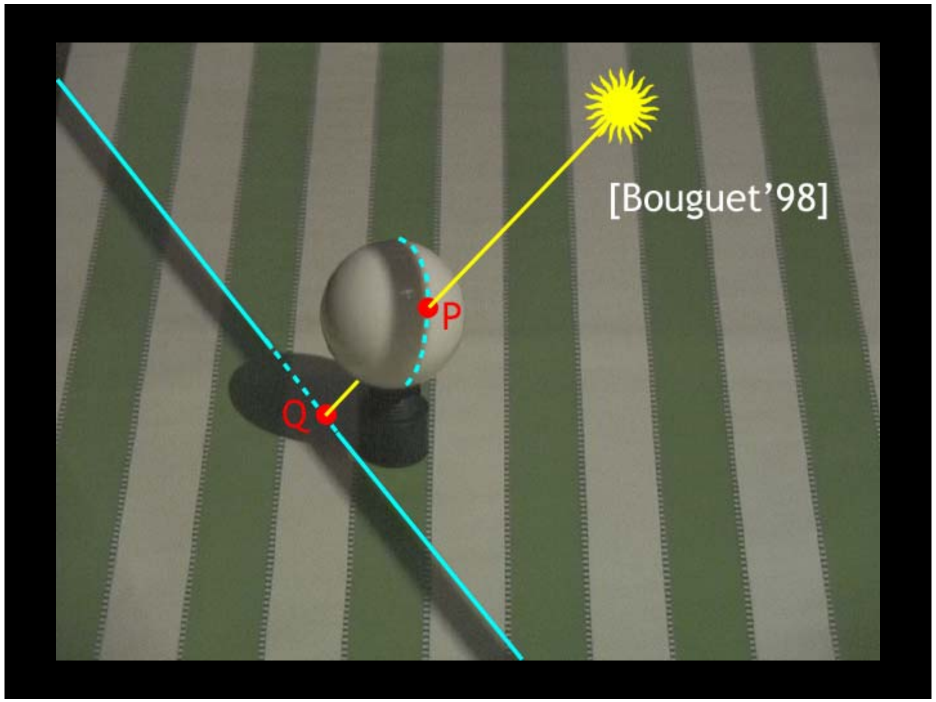

P
Q

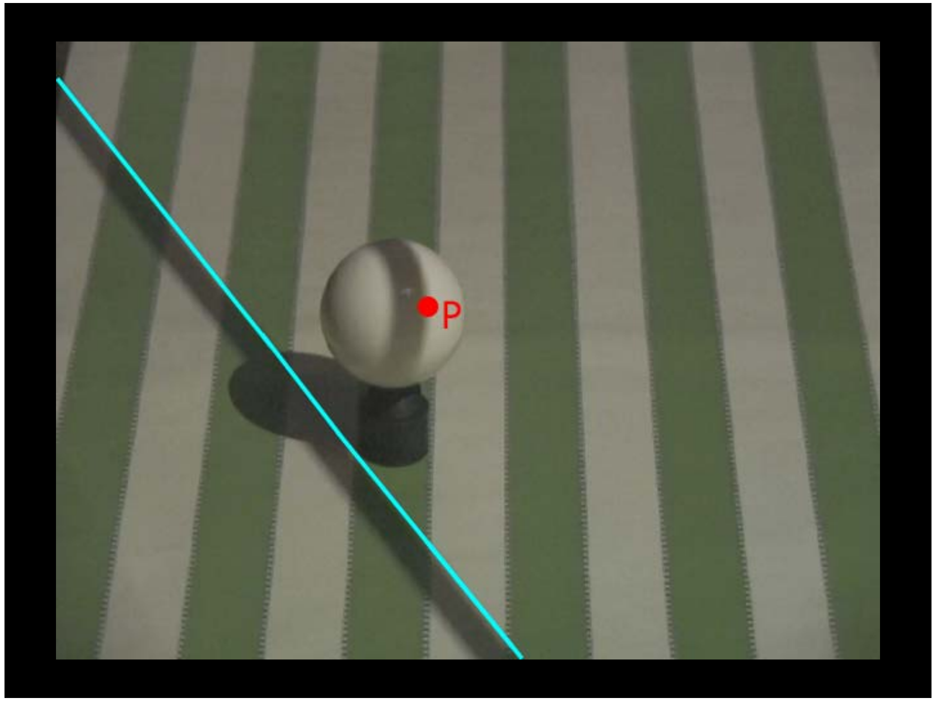

P
Q

P

P

P

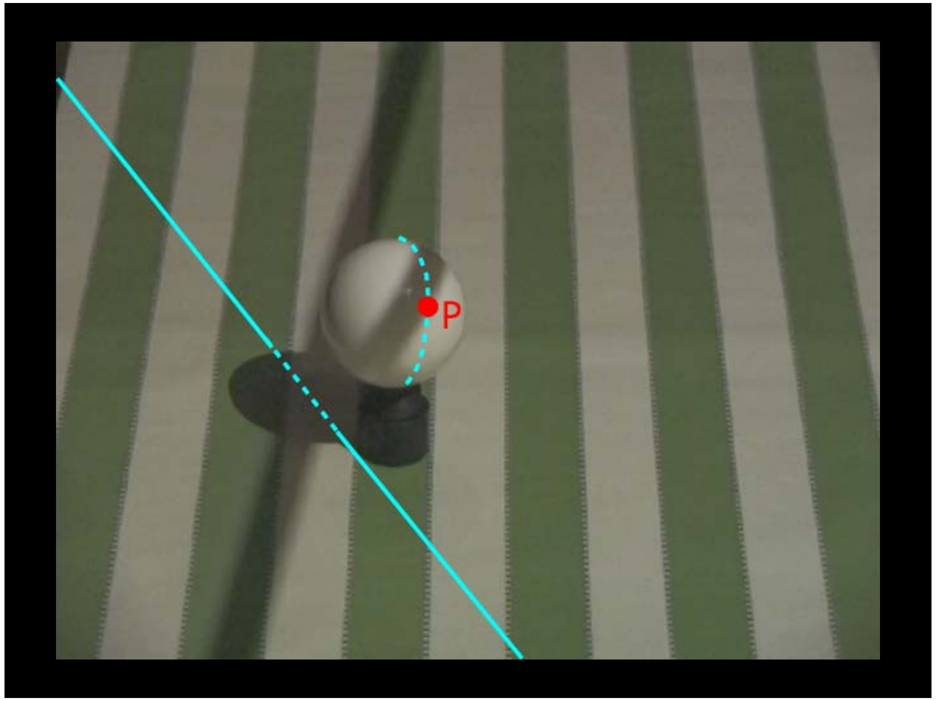

P

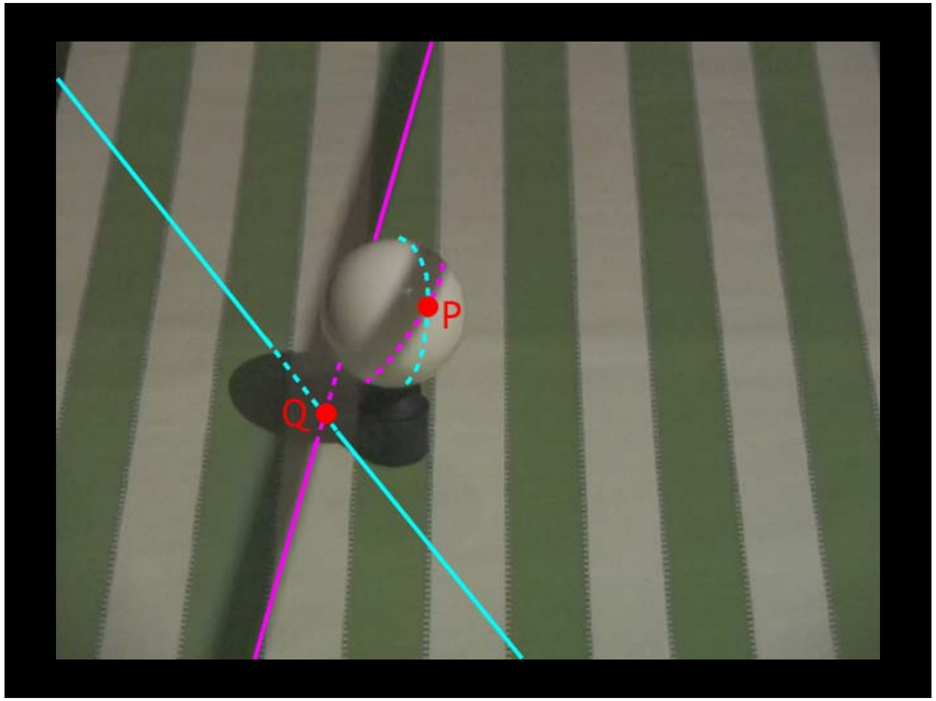

P

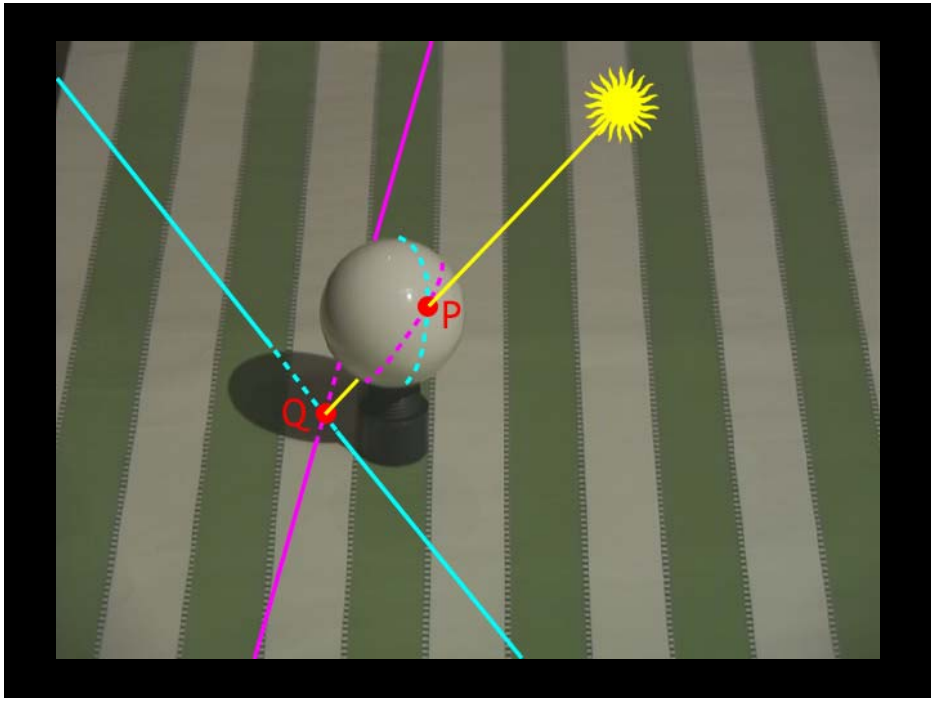

Q?
Q?
Q
Q?
P

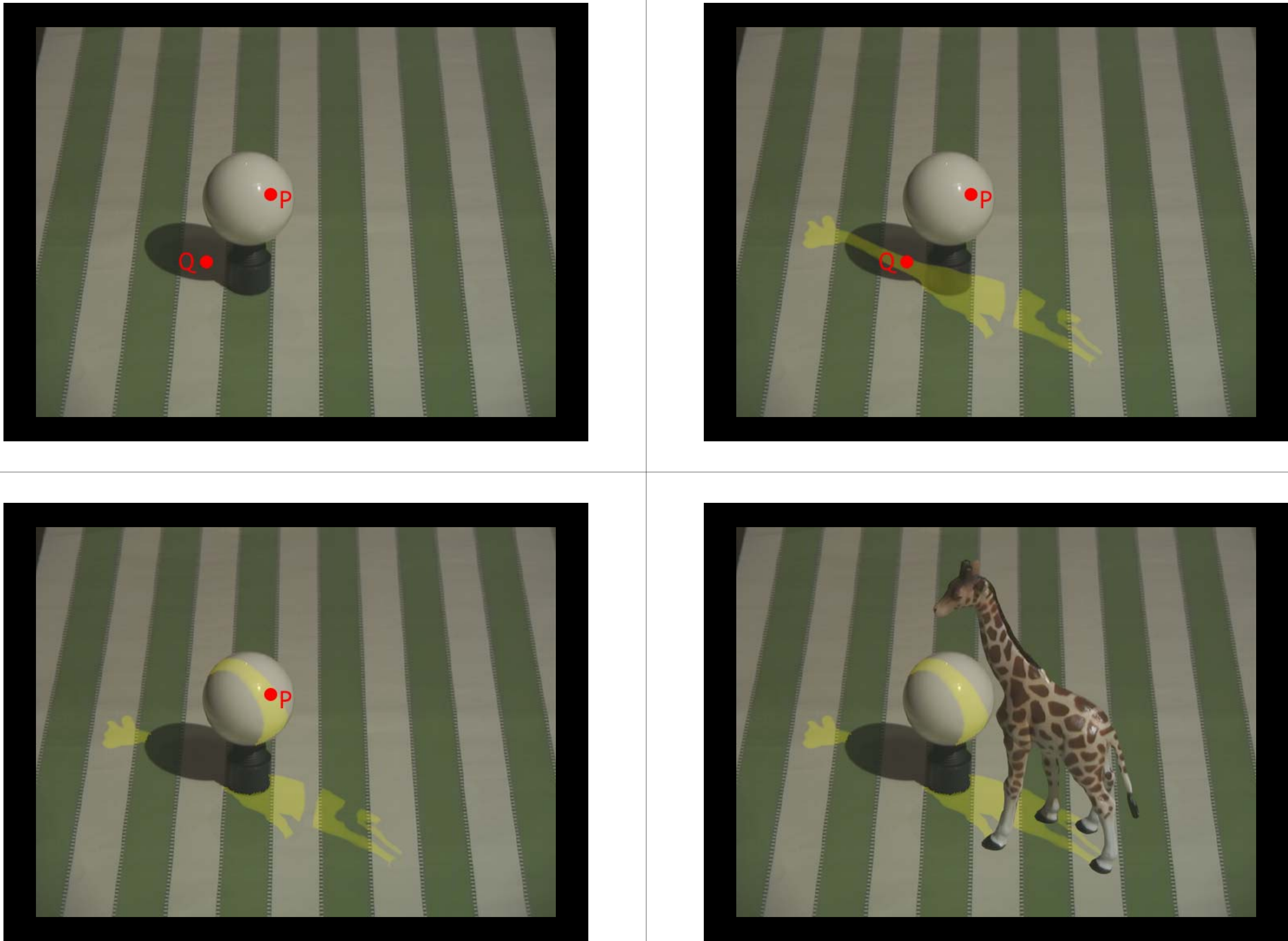

[Bouguet'98]
P
Q

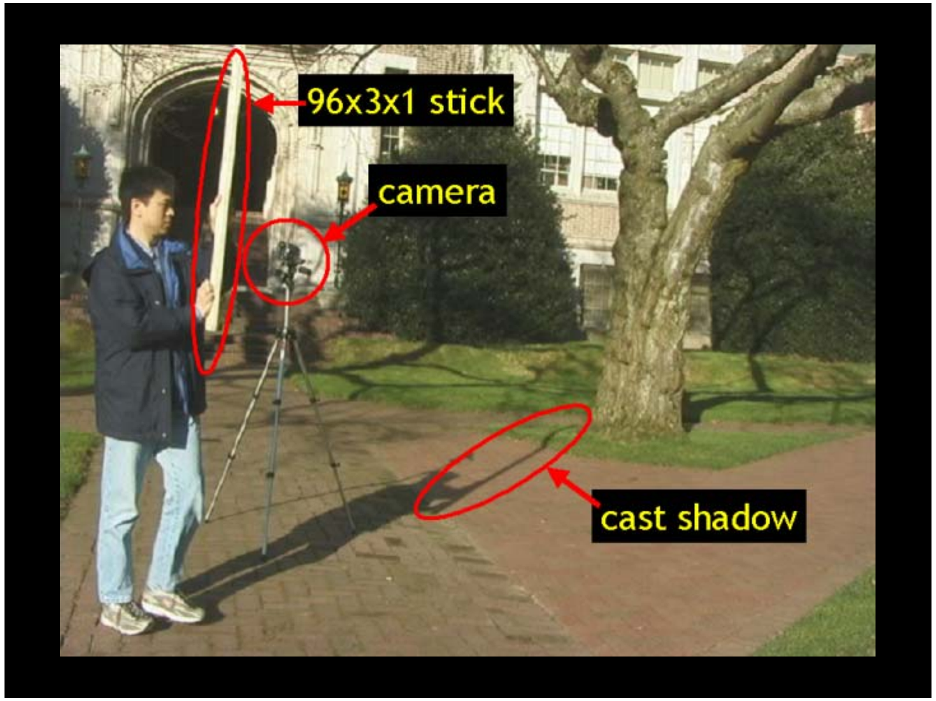

P

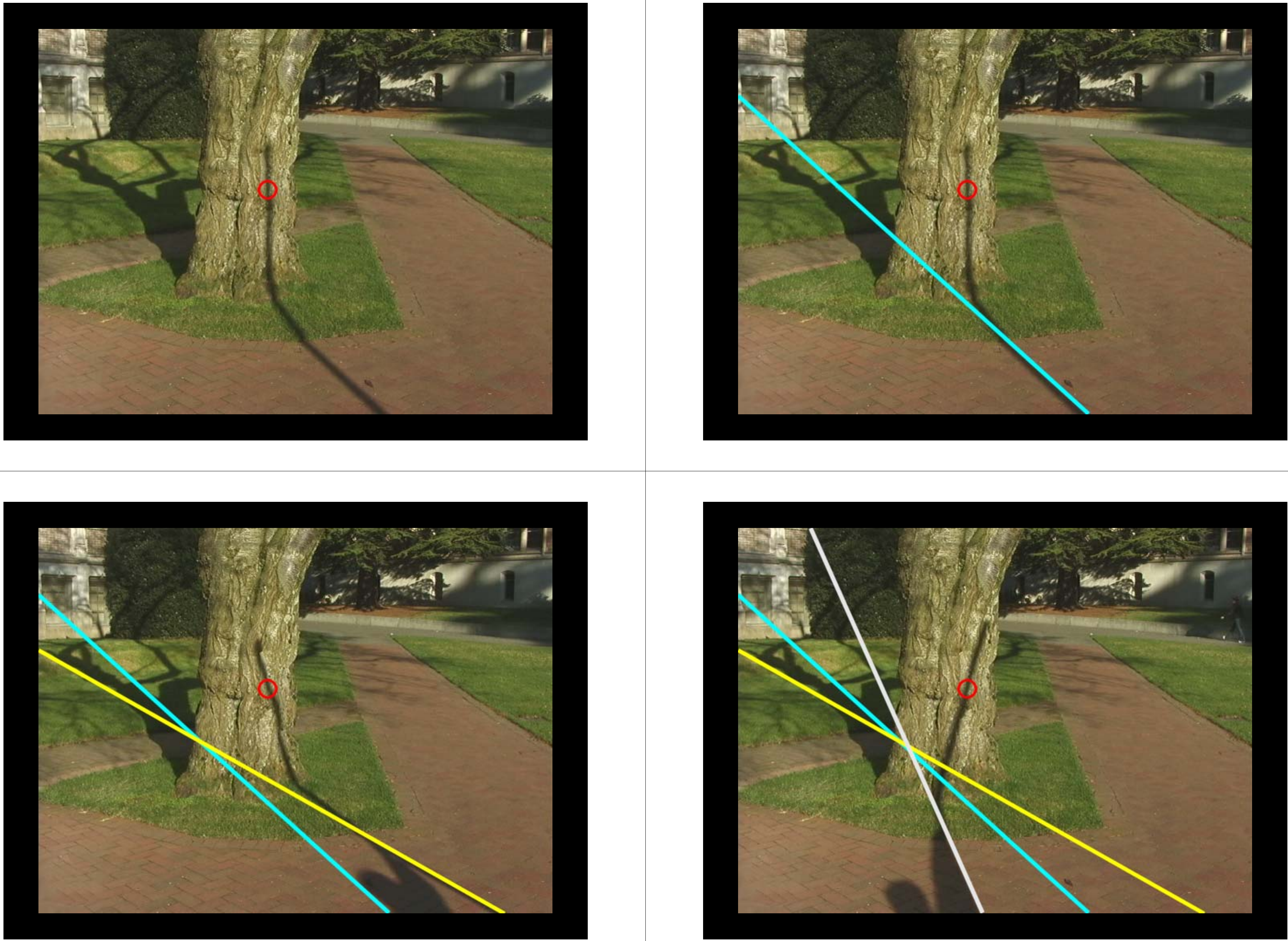

P

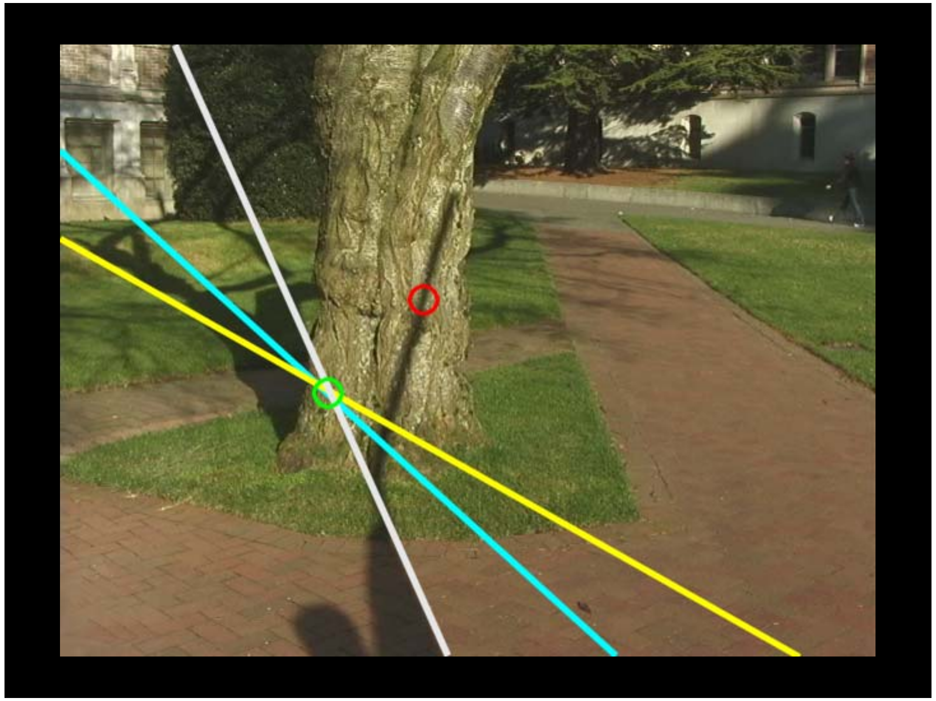
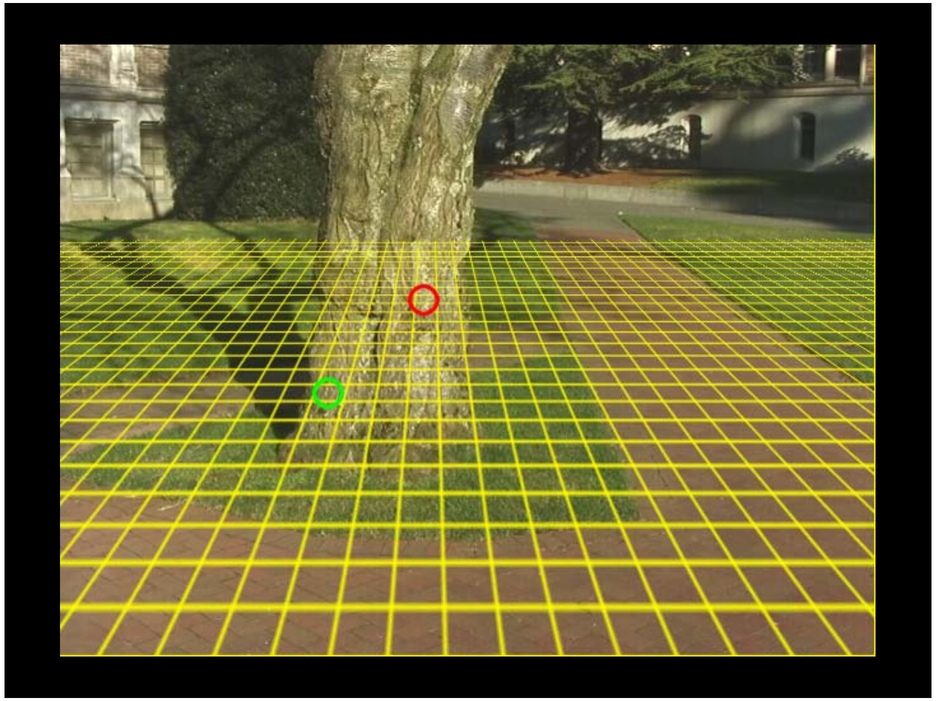
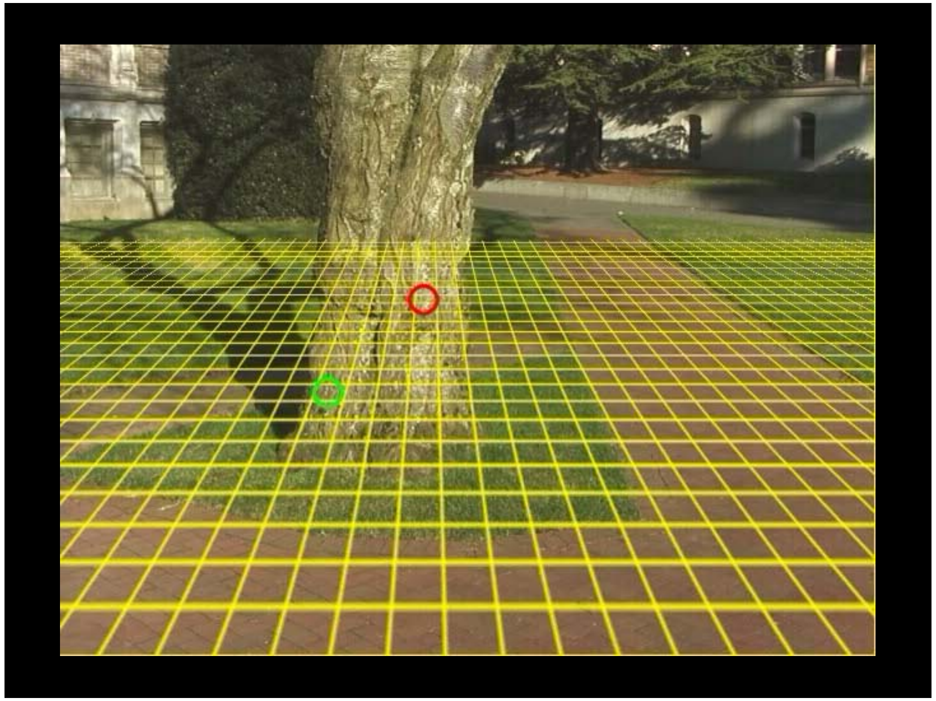
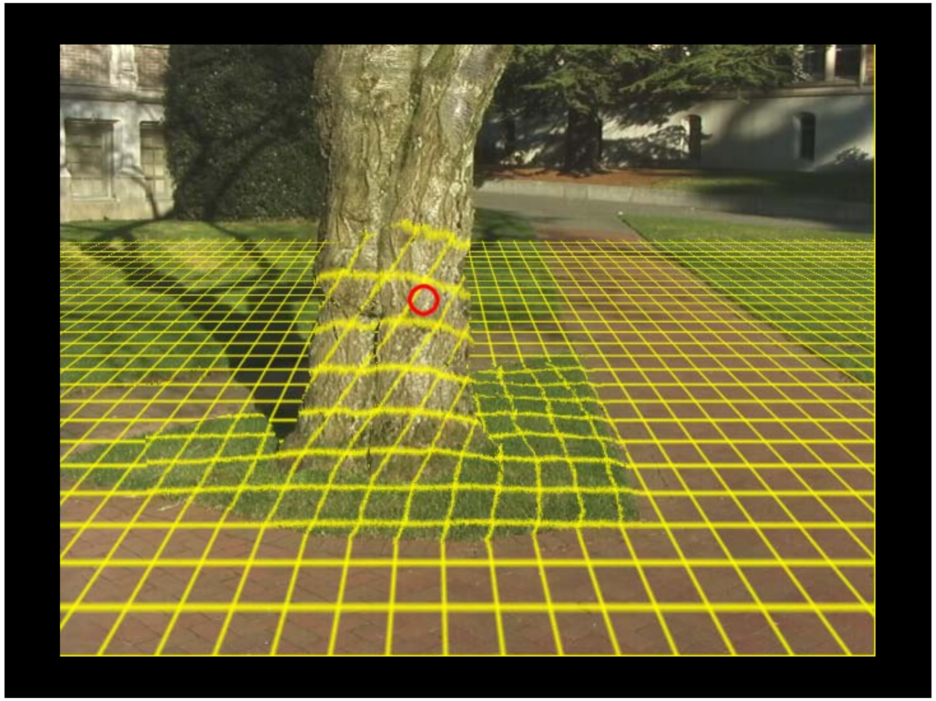

P
Q

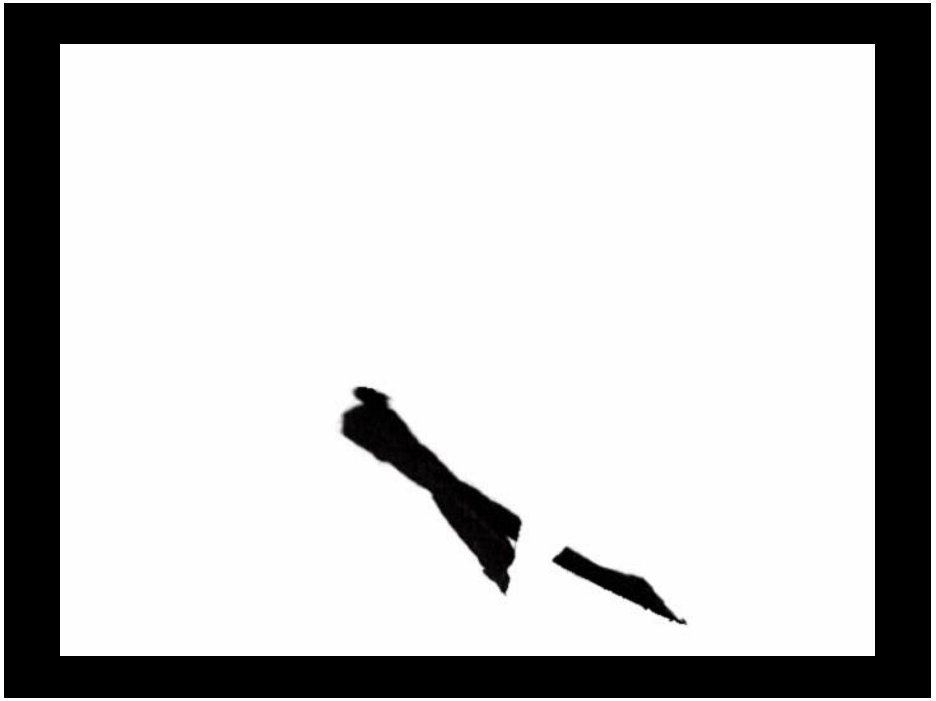

P
Q

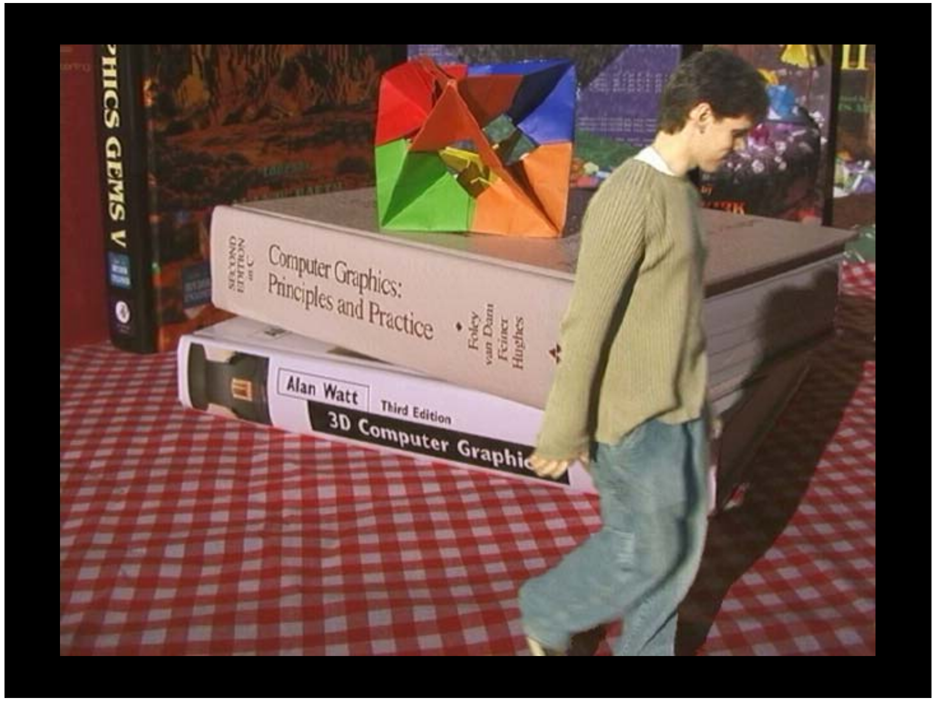

P
Q
P
Q
P

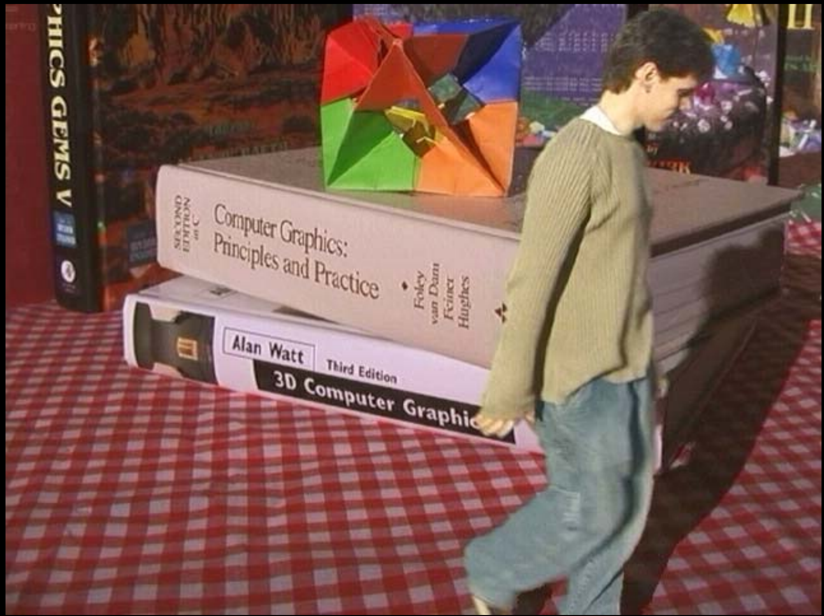

96x3x1 stick
camera
cast shadow






PHICS GEMS V
Computer Graphics:
Principles and Practice
Foley
van Dam
Feiner
Hughes
Alan Watt
Third Edition
3D Computer Graphic

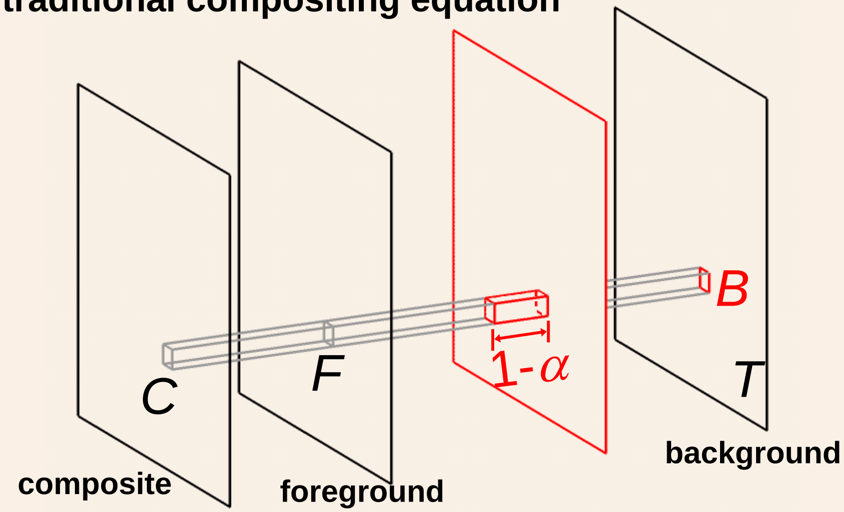


Environment matting

blue screen matting

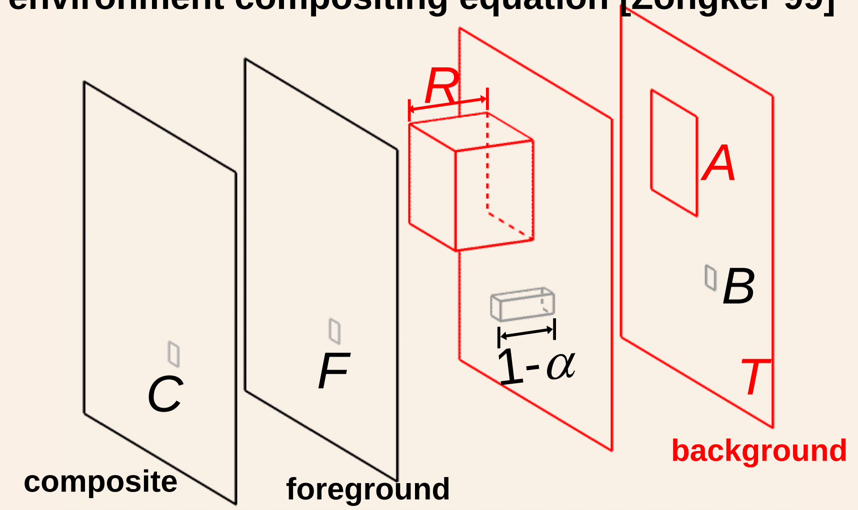
photograph

traditional compositing equation



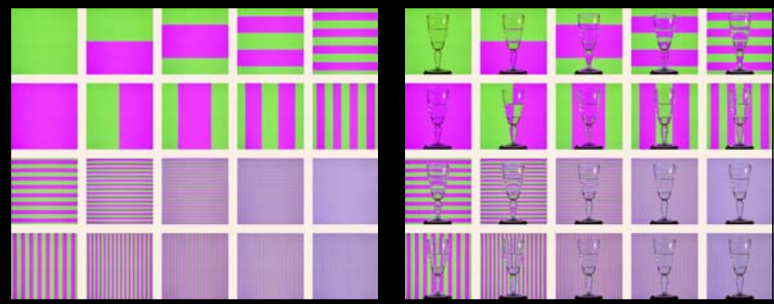
$$C = F + (1-\alpha)B$$

environment compositing equation [Zongker'99]



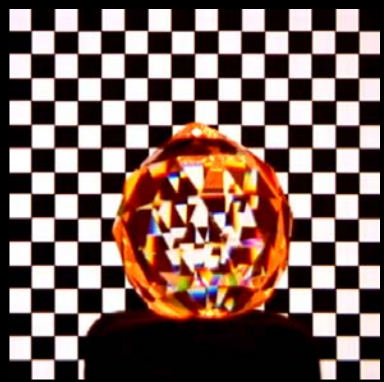
$$C = F + (1-\alpha)B + R\mathcal{M}(T, A)$$

O(k) images



Environment matting [Zongker'99]

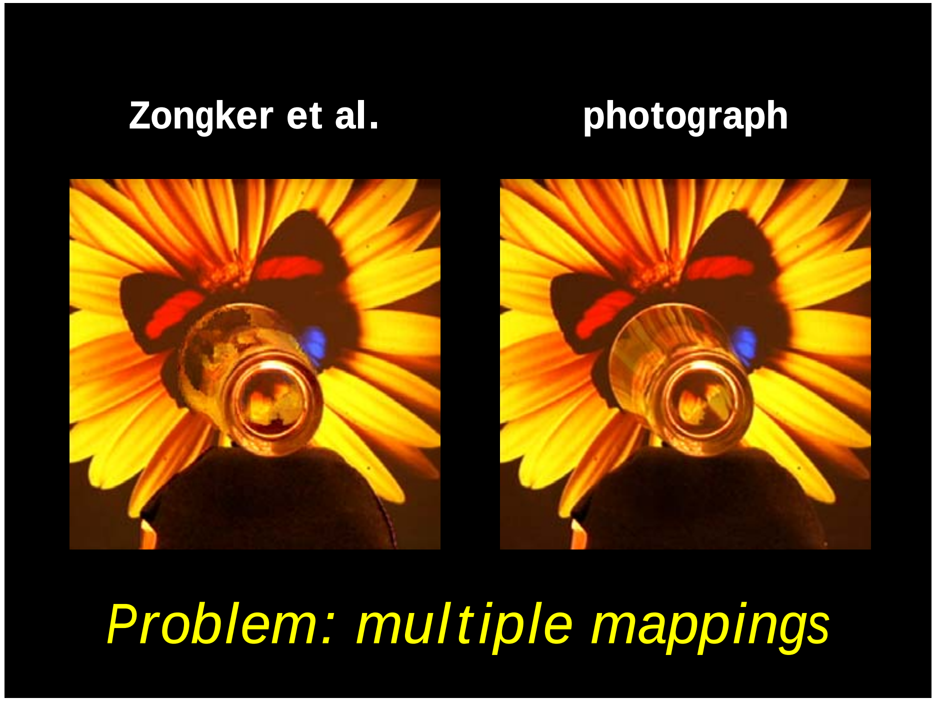
Zongker et al. | **photograph**

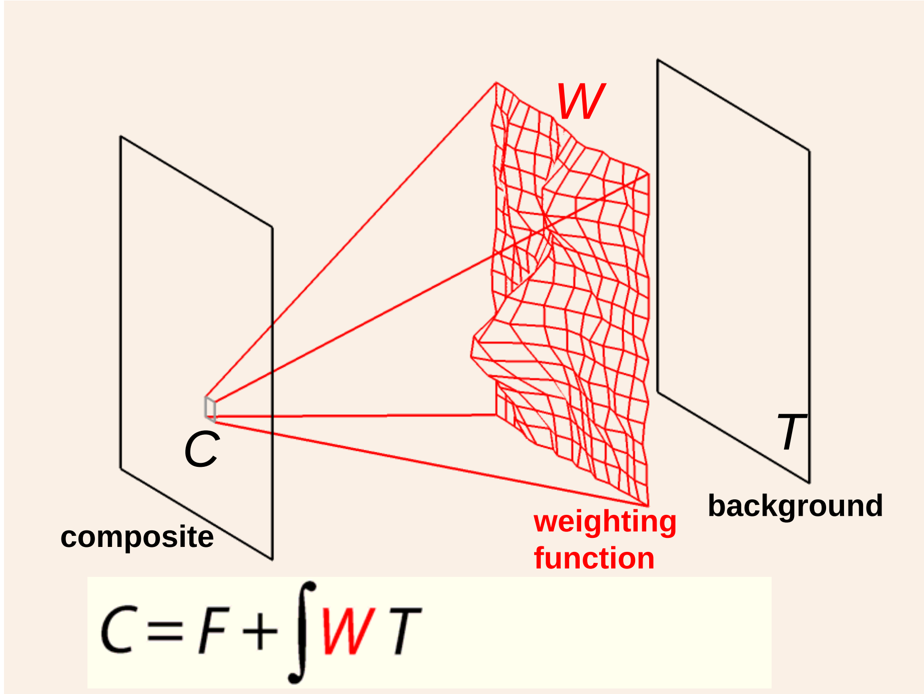


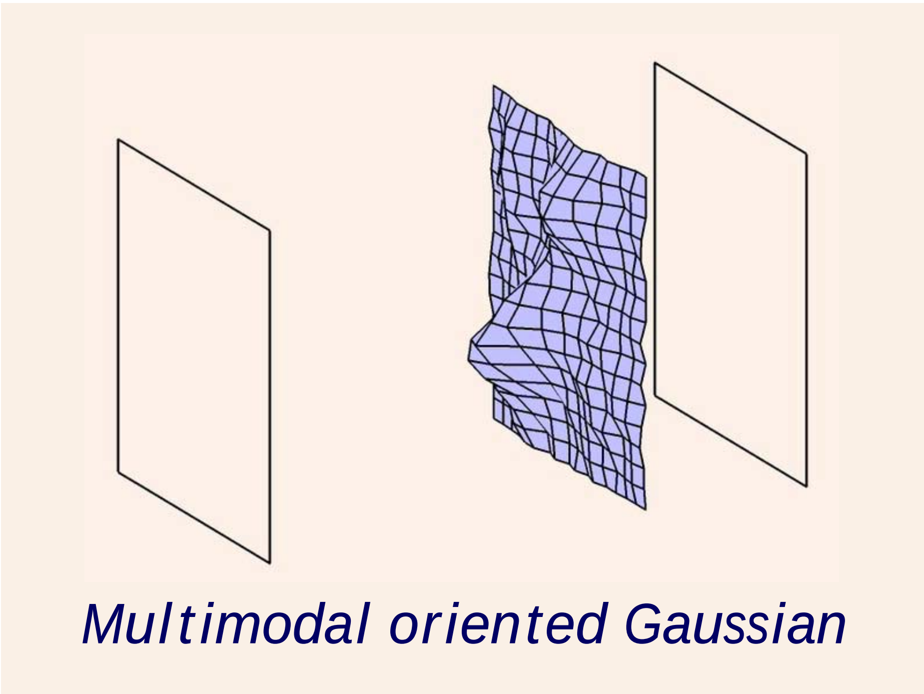
Problem: color dispersion

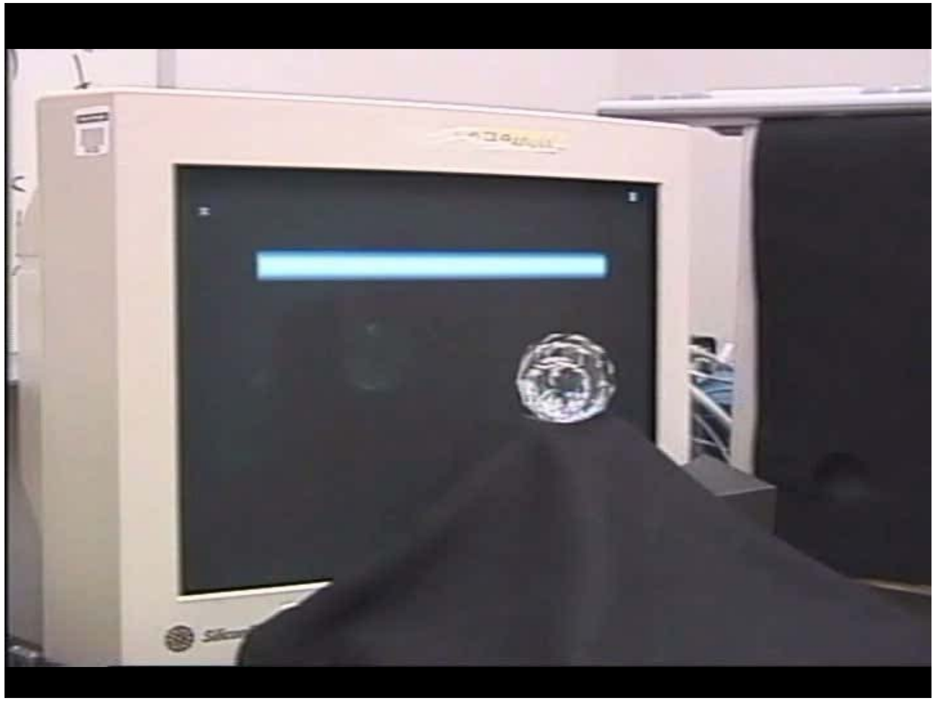
Zongker et al. | **photograph**

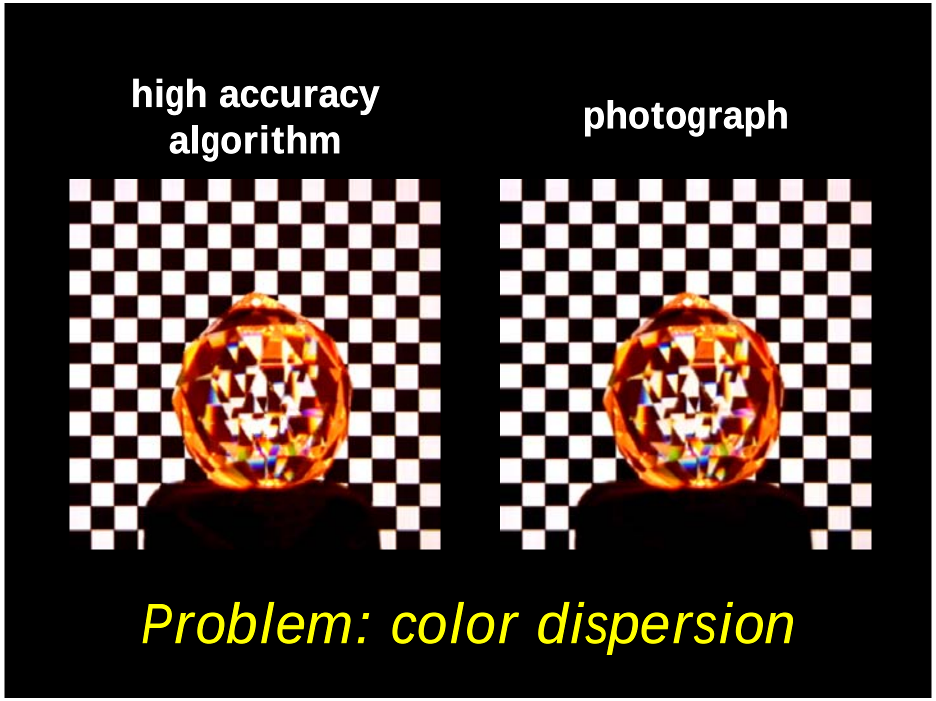
Problem: glossy surface

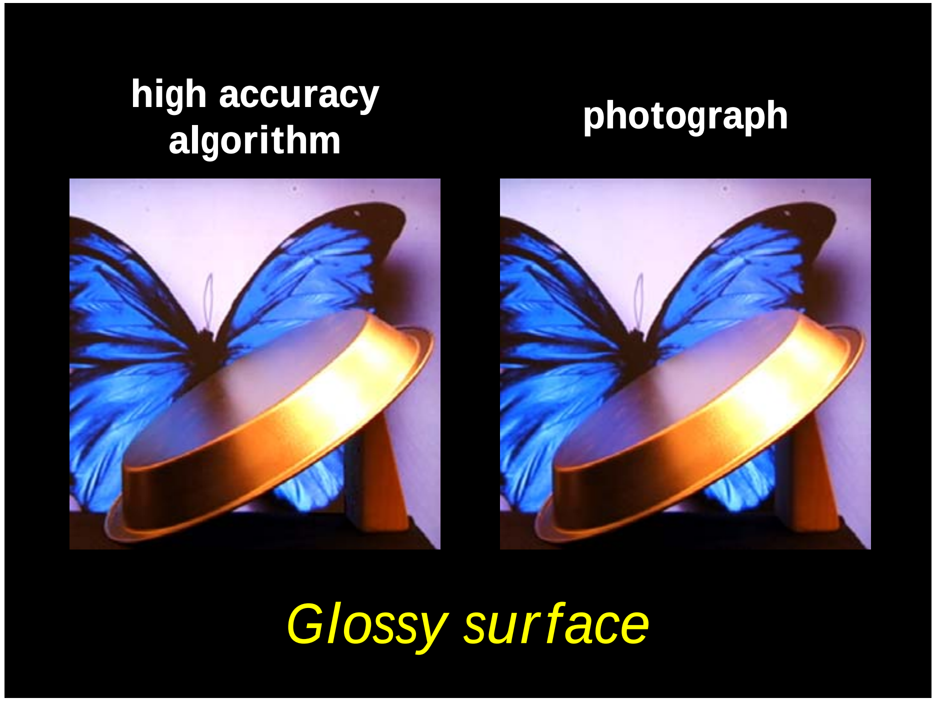

Zongker et al.
photograph
Problem: multiple mappings

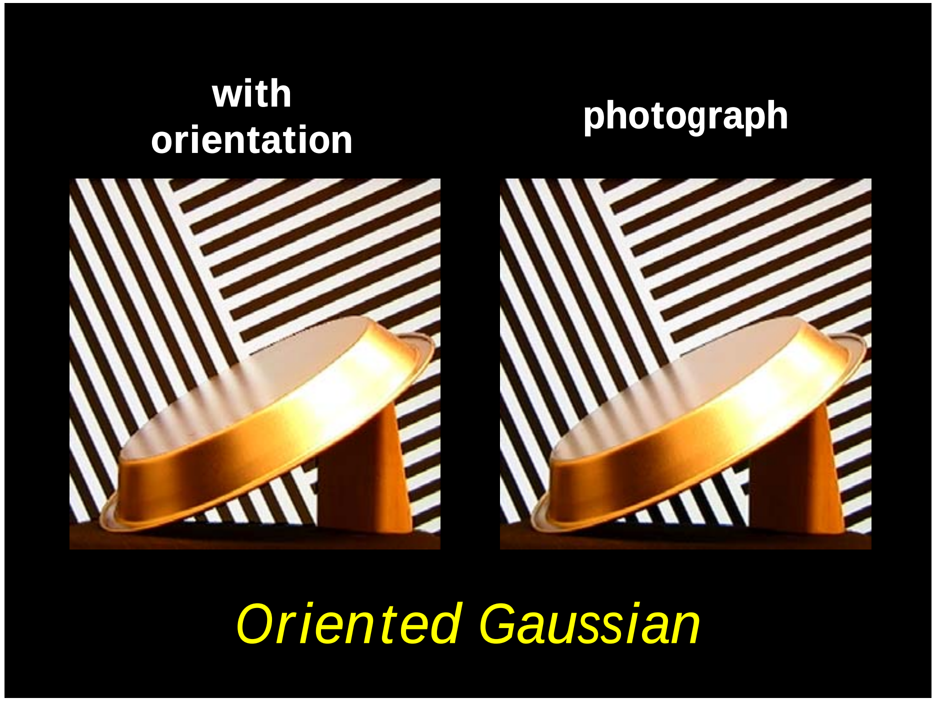

W
C
T
composite
weighting function
background
$C = F + \int W\,T$


Multimodal oriented Gaussian




high accuracy algorithm
photograph
Problem: color dispersion


high accuracy algorithm
photograph
Glossy surface

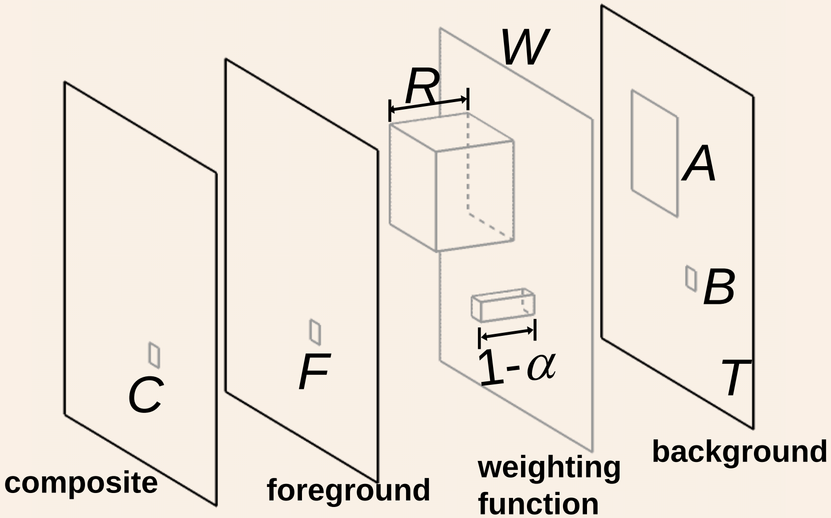

with orientation
photograph
Oriented Gaussian

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 ⟶ A, ρ colorless
- α
- F

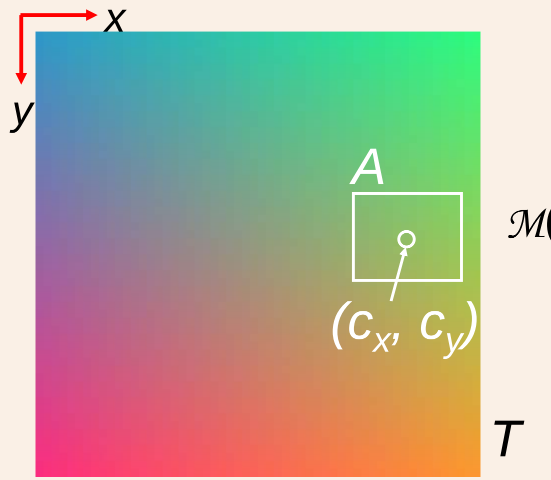
$$C = \rho\, T(c_x, c_y)$$

3 1 1 1

3 observations
3 variables

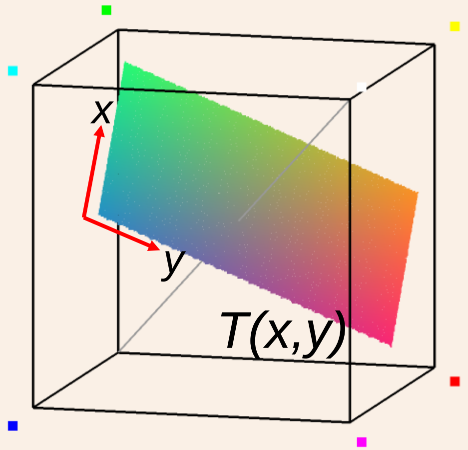
- A, R ⟶ A, ρ (colorless) ⟶ c_x, c_y, ρ (specularly refractive)
- α
- F

Stimulus function

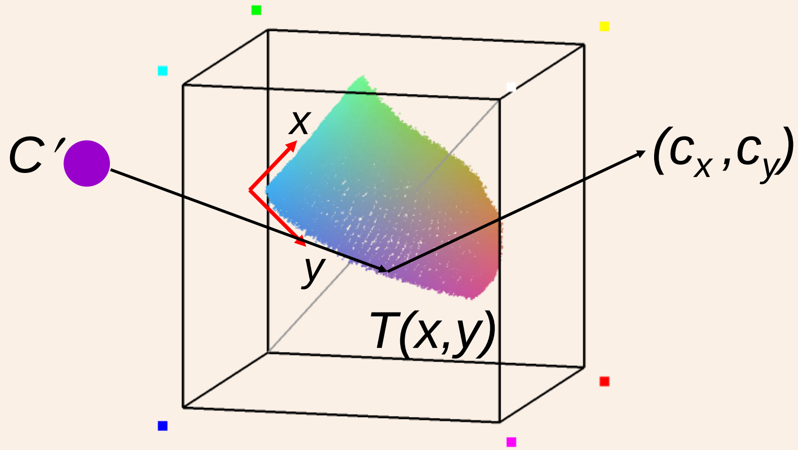


$$\mathcal{M}(T, A) \approx T(c_x, c_y)$$

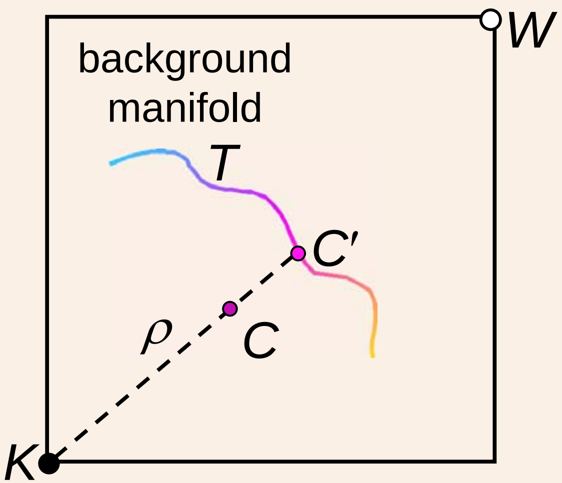
Ideal plane in RGB cube



Calibrated manifold in RGB cube



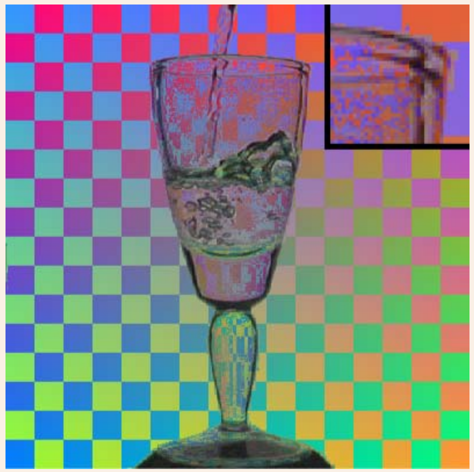
Estimate c_x ,c_y and ρ



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

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

Problem: noisy matte



Edge-preserving filtering

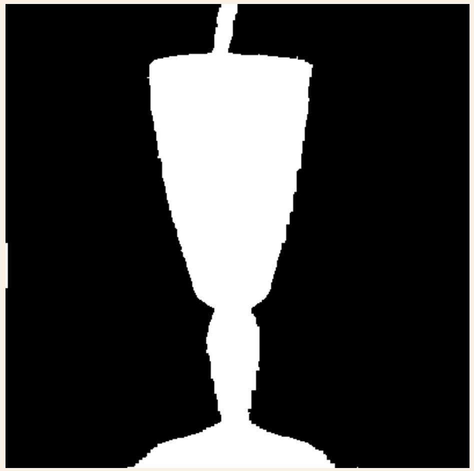
without filtering

with filtering

Input image

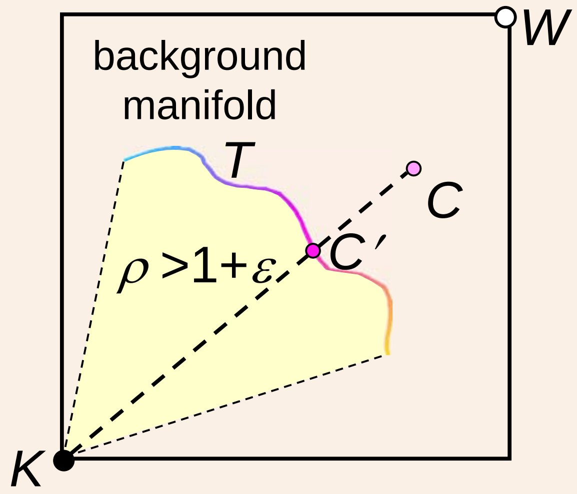
Difference thresholding

Morphological operation

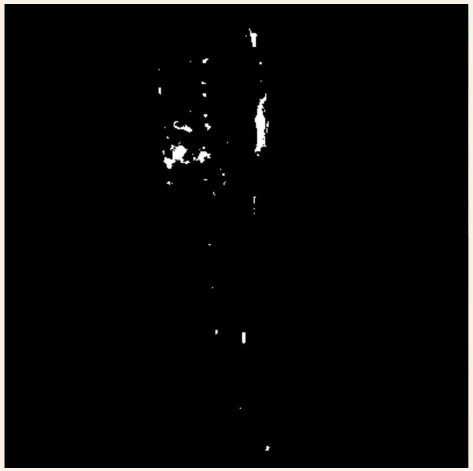


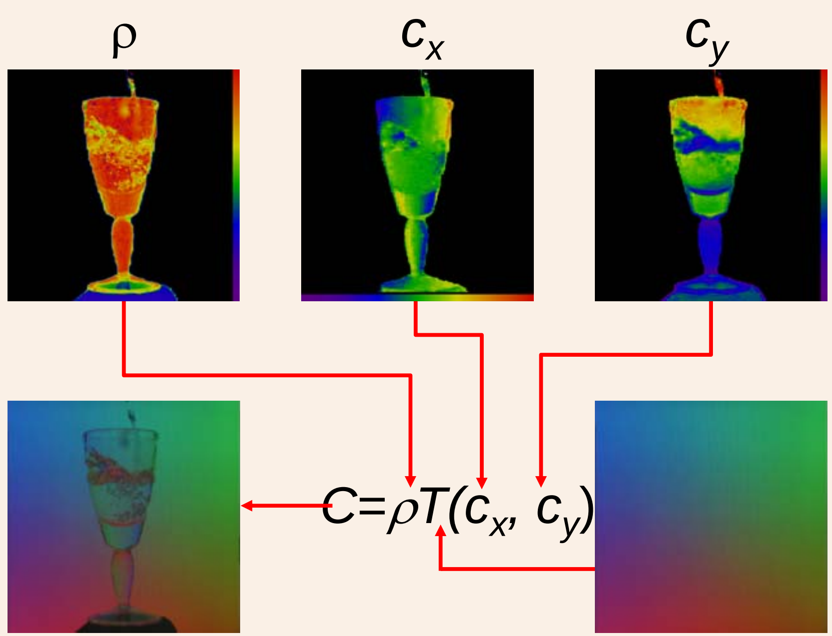
Feathering

Heuristics for specular highlights



Heuristics for specular highlights





Heuristics for specular highlights

input

–

estimation

=

foreground (highlights)

Composite with highlights

	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