SIGGRAPH2005

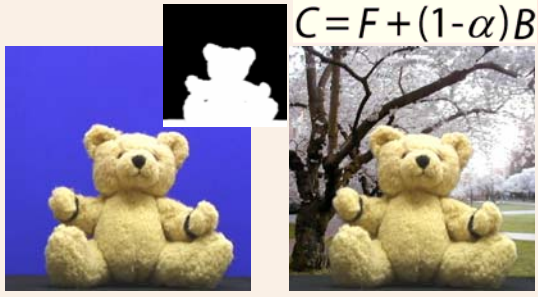
Course 10
Realistic Materials in Computer Graphics

Environment Matting

Yung-Yu Chuang
National Taiwan University

Blue screen matting

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



input image | alpha composite

Problem: blue foreground

source image | alpha composite

Two-screen matting

alpha composite

Problem: refractive object

alpha composite

Problem: refractive object

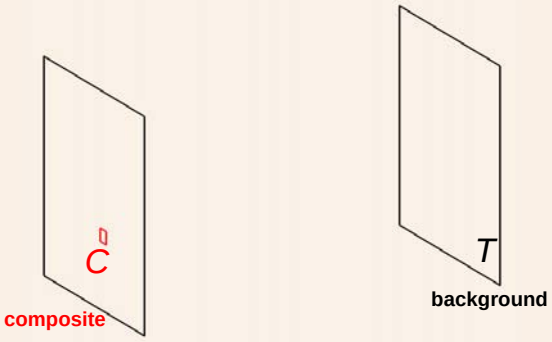
alpha composite

photograph

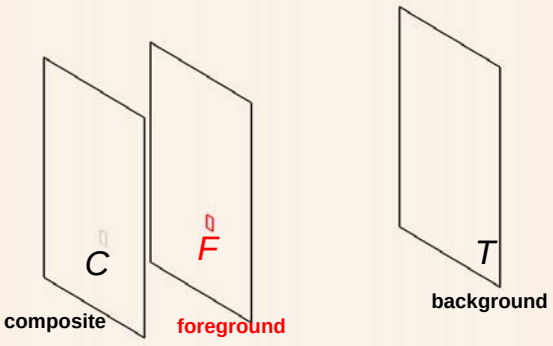
Refracted image of a single pixel

Environment matting framework

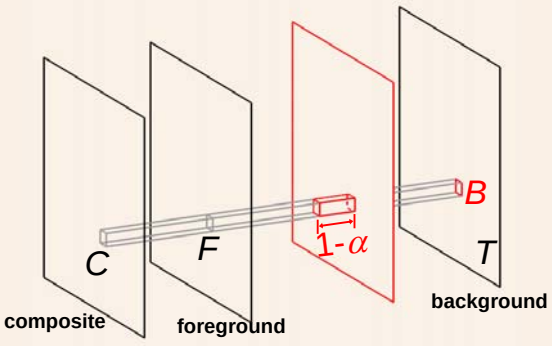
$C =$

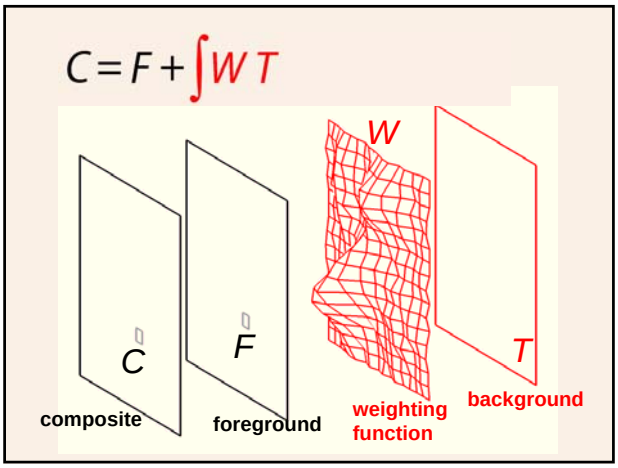


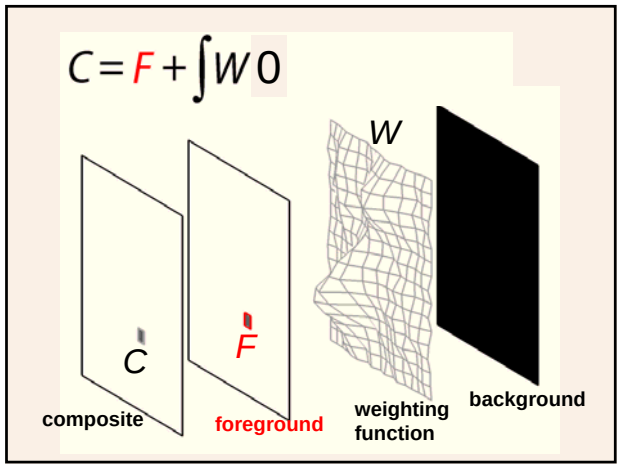
$C = F$

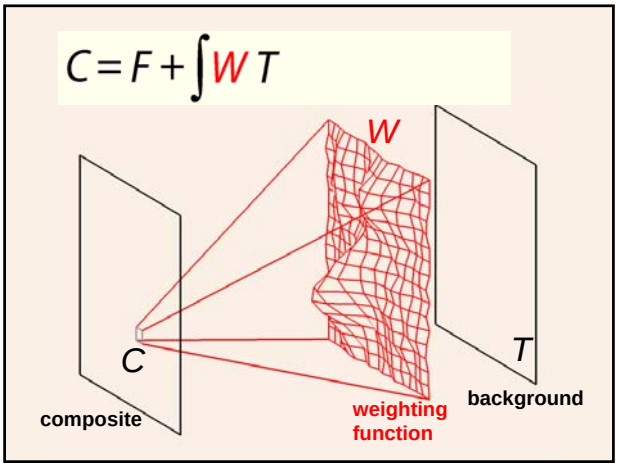


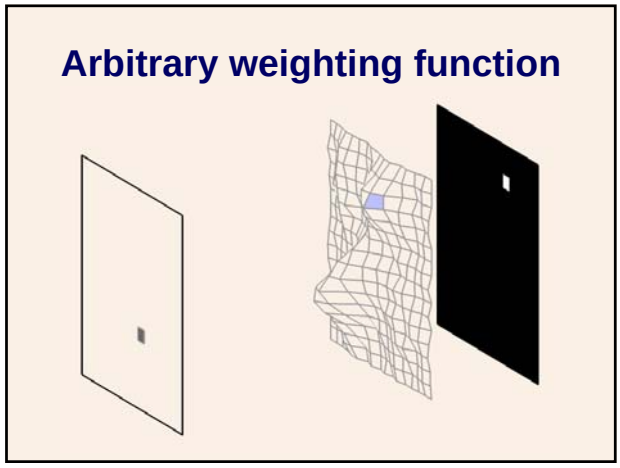
$C = F + (1-\alpha)B$

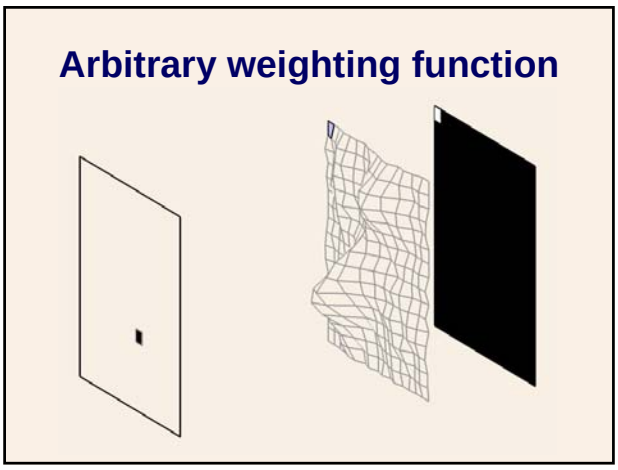












Environment matting algorithms

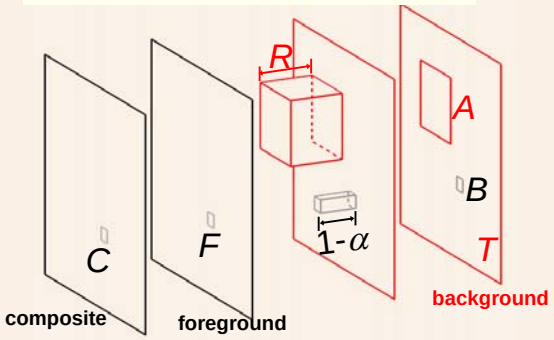
SIGGRAPH2005

- A model to approximate the environment compositing equation
- A method to estimate model parameters
- Complexity of the model determines the complexity of the captured effects

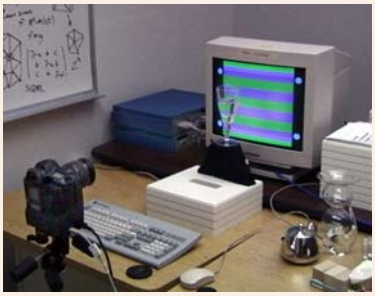
Environment Matting and Compositing

Douglas Zongker Dawn Werner
Brian Curless David Salesin
SIGGRAPH 1999

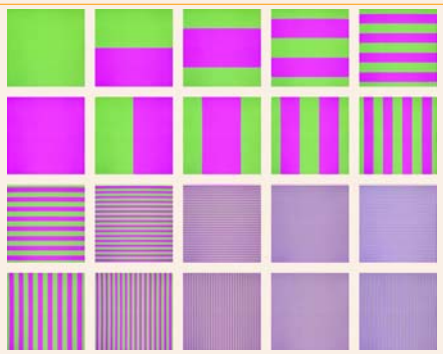
$$C = F + (1-\alpha)B + R\mathcal{M}(T, A)$$



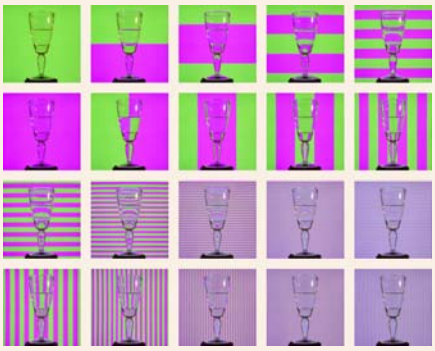
Acquisition setup



Hierarchical backgrounds

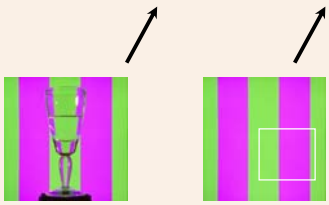


Hierarchical backgrounds



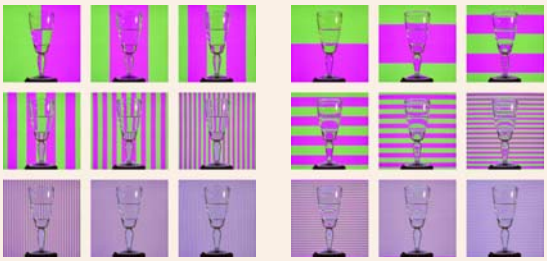
Searching for α and *A*

$$E = \sum \left\| C_{\text{observed}} - C_{\text{computed}}(A) \right\|^2$$



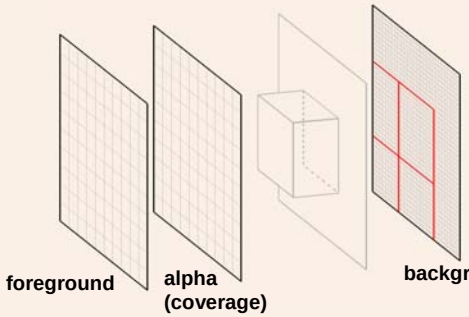
hypothesized *A*

Separate *x* and *y* extent searches



(l, r) (t, b)

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



foreground alpha (coverage) background

Environment matte composite

Results and comparisons

environment matte composite

alpha matte composite

Results and comparisons

environment matte composite

photograph

Results

environment matte composite

environment matte composite

Problem: glossy surface

environment matte composite

photograph

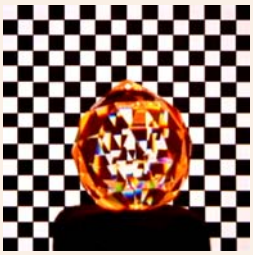
Problem: multiple mappings

environment matte composite

photograph

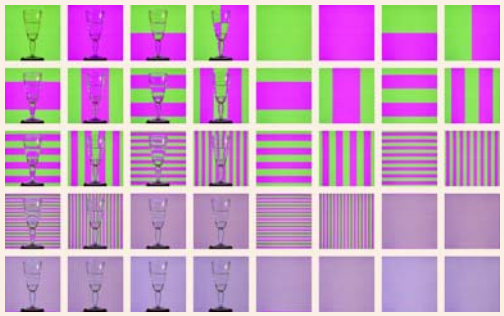
Problem: color dispersion

environment matte composite



photograph

Problem: many photographs

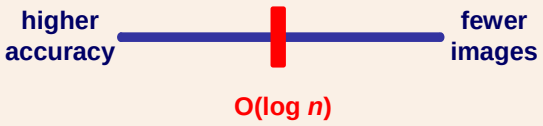


Problem: many photographs

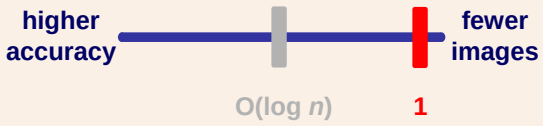
Environment Matting Extensions: Toward Higher Accuracy and Real-Time Capture

Yung-Yu Chuang *Douglas Zongker* *Joel Hindorff*
Brian Curless *David Salesin* Richard Szeliski
SIGGRAPH 2000

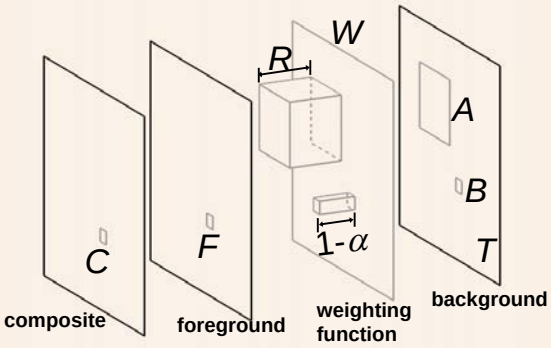
Environment matting



Towards real-time capture



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



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

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
- α colorless
- F

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

3 1 1 1

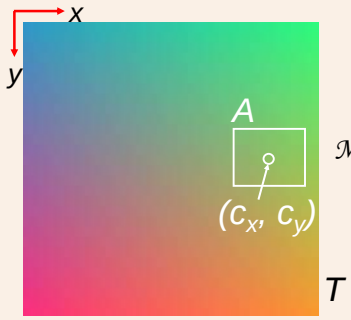
3 observations
3 variables

- $A, R \longrightarrow A, \rho \longrightarrow c_x, c_y, \rho$
- α
- F

colorless

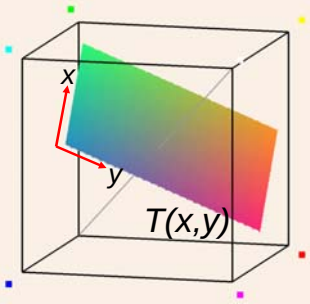
specularly refractive

Stimulus function

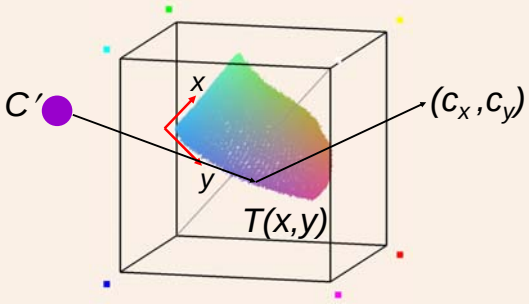


$\mathcal{M}(T, A) \approx T(c_x, c_y)$

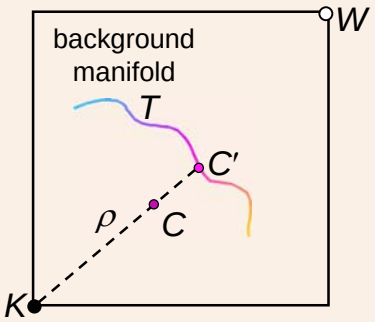
Ideal plane in RGB cube



Calibrated manifold in RGB cube



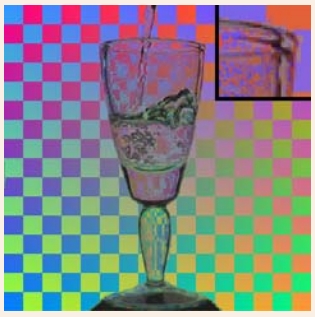
Estimate c_x, c_y and ρ



$C' \rightarrow (c_x, c_y)$

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

Problem: noisy matte



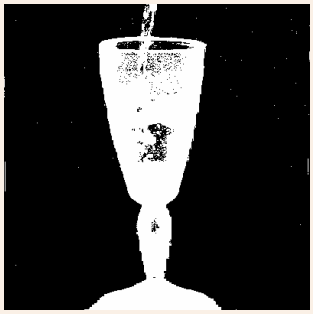
Edge-preserving filtering

without filtering

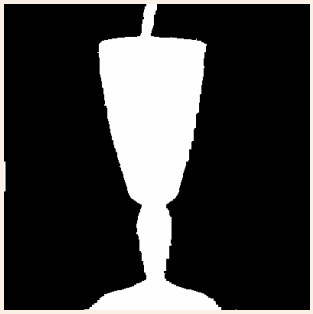
with filtering

Input image

Difference thresholding

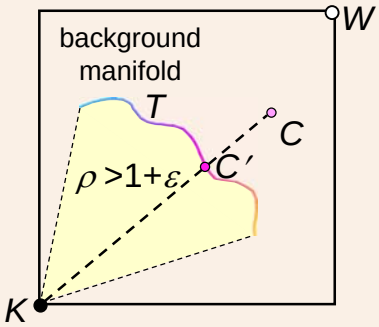


Morphological operation

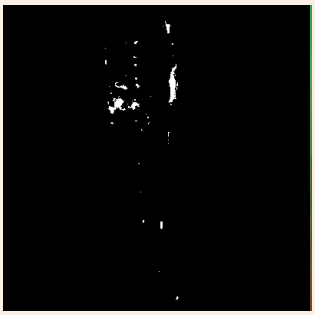


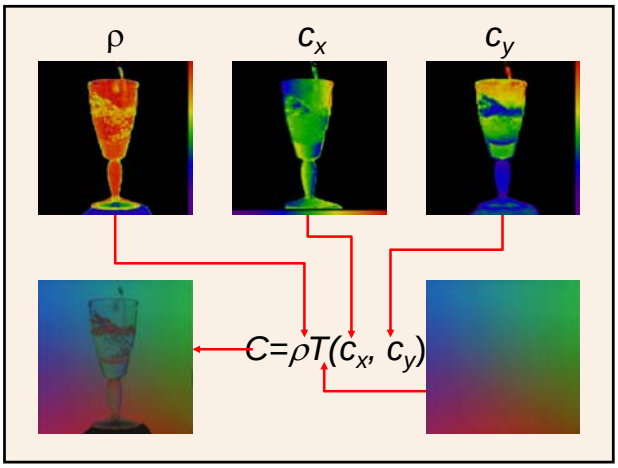
Feathering

Heuristics for specular highlights



Heuristics for specular highlights





Heuristics for specular highlights

input – estimation = foreground (highlights)

Composite with highlights

Towards real-time capture

higher accuracy — fewer images

O(log *n*) — 1

Towards higher accuracy

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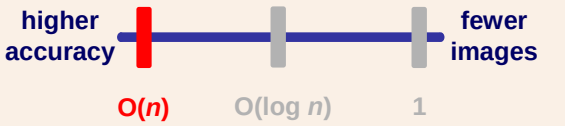
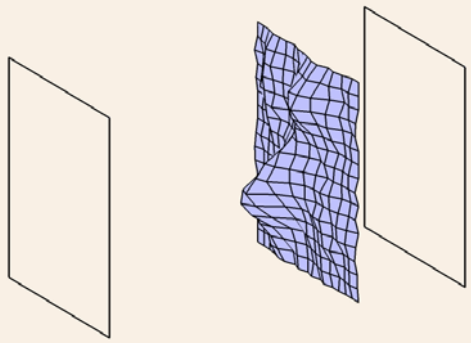
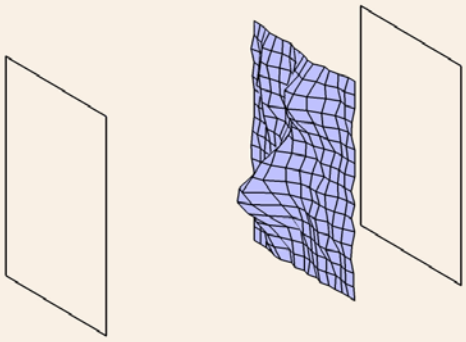


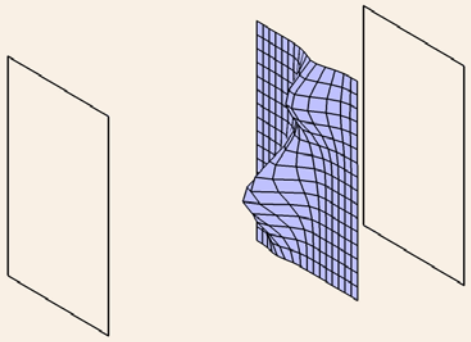
Arbitrary weighting function



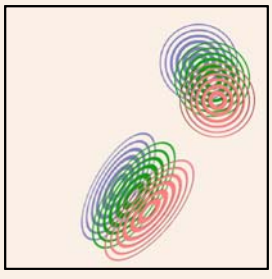
Multimodal oriented Gaussian



Multimodal oriented Gaussian

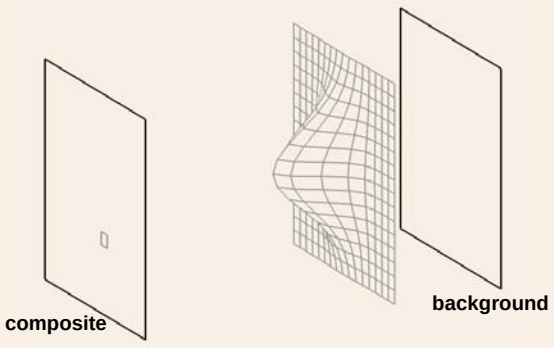


Multimodal oriented Gaussian

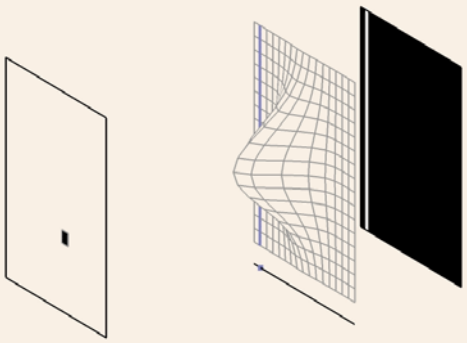


- Better BRDF approximation
- Multiple mappings
- Wavelength-coupled variation

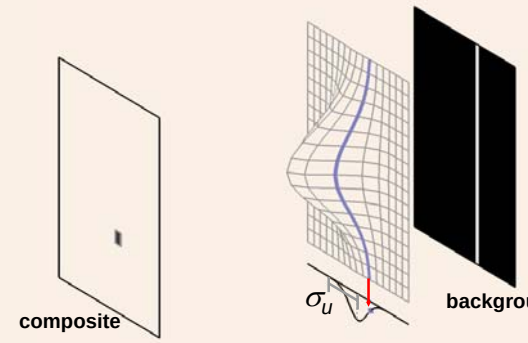
Unimodal axis-aligned Gaussian



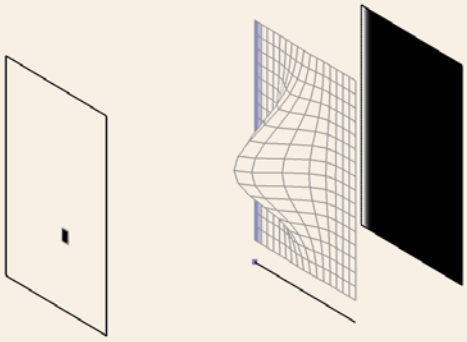
Unimodal axis-aligned Gaussian



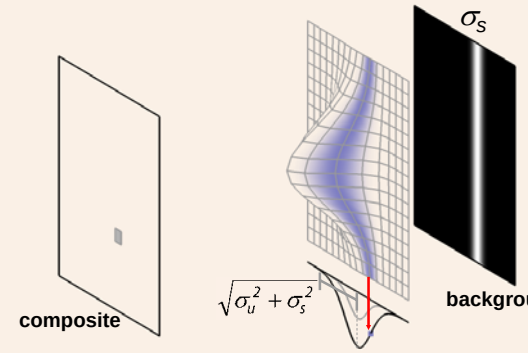
Unimodal axis-aligned Gaussian



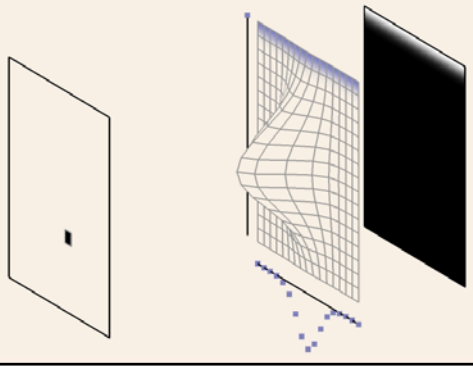
Unimodal axis-aligned Gaussian



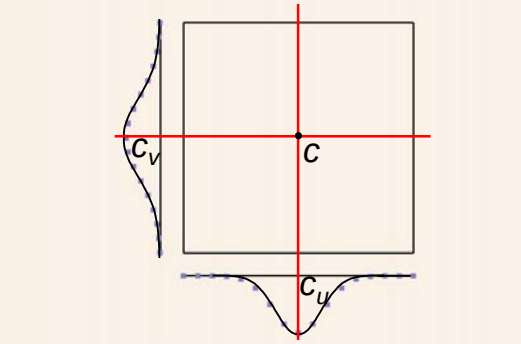
Unimodal axis-aligned Gaussian



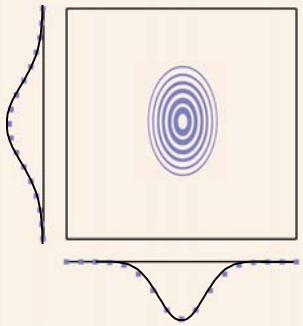
Unimodal axis-aligned Gaussian



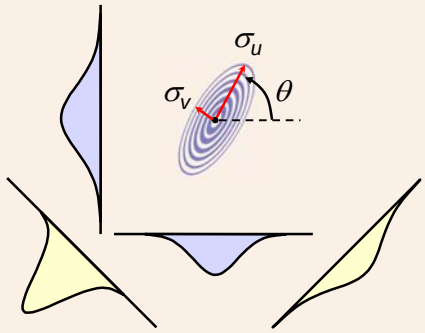
Unimodal axis-aligned Gaussian



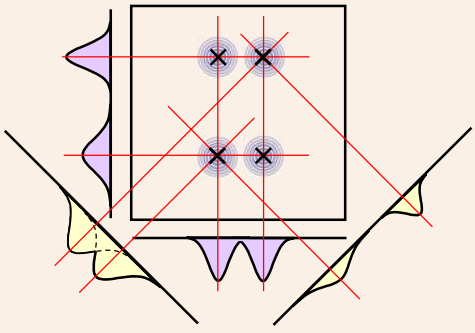
Unimodal axis-aligned Gaussian



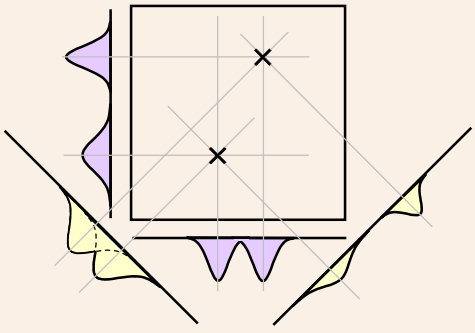
Unimodal oriented Gaussian



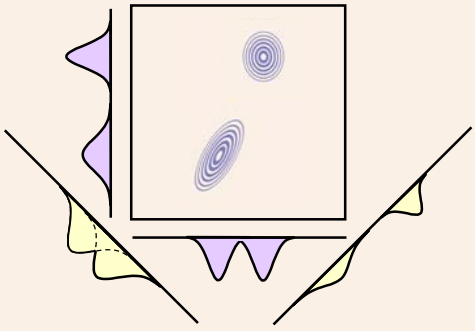
Multimodal oriented Gaussian



Multimodal oriented Gaussian



Multimodal oriented Gaussian



Glossy surface

SIGGRAPH 99

photograph

Glossy surface

higher accuracy algorithm

photograph

Oriented Gaussian

without orientation

photograph

Oriented Gaussian

with orientation

photograph

Multiple mappings

SIGGRAPH 99

photograph

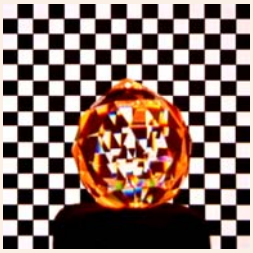
Multiple mappings

higher accuracy algorithm

photograph

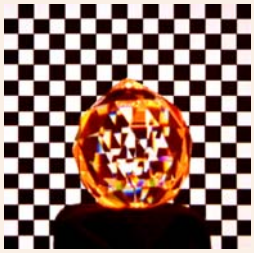
Color dispersion

SIGGRAPH 99

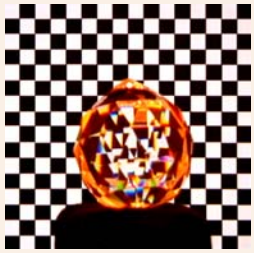


photograph

Color dispersion



higher accuracy algorithm



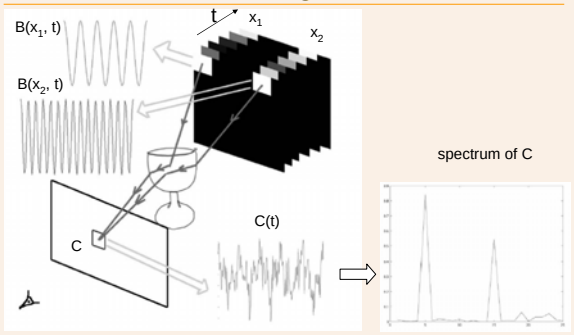
photograph

Frequency-based Environment Matting

Jiayuan Zhu *Yee-Hong Yang*

Pacific Graphics 2004

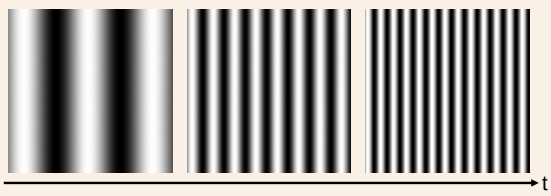
Frequency-based environment matting



Frequency-based environment matting

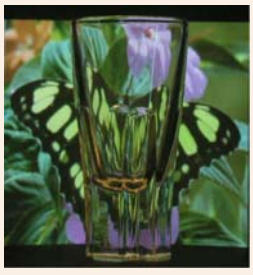
$$W(x,y) = W_x(x) \cdot W_y(y)$$

$$B(x,t) = \sin 2\pi xt$$



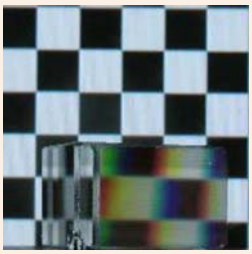
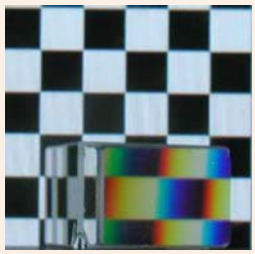
Results: refraction

frequency-based environment matting



photograph

Results: color dispersion

frequency-based environment matting

photograph

Results: oriented


frequency-based environment matting

photograph

Wavelet Environment Matting

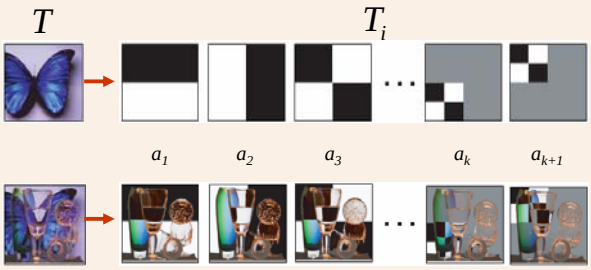
Pieter Peers *Philip Dutré*

Eurographics Symposium on Rendering 2003

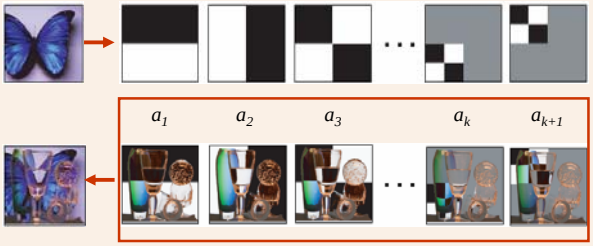
Wavelet environment matting

$$C = \int WT$$

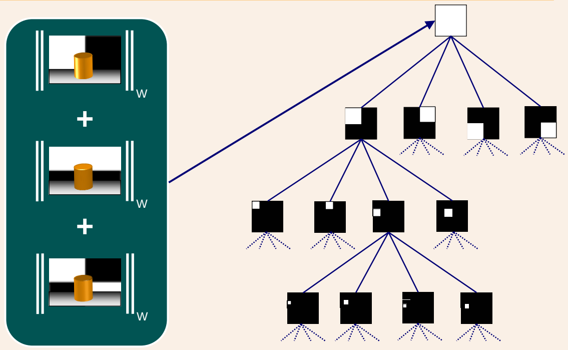
Wavelet environment matting



Wavelet environment matting



Error tree



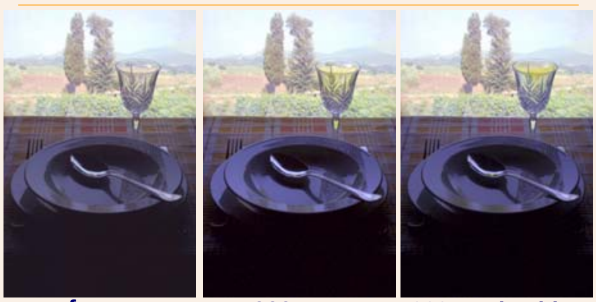
Results: number of basis images

reference image 1200 basis images

Results: number of basis images

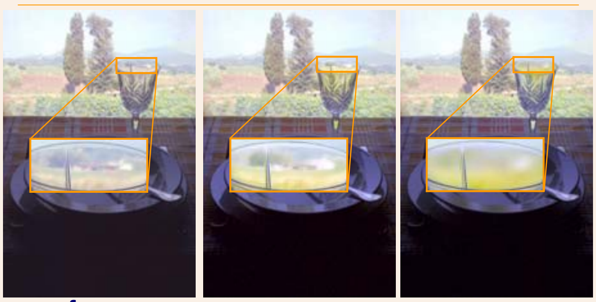
reference image 1200 basis images

Results: wavelet patterns



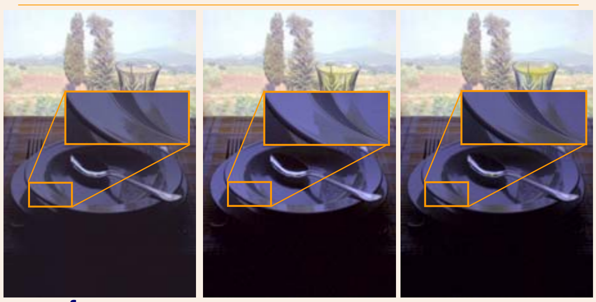
reference image | 1000 Haar patterns | 1000 Daubechies (9,7) patterns

Results: wavelet patterns



reference image | 1000 Haar patterns | 1000 Daubechies (9,7) patterns

Results: wavelet patterns



reference image | 1000 Haar patterns | 1000 Daubechies (9,7) patterns

Results: diffuse materials

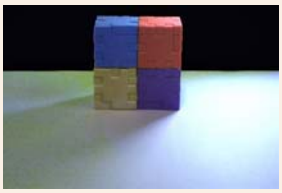
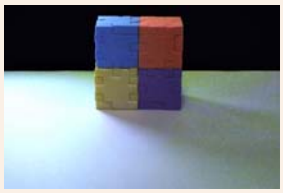



Image-based Environment Matting

Yonatan Wexler Andrew Fitzgibbon Andrew Zisserman

Eurographics Workshop on Rendering 2002

Image-based environment matting

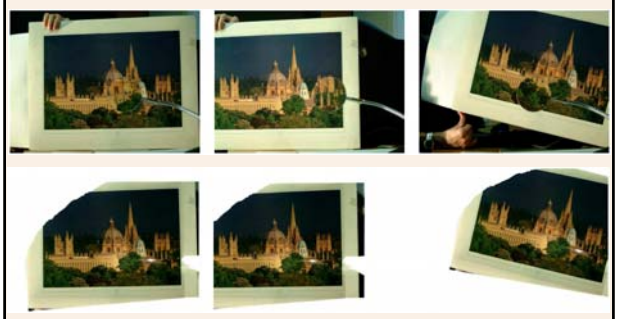
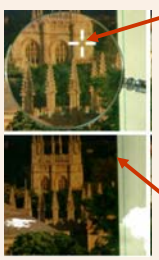


Image-based environment matting

$$P(q) = e^{-\|C(p)-B(q)\|^2}$$

Image-based environment matting



$$P(q) = e^{-\|C(p)-B(q)\|^2}$$

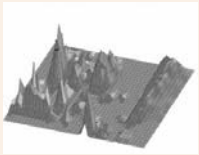
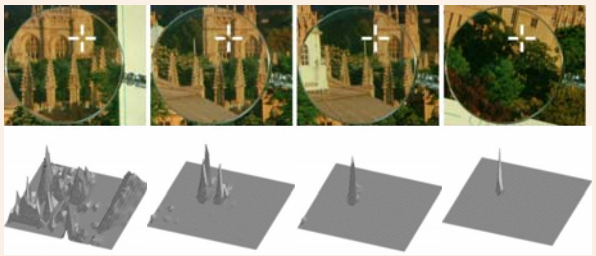


Image-based environment matting

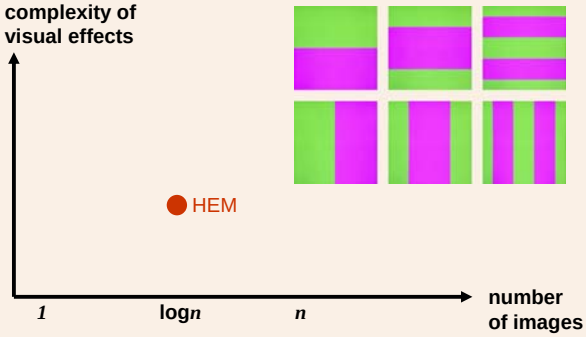
Image-based environment matting



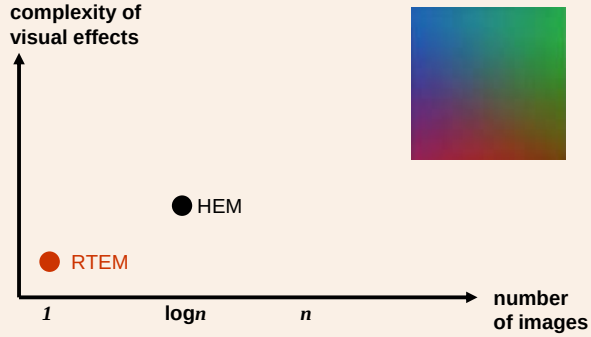
Results

Results

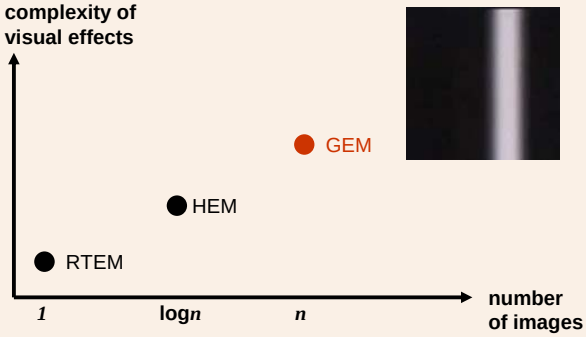
Summary



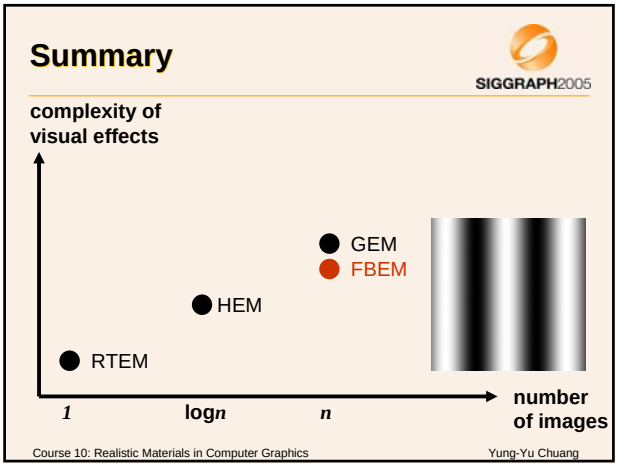
Summary



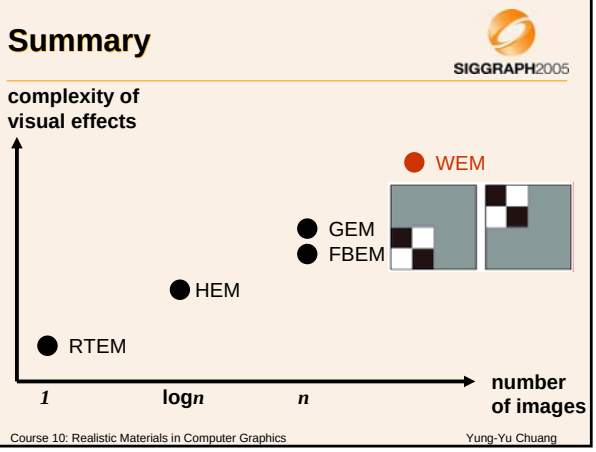
Summary



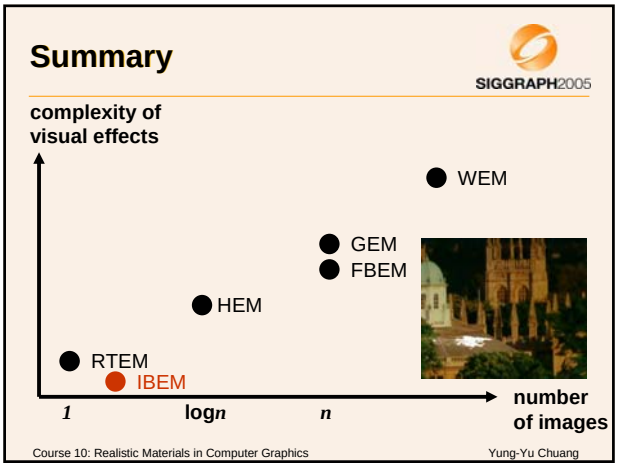
Summary



Summary



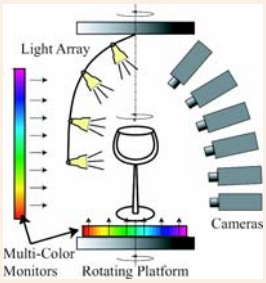
Summary



Acquisition and Rendering of Transparent and Refractive Objects

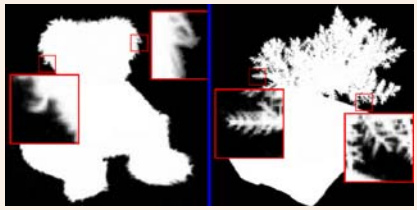
Wojciech Matusik *Hanspeter Pfister*
Remo Ziegler *Addy Ngan* *Leonard McMillan*
Eurographics Workshop on Rendering 2002

The system



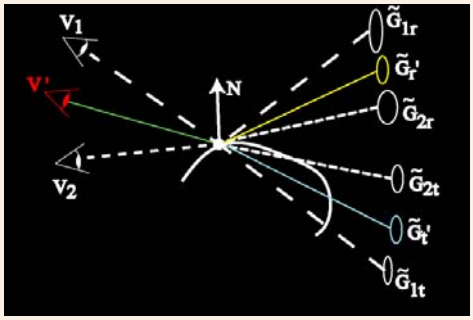
Geometry - opacity hull

- Visual hull augmented with view-dependent opacity
- Store the opacity of each observation at each point on the visual hull.



Results

Interpolation



Comparisons

category	method	asymptotic # of images	typical # of images	weighting function	materials
active	RTEM	1	1	warping function	colorless, specularly refractive
	HEM	$O(\log k)$	20	box filter	refraction, translucency, highly specular, color transparency
	GEM	$O(k)$	600	sum of Gaussians	+color dispersion, multiple mappings and glossy reflection
	FBEM	$O(k)$	1,200	product of two 1D functions	-multiple mappings
	WEM	$O(k^2)$	1,200	object images	+diffuse reflection
passive	IBEM	N/A	40	probability map	colorless, specularly refractive
	ROEM	N/A	200	warping function	colorless, specularly refractive

Reference

- D. Zongker, D. M. Werner, B. Curless, and D. H. Salesin. Environment Matting and Compositing, SIGGRAPH 1999, pp205-214.
- Yung-Yu Chuang, Douglas E. Zongker, Joel Hindorff, Brian Curless, David H. Salesin, Richard Szeliski, Environment Matting Extensions: Towards Higher Accuracy and Real-Time Capture, SIGGRAPH 2000.
- P. Peers and P. Dutre. Wavelet Environment Matting, EGSR 2003.
- J. Zhu and Y.-H. Yang. Frequency-Based Environment Matting, Pacific Graphics 2004.
- Y. Wexler, A. Fitzgibbon and A. Zisserman. Image-Based Environment Matting, EGWR 2002, pp279-289.

Future work

- More general materials (Specular + diffuse)
- Principled Bayesian approach
- Advanced rendering
- Editing

Conclusion

- No restriction on material properties
- Linearly combining weighted basis images
- Hierarchical algorithm
  - Wavelets
  - Feedback loop

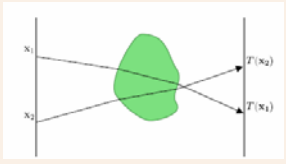
Future Work

- Extend to full Image Based Relighting technique
- Better stop-criterion
- Environment matting with moving camera

On Refractive Optical Flow

Sameer Agarwal *Satya Mallick*
David Kriegman *Serge Belongie*
ECCV 2004

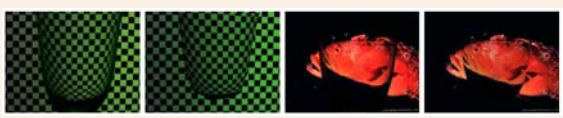
Refractive optical flow



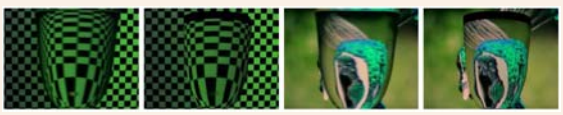
$$\mathbf{c}(T(\mathbf{x}),t)^{\top}\mathbf{J}^{-\top}(T(\mathbf{x}))\left[\nabla I(\mathbf{x},t) - I(\mathbf{x},t)\nabla\beta(\mathbf{x})\right] + I_t(\mathbf{x},t) = 0$$

refractive optical flow equation

Results



without water



with water

Acknowledgements

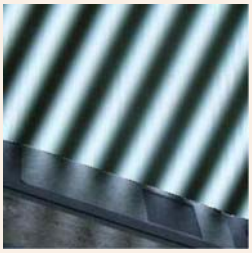
Douglas Zongker, Dawn Werner, Brian Curless, David Salesin, Joel Hindorff, Richard Szeliski, Jiayuan Zhu, Yee-Hong Yang, Pieter Peers, Philip Dutre, Yonatan Wexler, Andrew Fitzgibbon, Andrew Zisserman, Sameer Agarwal, Satya Mallick, David Kriegman, Serge Belongie, Wojciech Matusik, Hanspeter Pfister, Remo Ziegler, Addy Ngan, Leonard McMillan

Results: oriented

frequency-based environment matting

photograph

Results: oriented



frequency-based environment matting

photograph

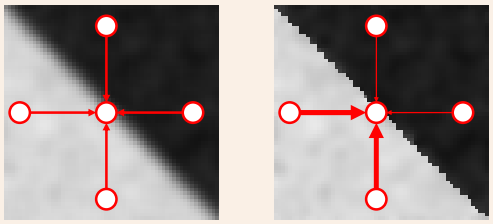
Refracted image of a single pixel

Refracted image of a single pixel

Refracted image of a single pixel

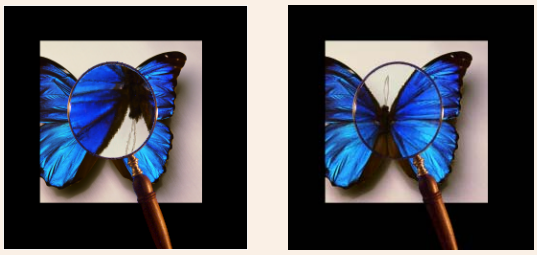
Refracted image of a single pixel

Edge-preserving filtering

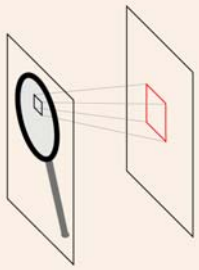


isotropic filter anisotropic filter

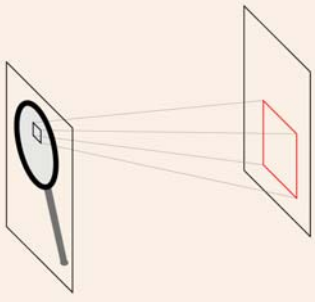
Depth correction



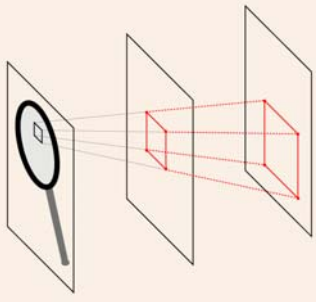
Capturing at a single depth



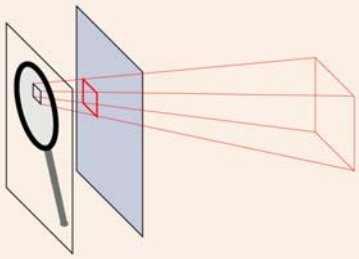
Capturing a second depth



Constructing the 3D beam



Rendering at novel depths



Rendering at novel depths

Wavelet environment matting

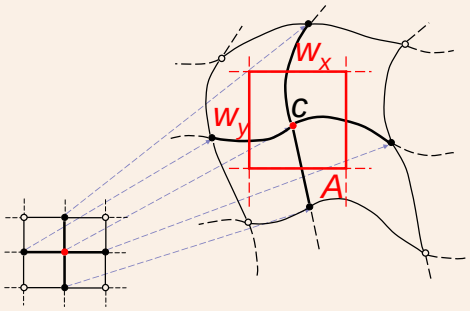
$$C = \int WT \qquad T = \sum_i a_i T_i$$

$$= \int W\left(\sum_i a_i T_i\right)$$

$$= \sum_i a_i \int WT_i \qquad C_i = \int WT_i$$

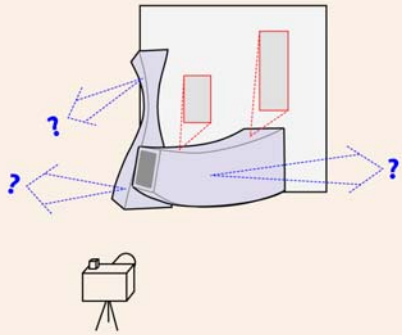
$$= \sum_i a_i C_i$$

Estimate w_x ,w_y

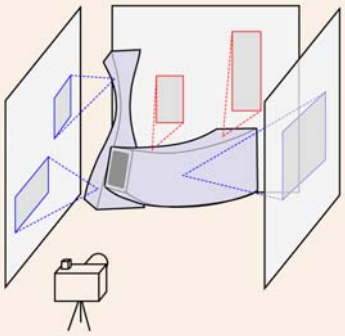


Reflective objects

Many rays not captured



Add sidedrops to capture these rays



Capturing multiple sides

Contributions from multiple sides

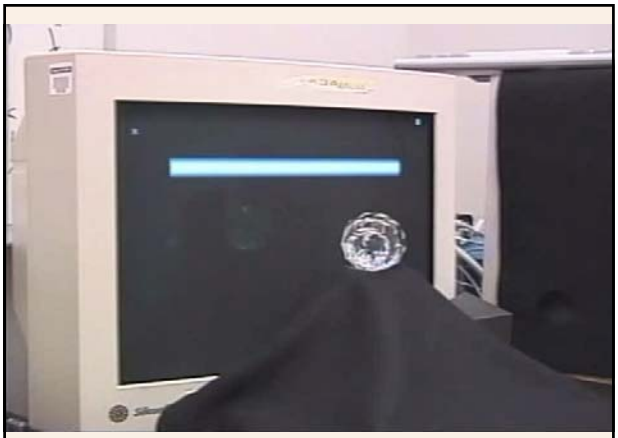
Computing R and F from alpha

$$C = F + (1-\alpha)X + RX$$

$$C' = F + (1-\alpha)X' + RX'$$

$$R(\alpha) = \frac{C - C'}{X - X'} - (1-\alpha)$$

$$F(\alpha) = C - (1 - \alpha + R(\alpha))X$$



Results and comparisons

environment matte composite

alpha matte composite

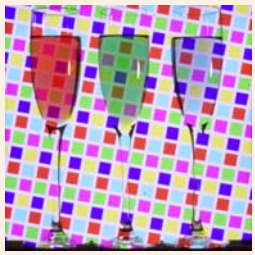
Results and comparisons

environment matte composite

photograph

Results and comparisons

environment matte composite



alpha matte composite

Results and comparisons

environment matte composite

photograph