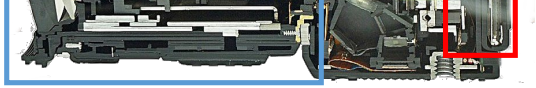
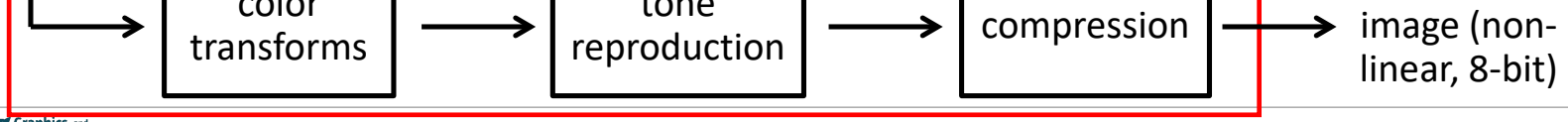


Sources: CMU 15-463, Dartmouth College CS89/189.



Sources: CMU 15-463, Dartmouth College CS89/189.

✓ Computational displays (Lecture #6)

✓ Computational illumination (Lecture #7)

✓ Computational displays (Lecture #6)

✓ Computational illumination (Lecture #7)

- Generalized optics encode world into intermediate representation.
- Generalized computation decodes representation into multiple images.

Source: CMU 15-436

Inspired by a slide by Ramesh Raskar

Inspired by a slide by Ramesh Raskar

Inspired by a slide by Ramesh Raskar

✓ Computational displays (Lecture #6)

✓ Compressive sensing (Lecture #5)

➡ Computational illumination (Lecture #6)

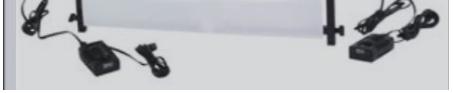
After a slide by Ramesh Raskar

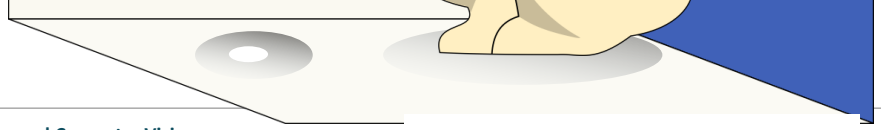
a) Ultrashort exposure time
b) Ultrashort illumination

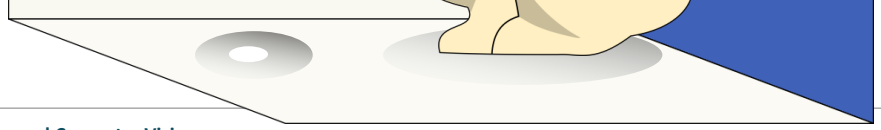
H. Edgerton's strobsocope (1930)

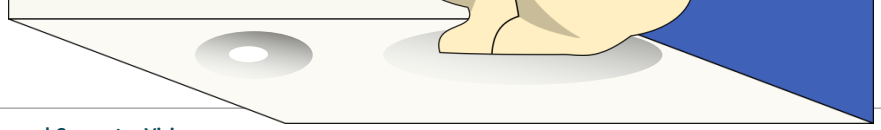
H. Edgerton's strobsocope (1930)











Source: Heaberly, 1992

Source: Heaberly, 1992

Source: Heaberly, 1992

(computational light transport)

Inspired by a slide by Ramesh Raskar

Inspired by a slide by Ramesh Raskar

Does this ring a bell?

✓ Computational displays (Lecture #6)

✓ Compressive sensing (Lecture #5)

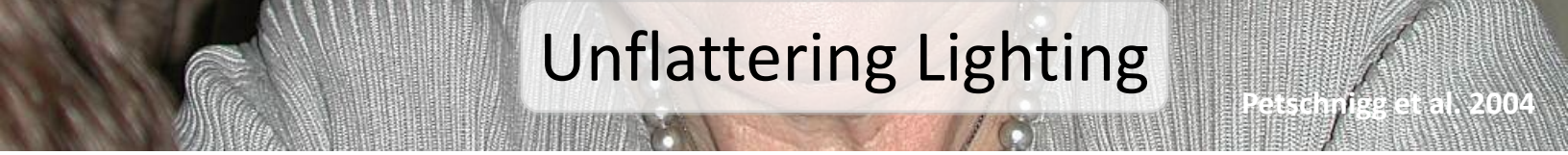
➡ Computational illumination (Lecture #6)

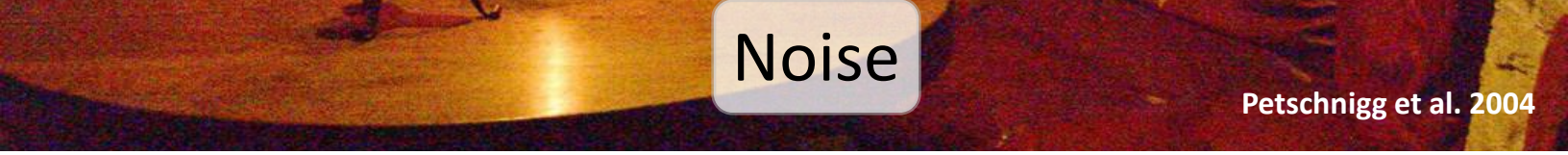
a) Pulsed/Stroboscopic Light, b) Temporally Modulated Light, …

b) A decent mask (e.g. an LCoS display) in front of the light source

Inspired by a slide by Ramesh Raskar

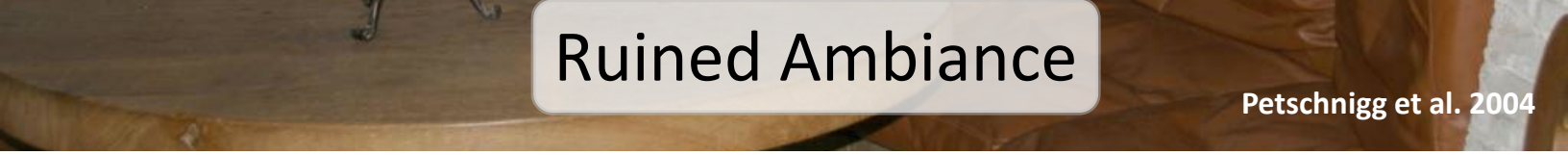

Red Eye
Petschnigg et al. 2004


Unflattering Lighting
Petschnigg et al. 2004


Noise
Petschnigg et al. 2004

A lot of Noise

Petschnigg et al. 2004

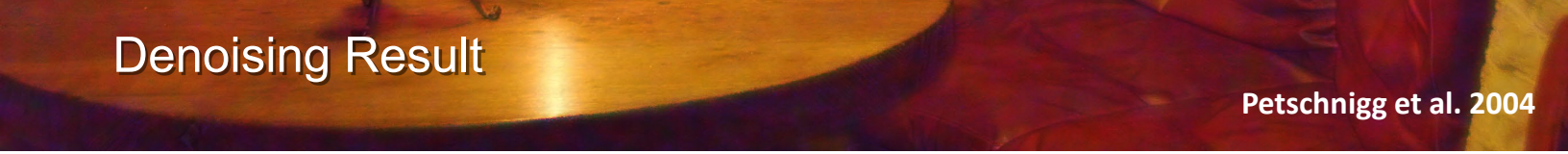


Ruined Ambiance

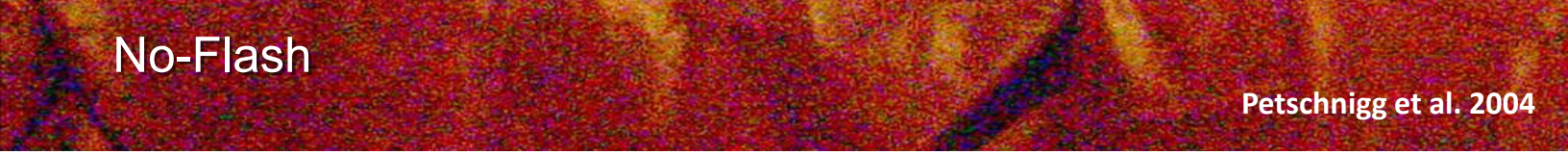
Petschnigg et al. 2004


+ Sharp
- Artificial Light
- Jarring Look
+ Lacks Detail
+ Ambient Light
+ Natural Look
Petschnigg et al. 2004

Denoising Result



Petschnigg et al. 2004


No-Flash
Petschnigg et al. 2004

Denoising Result

Petschnigg et al. 2004

Sources: CMU 15-463, Dartmouth College CS89/189.

Sources: CMU 15-463, Dartmouth College CS89/189.

Sources: CMU 15-463, Dartmouth College CS89/189.

$$i = tp$$

$$\mathbf{i} = \mathbf{t}\mathrm{p}$$

$$\mathbf{i} = \mathbf{T}\mathbf{p}$$

$$\mathbf{i} = \mathbf{T}\mathbf{p}$$ **Light Transport Equation** [Ng et al. 2003]

Sources: CMU 15-463, Dartmouth College CS89/189.

Sources: CMU 15-463, Dartmouth College CS89/189.

Sources: CMU 15-463, Dartmouth College CS89/189.

Sources: CMU 15-463, Dartmouth College CS89/189.

$\mathbf{T}$ - *Light transport matrix (NxM):* Encodes transport through the scene between $\mathbf{p}$ and $\mathbf{I}$

8x8 image

Sources: CMU 15-463, Dartmouth College CS89/189.

$\mathbf{i}$

(64x1)

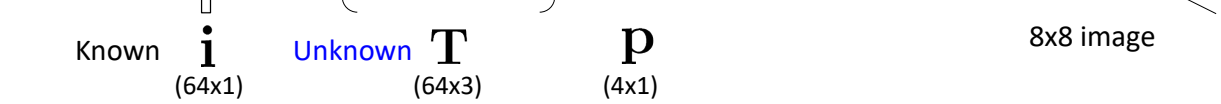
8x8 image

Sources: CMU 15-463, Dartmouth College CS89/189.

Known $\mathbf{i}$ (64x1)

8x8 image

Sources: CMU 15-463, Dartmouth College CS89/189.



Sources: CMU 15-463, Dartmouth College CS89/189.

Known $\mathbf{i}$ (64x1)

Unknown $\mathbf{T}$ (64x3)

$\mathbf{p}$ (4x1)

8x8 image

Sources: CMU 15-463, Dartmouth College CS89/189.

Known $\mathbf{i}$ (64x1)

Unknown $\mathbf{T}$ (64x3)

$\mathbf{p}$ (4x1)

Maybe known

Maybe unknown

8x8 image

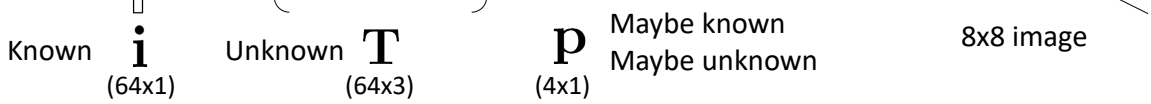
Known $\mathbf{i}$ (64x1)

Unknown $\mathbf{T}$ (64x3)

$\mathbf{p}$ (4x1)

Maybe known
Maybe unknown

8x8 image


Known
i
(64x1)
Unknown
T
(64x3)
p
(4x1)
Maybe known
Maybe unknown
8x8 image

Known $\mathbf{i}$ (20e6x1)

Unknown $\mathbf{T}$ (20e6x?)

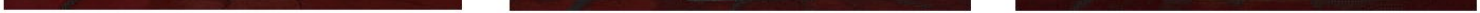
$\mathbf{p}$ (?x1)

Maybe known
Maybe unknown

20MP image

(a) (b) (c) (d)

Sources: CMU 15-463, Dartmouth College CS89/189.



(a) Scene (b) Direct Component (c) Global Component

Inspired by a slide by Ramesh Raskar

Inspired by a slide by Srinivas Narasimhan

Correspondence is hard!

Inspired by a slide by Srinivas Narasimhan

Inspired by a slide by Srinivas Narasimhan

surface or volume.

Inspired by a slide by Srinivas Narasimhan

Correspondence becomes much easier!

Inspired by a slide by Srinivas Narasimhan

many images and takes time

Can we do better?

Inspired by a slide by Srinivas Narasimhan

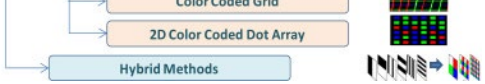
Pattern 1

Sources: CMU 15-463, Dartmouth College CS89/189.

- Need very few images (one or two), real-time and dynamic scenes
- But needs a more complex correspondence algorithm

Sources: CMU 15-463, Dartmouth College CS89/189.

[Geng 2011]



Sources: CMU 15-463, Dartmouth College CS89/189.

Slow, robust

Fast, fragile

Sources: CMU 15-463, Dartmouth College CS89/189.

- Can we do more?

Inspired by a slide by Ramesh Raskar

Source: Heaberly, 1992

Source: Heaberly, 1992

Source: Heaberly, 1992

$$i = tp$$

$$\mathbf{i} = \mathbf{T}\mathbf{p}$$ [Debevec et al. 2000]

$\mathbf{T}$ - *Light transport matrix (NxM):* Encodes transport through the scene between $\mathbf{p}$ and $\mathbf{I}$

(N^2x1)

Known

(N^2xM)

Unknown

(Mx1)

Maybe
(un)known

NxN image

[O’Toole & Kutulakos 2010]

Avatar © 2009 20th Century Fox & Weta Digital Ltd
Source: [Pantaleoni et al. SIG 2010]

Halo 3 ©Bungie
Source: [Chen and Liu, SIG 2008]

Inspired by a slide by Ramesh Raskar

n pixels

Source: [O'Toole & Kutulakos 2010]

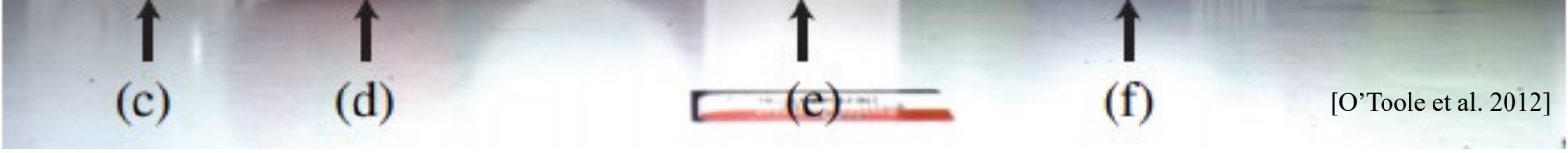
Non-symmetric LTM

Source: [O'Toole & Kutulakos 2010]

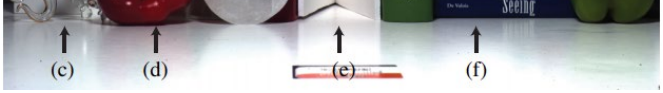
Symmetric LTM

n pixels

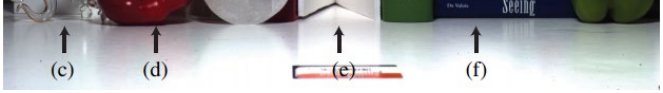
Source: [O'Toole & Kutulakos 2010]



[O'Toole et al. 2012]

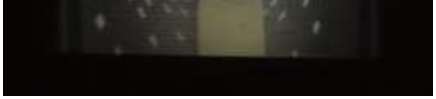


Source: [O'Toole et al. 2012]

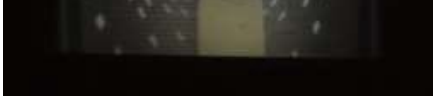


Source: [O'Toole et al. 2012]

Source: [O'Toole et al. 2012]



Source: [O'Toole et al. 2012]



light paths

Source: [O'Toole et al. 2012]

Source: [O'Toole et al. 2012]

Source: [O'Toole et al. 2012]

indirect light paths

Source: [O'Toole et al. 2012]

light paths

Source: [O'Toole et al. 2012]

Source: [O'Toole et al. 2012]

light paths

Source: [O'Toole et al. 2012]

Source: [O'Toole et al. 2012]

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Source: [O'Toole et al. 2012]

Source: [O'Toole et al. 2012]

Source: [O'Toole et al. 2012]

Source: [O'Toole et al. 2012]

for direct-indirect separation.

$$L[c,i] = L_d[c,i] + L_g[c,i]$$

radiance direct global

$$L_g[c,i] = \sum_P A[i,j]\, L[i,j]$$

BRDF and geometry

$$L'[c,l] = L_d[c,l] + \alpha L_g[c,l]$$

fraction of activated source elements

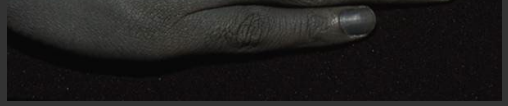
$L'[c,l] = L_d[c,l] + \alpha L_g[c,l]$

$L'[c,l] = (1-\alpha) L_g[c,l]$

fraction of activated source elements

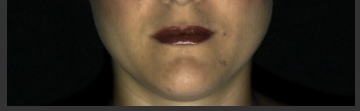
Direct

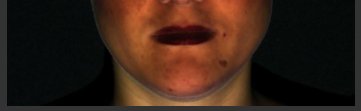
Global

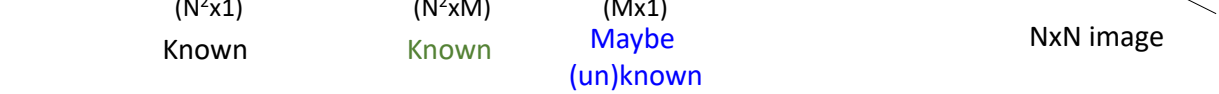


Direct

Global







(N^2x1)

Known

(N^2xM)

Known

$(Mx1)$

Maybe
(un)known

NxN image

(MxN^2)

Known

(N^2x1)

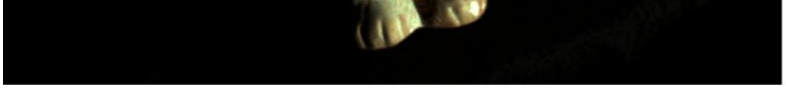
Known

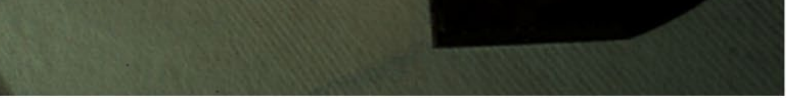
$(Mx1)$

Unknown

NxN light sources

Source: [O'Toole & Kutulakos 2010]





(N^2x1) (N^2xM) $(Mx1)$

Known Unknown Calibrated

NxN image

(N^2x1) (N^2xM) $(Mx1)$

Known Unknown Calibrated

NxN image

(N^2x1) (N^2xM) $(Mx1)$

Known Unknown Calibrated

NxN image

(N^2x1) (N^2xM) $(Mx1)$

Known Unknown Calibrated

NxN image

(N^2x1) (N^2xM) $(Mx1)$

Known Unknown Calibrated

NxN image

decomposition, dehazing or dual photography.

Sources: CMU 15-463, Dartmouth College CS89/189.