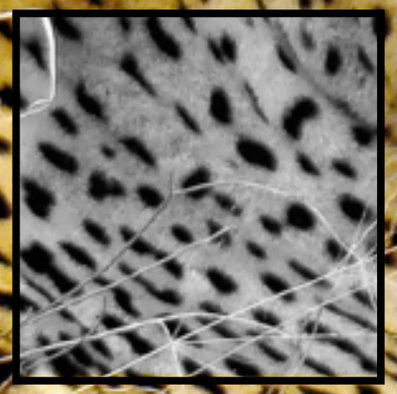
Camouflaging an object from many viewpoints

Andrew Owens Connelly Barnes

Alex Flint Hanumant Singh Bill Freeman

Object detection

Object “non-detection”

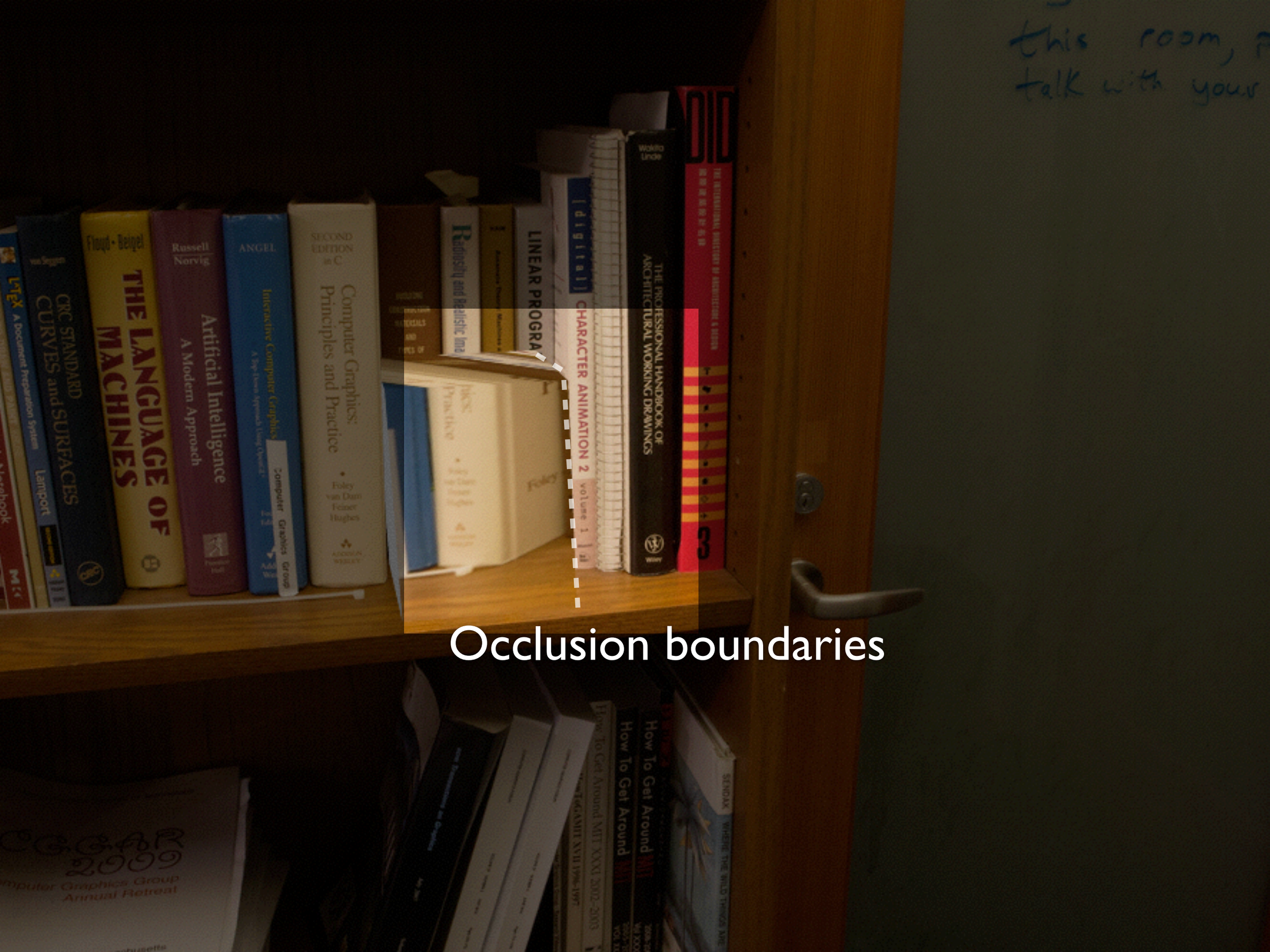


http://www.youtube.com/watch?v=JSq8nghQZqA

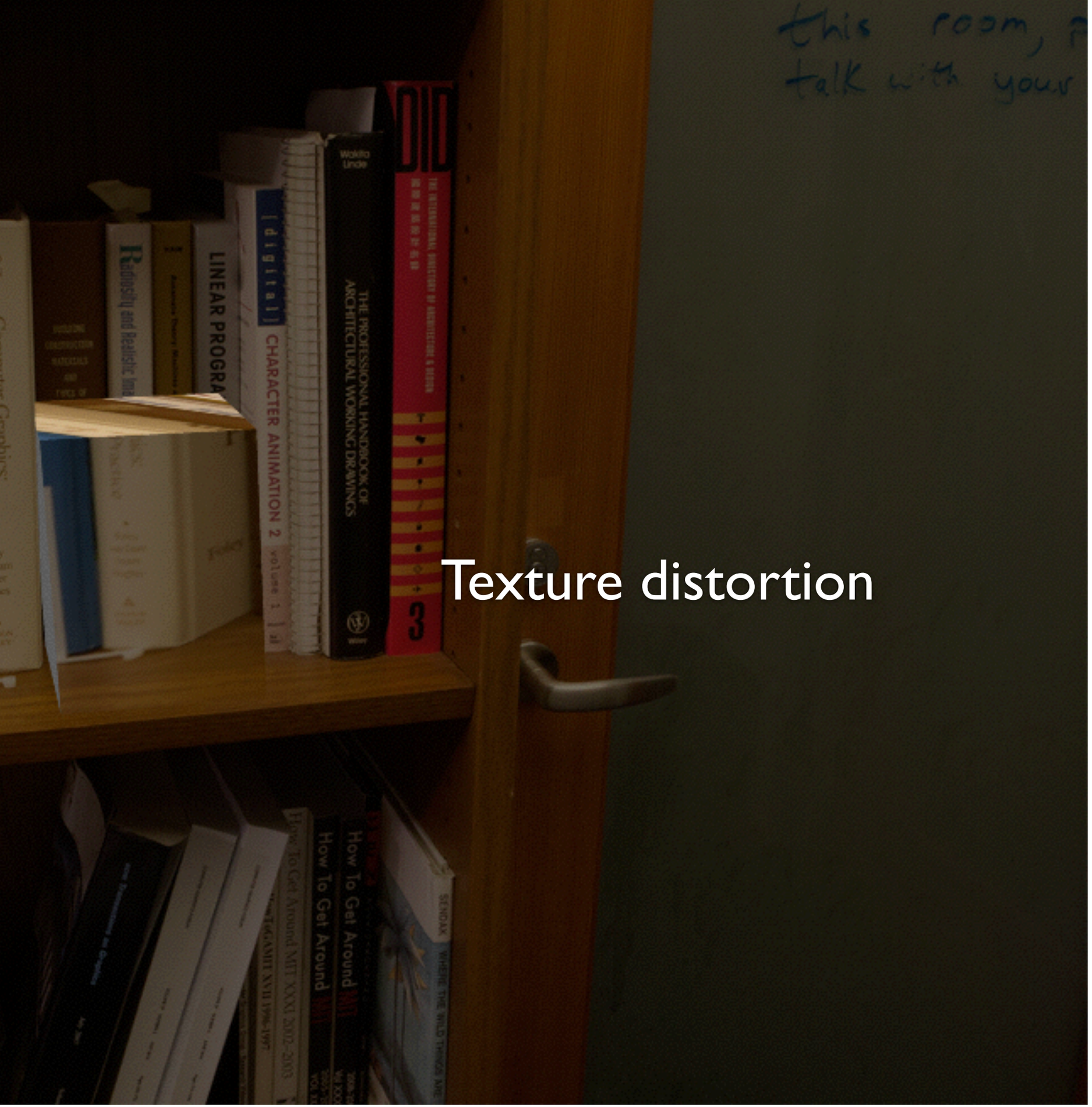
Camouflage problem

Camouflage problem


The Cg Tutorial
CRC STANDARD CURVES and SURFACES
Artificial Intelligence
A Modern Approach
MACHINES
THE PROFESSIONAL HANDBOOK OF
ARCHITECTURAL WORKING DRAWINGS
CGGM 2009



Occlusion boundaries



Texture distortion


Computer Graphics:
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A Top-Down Approach Using OpenGL
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ARCHITECTURAL WORKING DRAWINGS
Metric
How To Get Around
How To Get Around MIT XXXI 2002-2003
How To Get Around
SENDAK
WHERE THE WILD THINGS ARE
this room
talk with you

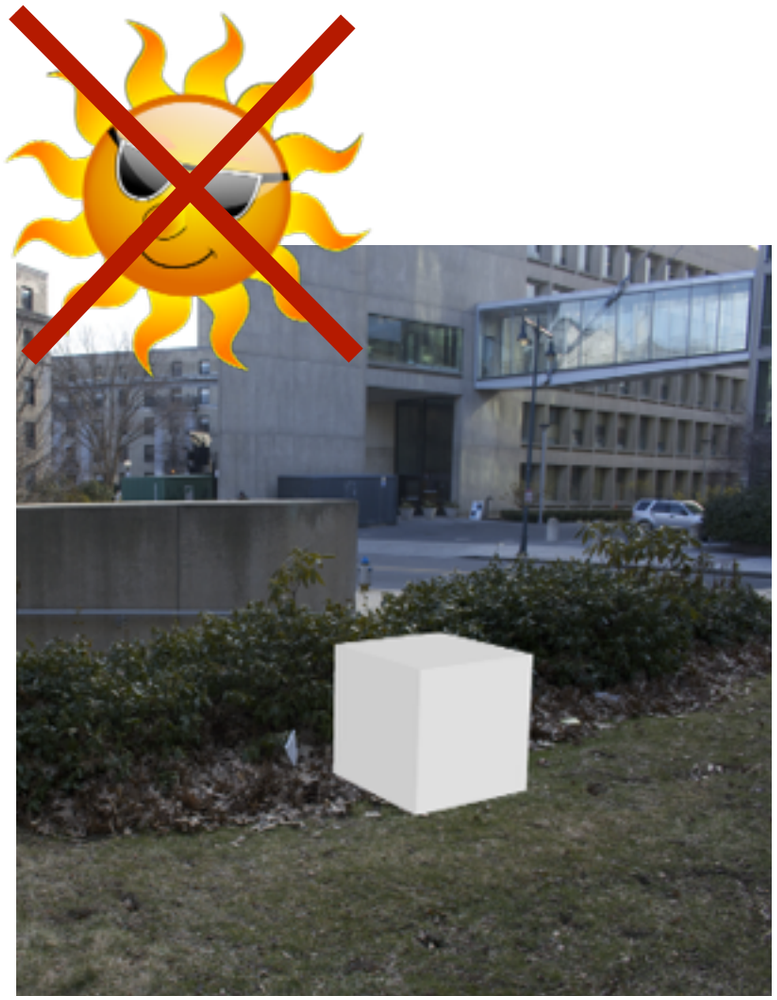
Interior seams

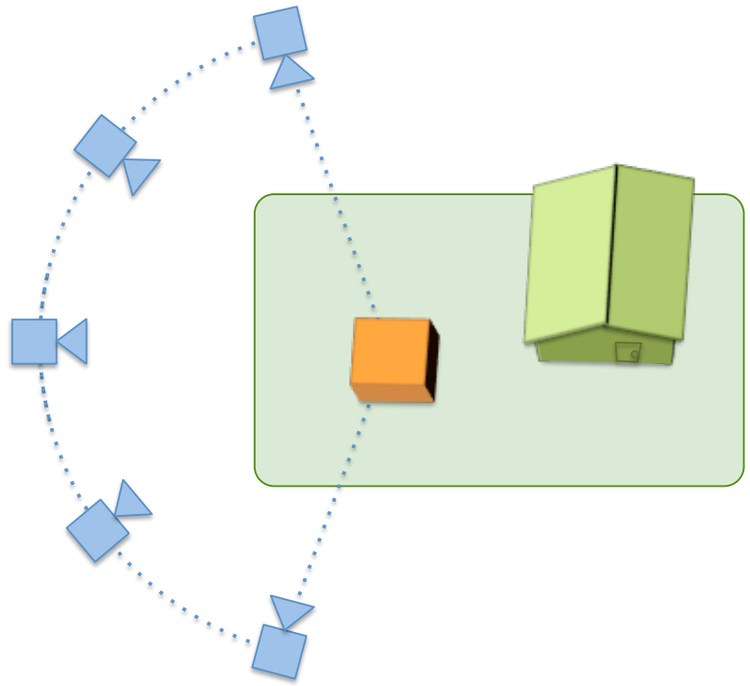
Camouflage model

Capturing a scene for camouflage

≈ 15 photos + camera pose

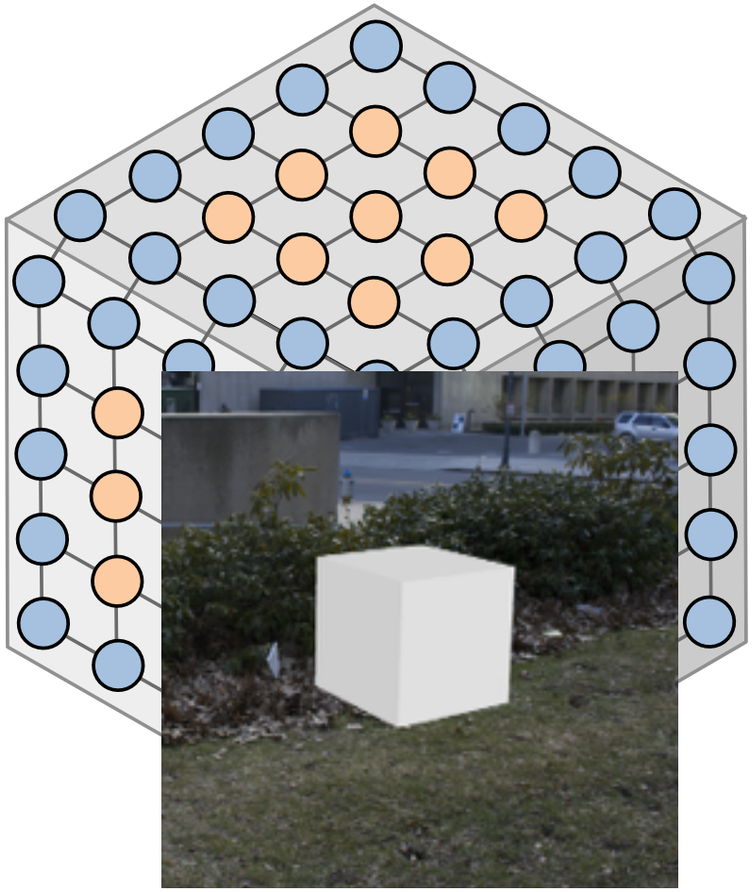
Capturing a scene for camouflage



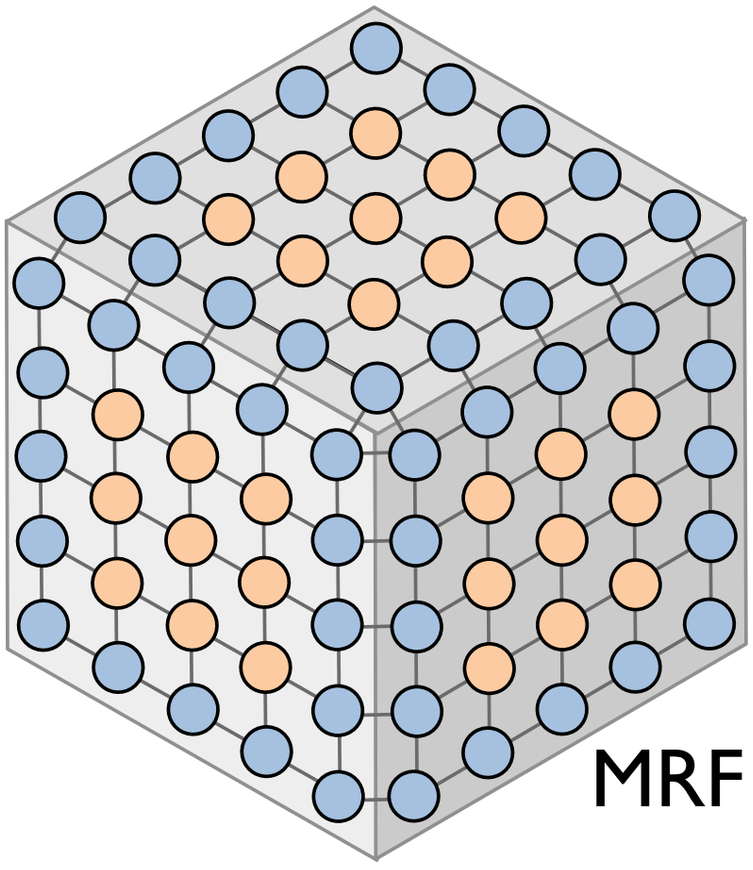


≈ 15 photos + camera pose

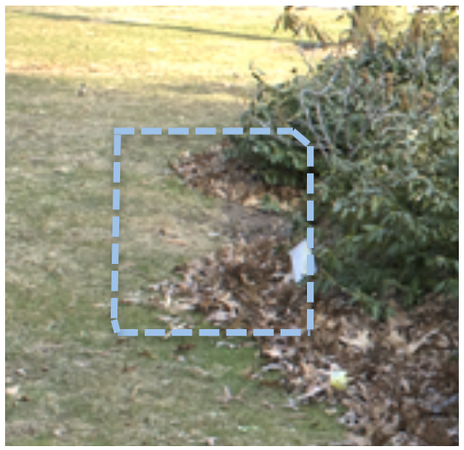
Texture synthesis model



Texture synthesis model

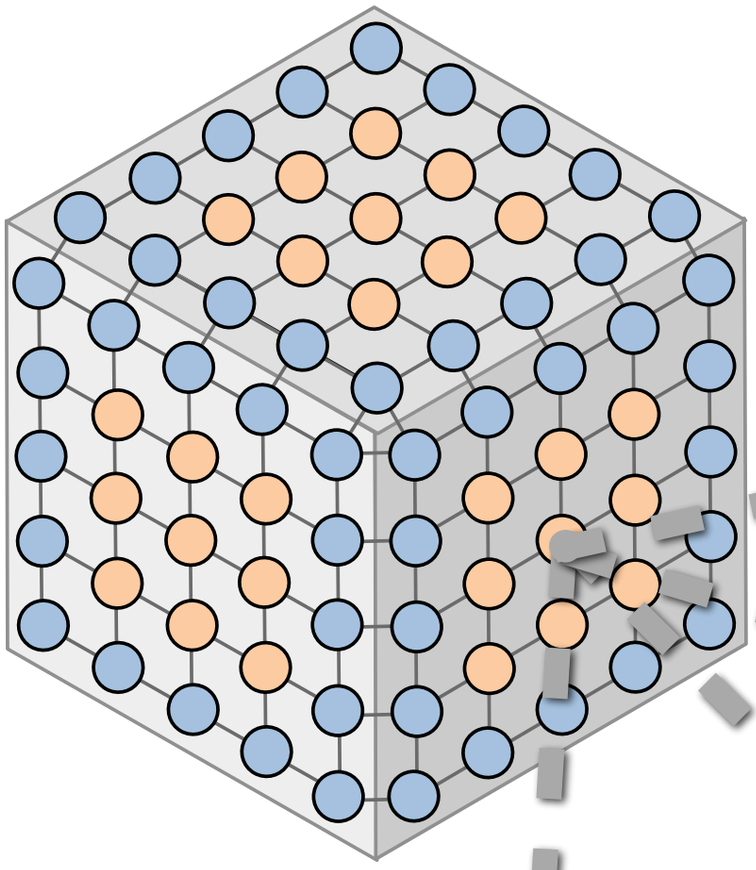


MRF

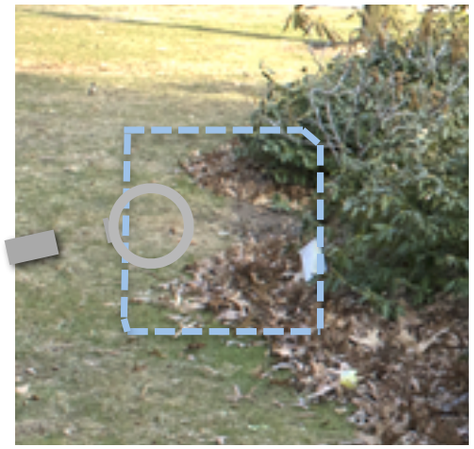


Shift-map image editing [Pritch09]
Seamless montage [Gal10]
Photomontage [Agrawala04]

Texture synthesis model



Label = view index



Label 4

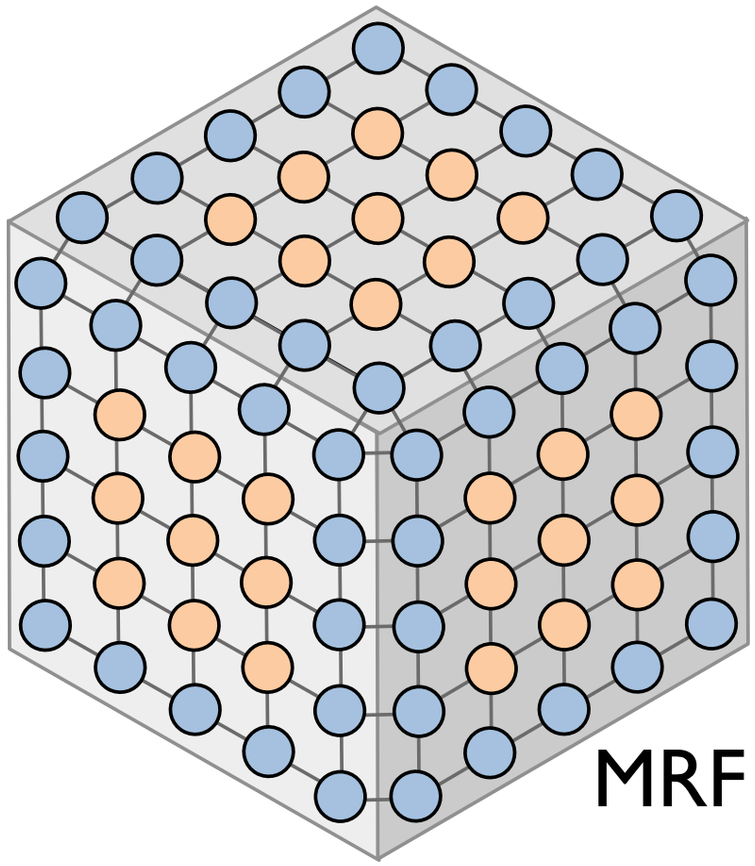
Label 3

Label 2

Label 1

Can optionally use pixel-shifted images for more labels [Pritch09]

Texture synthesis model



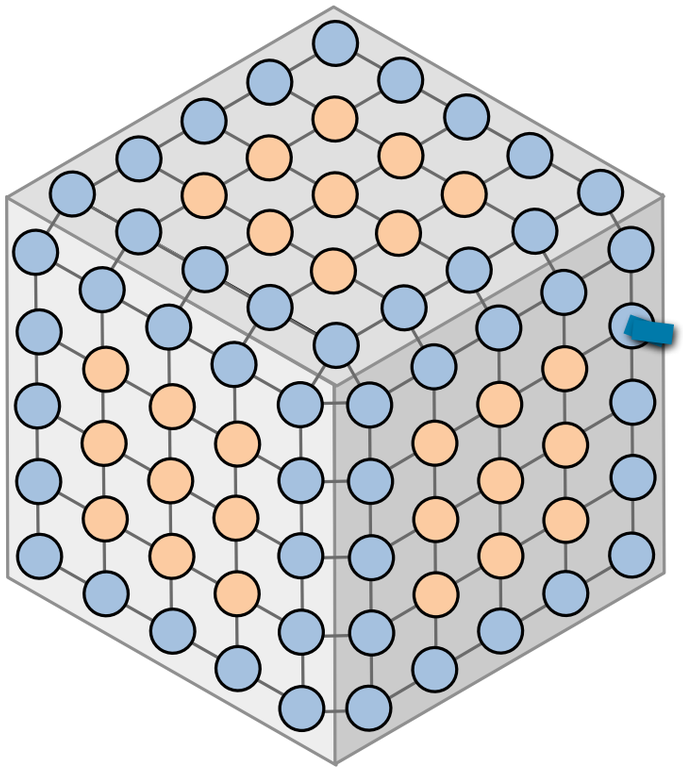
MRF

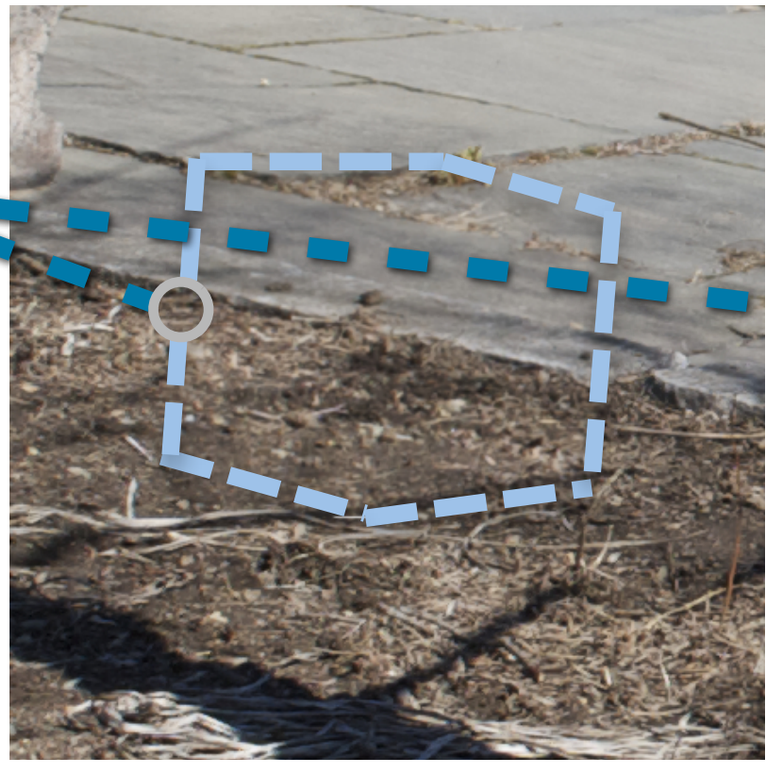
$$\sum_i \boxed{E_i(x_i)} + \sum_{i,j} E_{ij}(x_i, x_j)$$

discourages interior seams

$$E_i(x_i) = E_i^{\text{occlusion}}(x_i) + E_i^{\text{distortion}}(x_i)$$

Occlusion cues





View 1

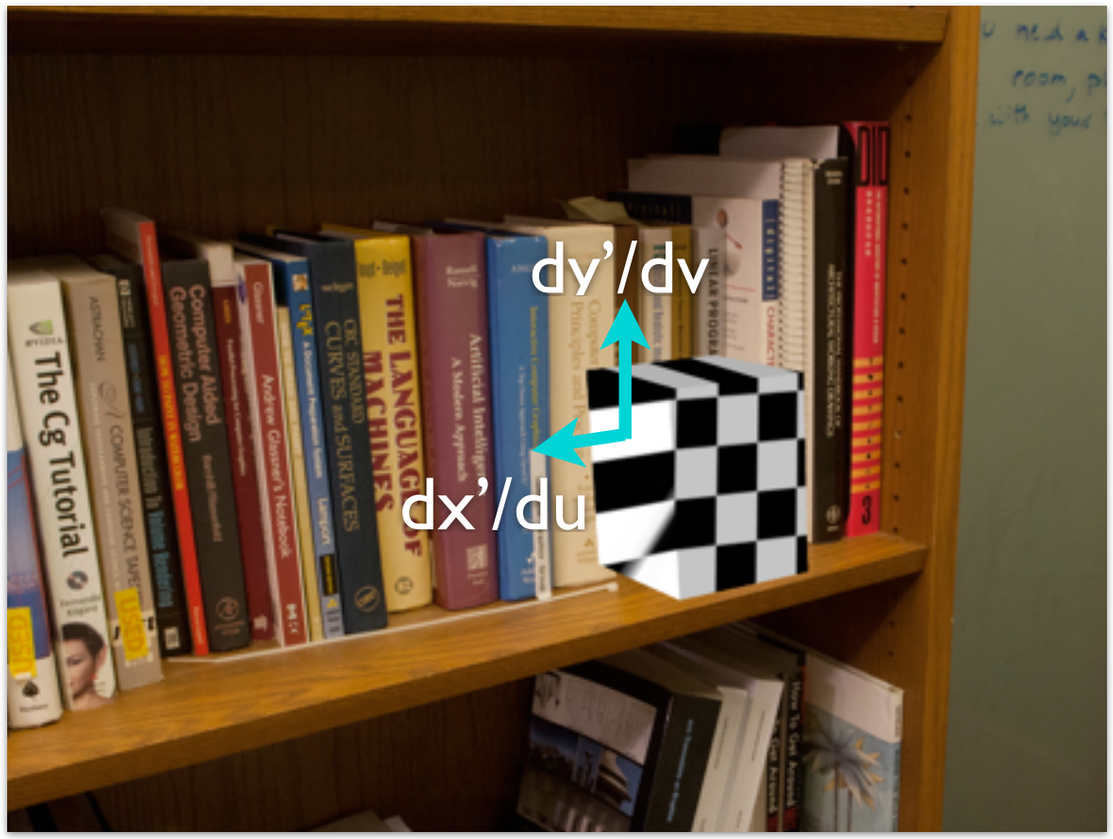
View 2

...

Measure how conspicuous the boundaries will be.

$$E^{\text{occlusion}}(x_i) = \frac{1}{n}\sum_{j=1}^{n} ||\underbrace{c_i(x_i)}_{\text{Label color}} - \underbrace{\tilde{c}_j}_{\text{Color seen in view } j}||$$

Texture distortion

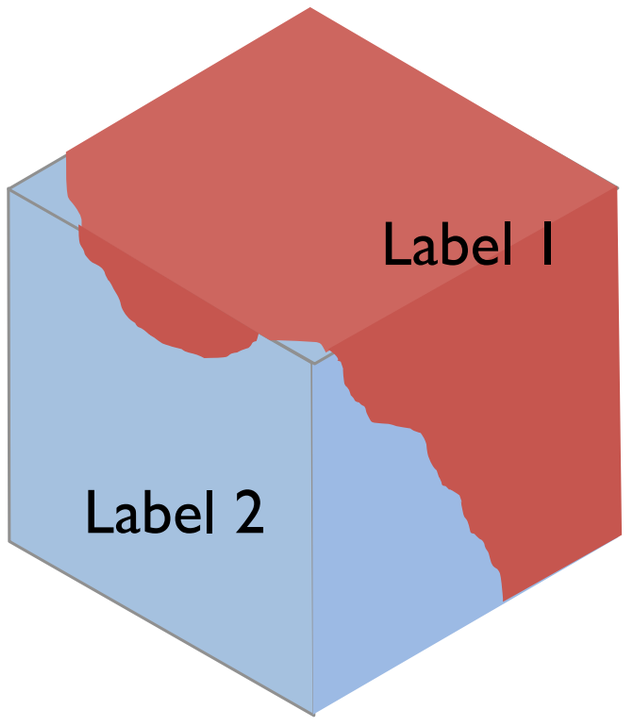


Discourage textures that will look distorted from other views.

$$E_i^{\text{distortion}}(x_i) = \frac{1}{n}\sum_{j=1}^{n} \underbrace{\rho(x_i, j)}_{\text{Distortion in view } j}$$

$\rho(x_i, j)$ penalizes large eigenvalues of $J = \begin{pmatrix} \frac{\partial x'}{\partial x} & \frac{\partial x'}{\partial y} \\ \frac{\partial y'}{\partial x} & \frac{\partial y'}{\partial y} \end{pmatrix}$

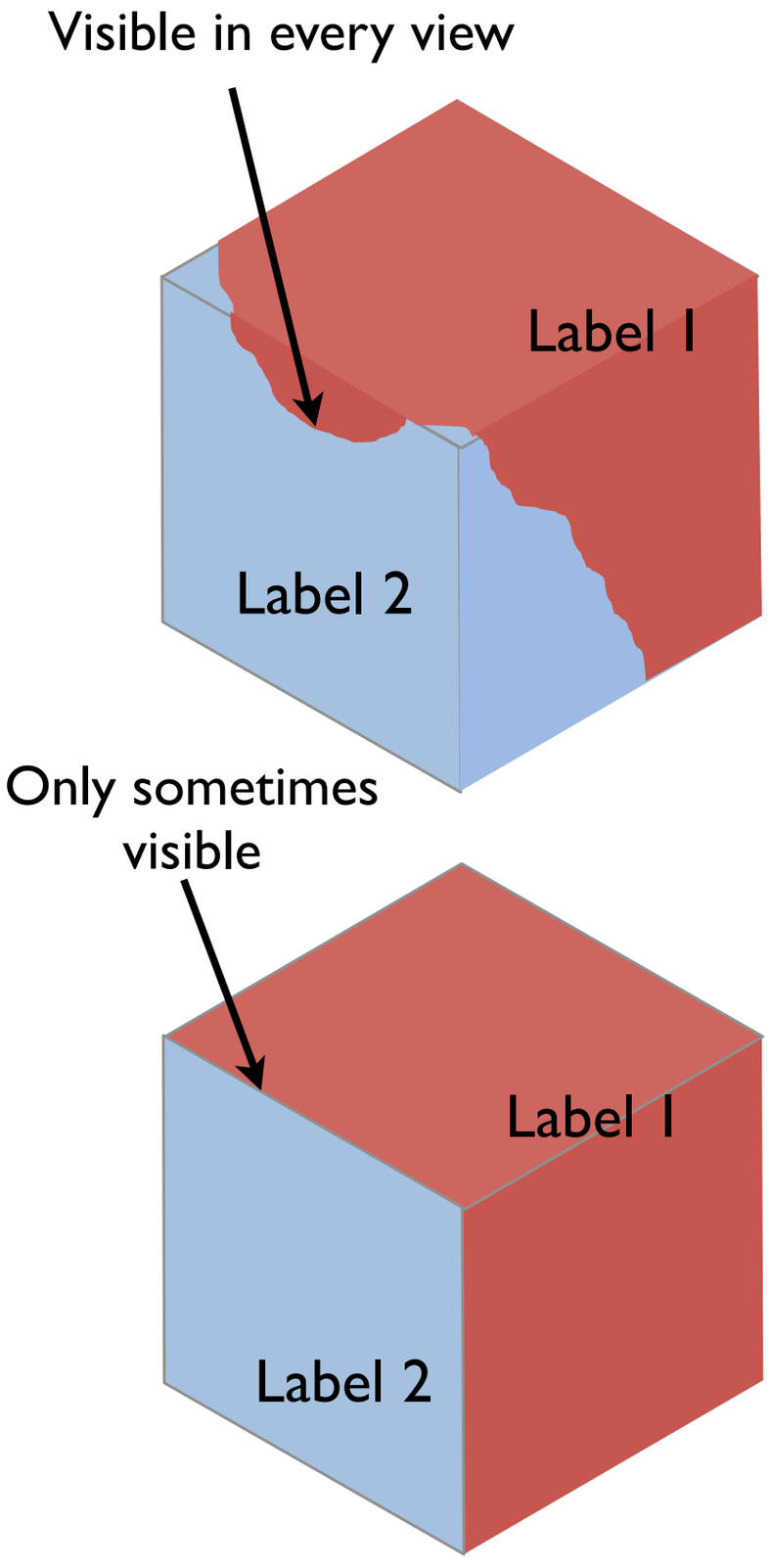
Interior seams



Interior MRF

- Allow seams to occur anywhere on the object
- Avoid texture gradients
- Shift-map smoothness function [Pritch09]

Interior seams

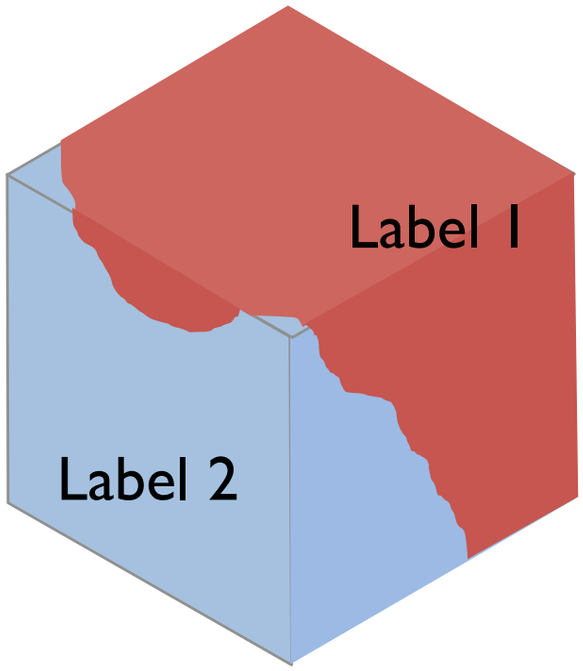


Interior MRF

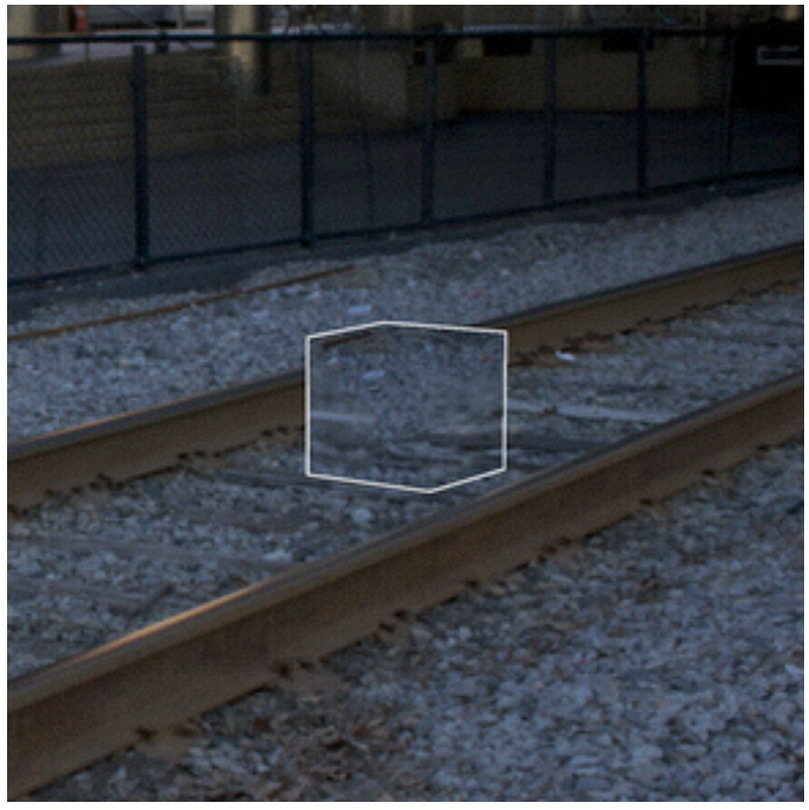
- Allow seams to occur anywhere on the object
- Avoid texture gradients
- Shift-map smoothness function [Pritch09]

Boundary MRF

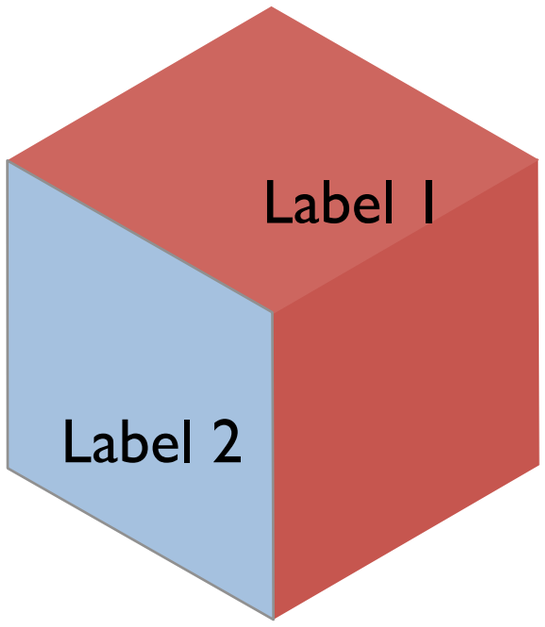
- Only allow seams at face boundaries
- Assign same label to all texels on a face
- Typically uses two labels for whole cube



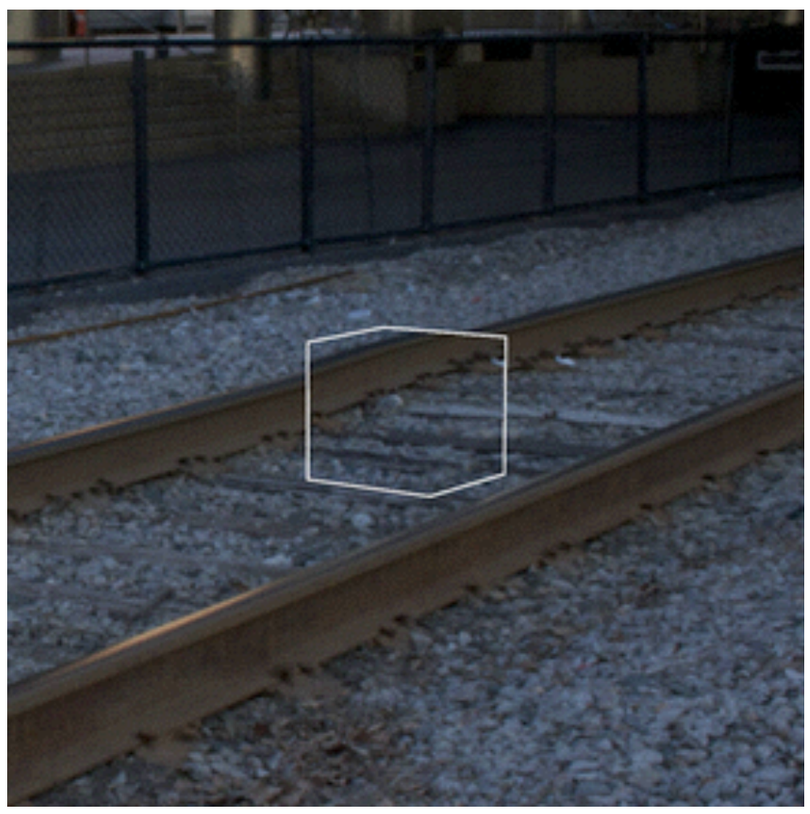
Interior MRF



Stitch together a texture from many images.



Boundary MRF



Hide perfectly from a representative viewpoint.

Camouflage game!

More at http://camouflage.csail.mit.edu


SUFFOLK

No box!

Experiments

Mean (baseline)

Random

- Mechanical Turk
- Measure *confusion rate* and *time-to-find*
- Show random viewpoint (varied per subject)
- Dataset containing 37 scenes

Experiments

Model	Confusion	Time to find	n
Mean	$9\% \pm 0$	$1.70\text{s} \pm 0.04$	328
Random	$25\% \pm 0$	$2.59\text{s} \pm 0.08$	288
Interior MRF	$\mathbf{30\% \pm 1}$	$2.90\text{s} \pm 0.10$	299
Boundary MRF	$\mathbf{30\% \pm 1}$	$\mathbf{3.25\text{s} \pm 0.13}$	284

1.5s

- Models significantly outperform *Mean* baseline
- Similar confusion rates
- Boundary MRF takes longest to find.

Applications

By Joshua Callaghan

Trompe-l'œil


au bon pain au bon pain au bon
au bon pain au bon


au bon pain au bon pain
au bon pain au bon pain

Code and data will be released on our webpage: http://camouflage.csail.mit.edu

Thank you!

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Thanks: Yichang Shih, Abe Davis, Phillip Isola, Yair Weiss, Ruth Rosenholtz's group