Computational Photography

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http://www.cs.pdx.edu/~fliu/courses/cs510/

05/10/2022

With slides by S. Chenney , Y.Y. Chuang, F. Durand, and J. Sun.

Last Time

- Image segmentation

Today

- Matting

Input | user specified trimap | matte | foreground colors | a new composite

Reprint from Wang and Cohen 2007

Problem of segmentation

- Each pixel is assigned a binary label
  - Foreground or
  - Background
- Cannot generate natural boundaries for semi-transparent objects

Problem of segmentation

Input
Reprint from Sun et al. 2004

Photoshop segmentation result

Segmentation and Matting

- Segmentation
  - Binary labeling, 0 or 1
- Matting
  - A continuous value between [0, 1]

Background: Compositing

- Compositing combines components from two or more images to make a new image
  - Special effects are easier to control when done in isolation
  - Even many all live-action sequences are more safely shot in different layers

Credit: S. Chenney

Example: Perfect Storm

Credit: S. Chenney

Mattes

- A *matte* is an image that shows which parts of another image are foreground objects
- Term dates from film editing and cartoon production
- How would I use a matte to insert an object into a background?
- How are mattes usually generated for television?

Credit: S. Chenney

Working with Mattes

- Compositing: insert an object into a background
  - Call the image of the object the source
  - Put the background into the destination
  - For all the source pixels, if the matte is white, copy the pixel, otherwise leave it unchanged
- Matting: generate mattes
  - Use smart selection tools in Photoshop or similar
    - They outline the object and convert the outline to a matte
  - **Blue Screen:** Photograph/film the object in front of a blue background, then consider all the blue pixels in the image to be the background
  - Advanced matting techniques

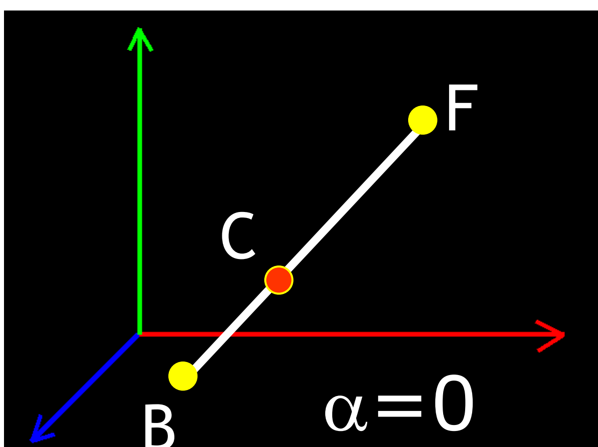
Credit: S. Chenney

Alpha

- Basic idea: Encode opacity information in the image
- Add an extra channel, the *alpha* channel, to each image
  - For each pixel, store R, G, B and Alpha
  - alpha = 1 implies full opacity at a pixel
  - alpha = 0 implies completely clear pixels
  - alpha in (0,1) implies semi-transparency
- There are many interpretations of alpha
  - Is there anything in the image at that point (web graphics)
  - Transparency (real-time OpenGL)
- Images are now in RGBA format, and typically 32 bits per pixel (8 bits for alpha)

Credit: S. Chenney

Over Compositing



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

Credit: Y.Y. Chuang

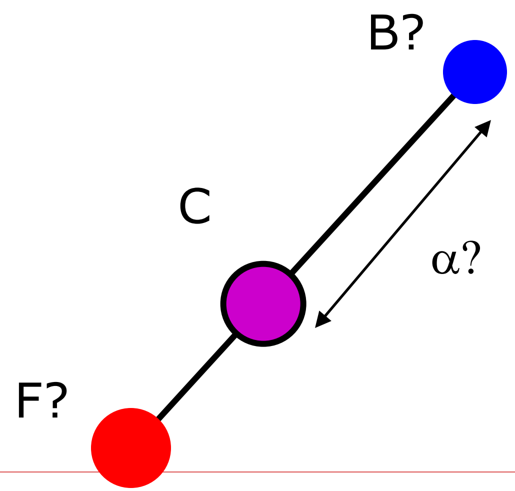
Oscar Award, 1996

Smith Duff Catmull Porter

Credit: Y.Y. Chuang

Matting problem

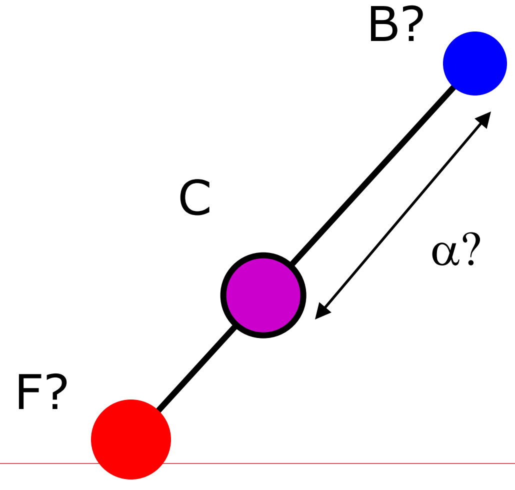
- Inverse problem:
  Assume an image is the *over* composite of a foreground and a background
- Given an image color C, find F, B and α so that
  $C=\alpha F+(1-\alpha)B$



Credit: F. Durand

Matting ambiguity

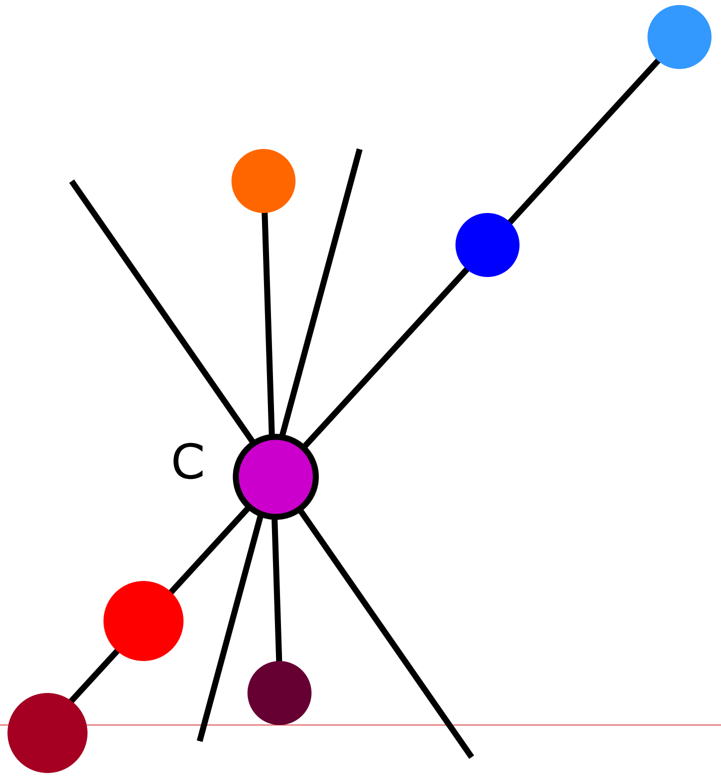
- $C = \alpha F + (1-\alpha)B$
- How many unknowns, how many equations?



Credit: F. Durand

Matting ambiguity

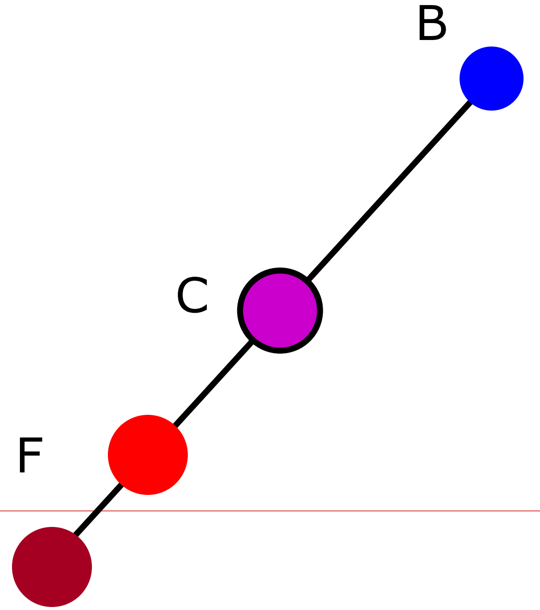
- $C=\alpha F+(1-\alpha)B$
- 7 unknowns: α and triplets for F and B
- 3 equations, one per color channel



Credit: F. Durand

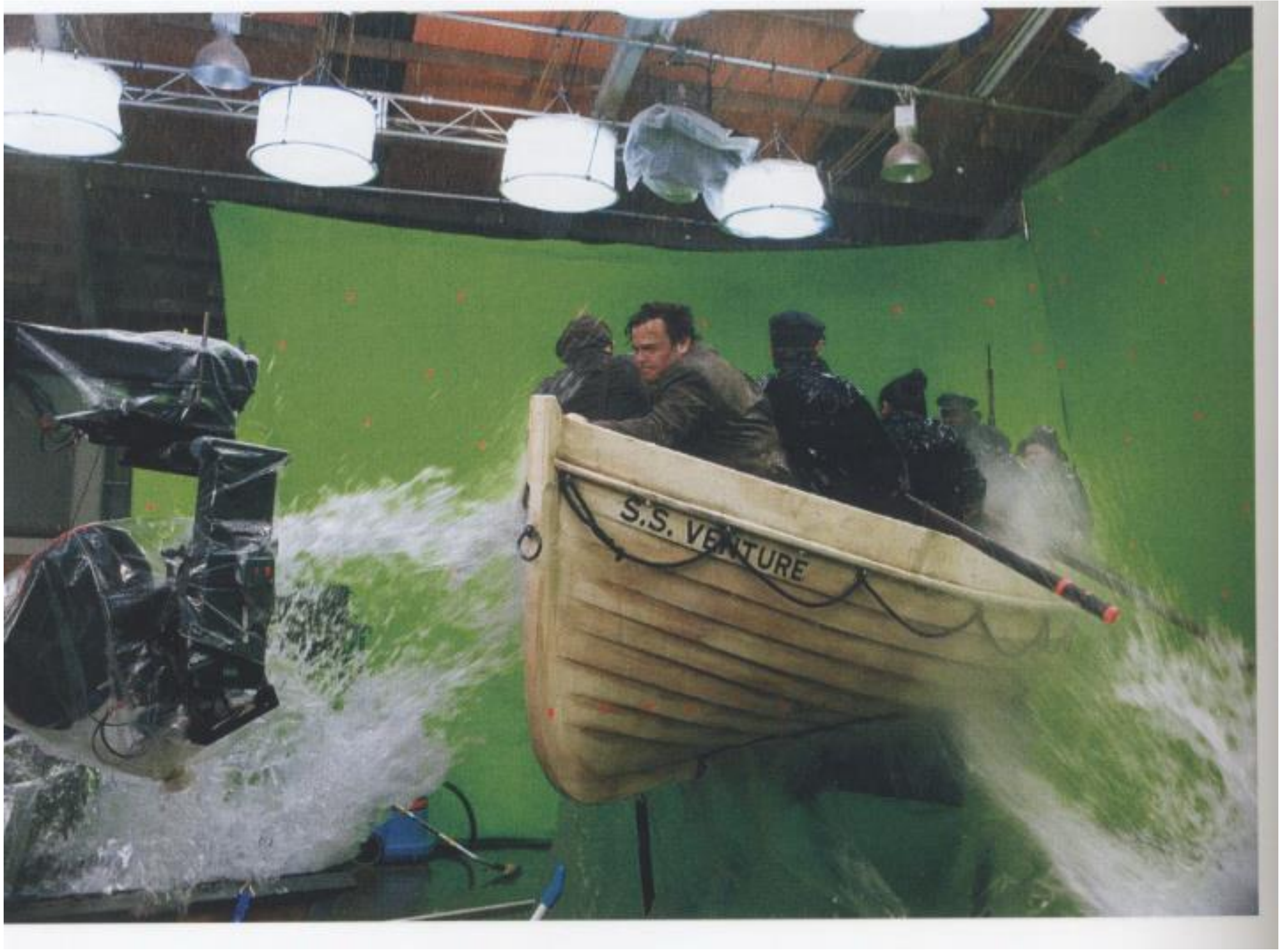
Matting ambiguity

- $C=\alpha F+(1-\alpha)B$
- 7 unknowns: α and triplets for F and B
- 3 equations, one per color channel
- With known background (e.g. blue/green screen): 4 unknowns, 3 equations



Credit: F. Durand

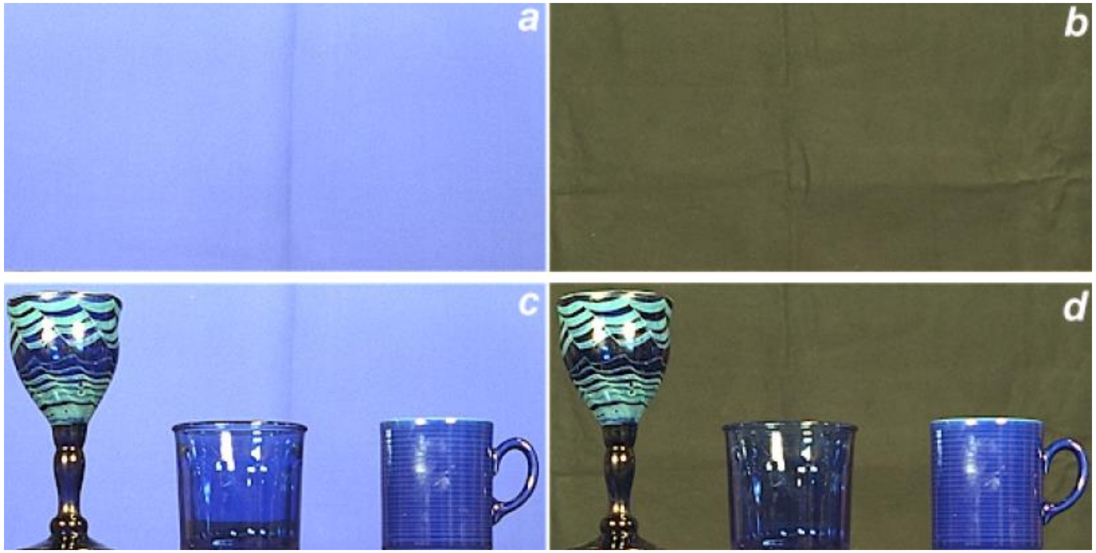
Questions?



Credit: F. Durand

From Cinefex

Multiple backgrounds matting



→ Backgrounds are estimated

→ Unknown: $\{\alpha, F_r, F_g, F_b\}$

We have 6 equations for 3 color channels in 2 images, and 4 unknowns.

Credit: J. Sun

Traditional blue screen matting

- Invented by Petro Vlahos
  (Technical Academy Award 1995)
- Recently formalized by Smith & Blinn
- Initially for film, then video, then digital
  - Assume that the foreground has no blue

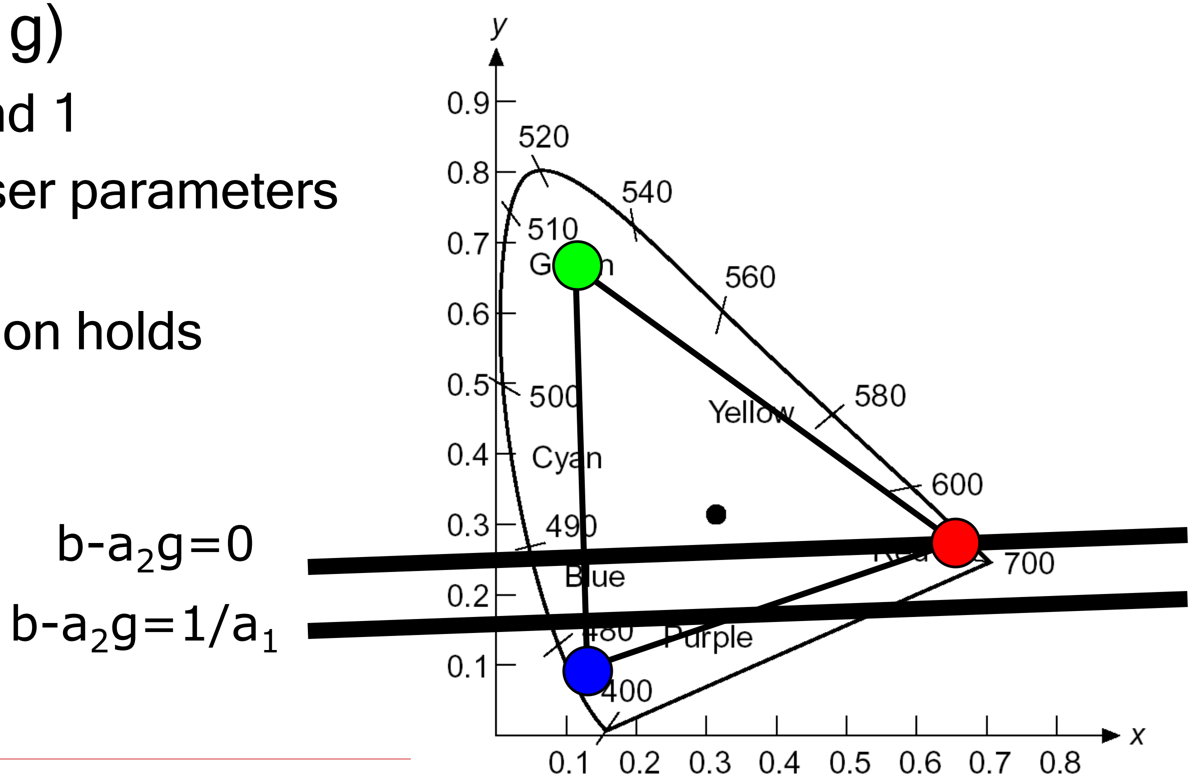
Petro Vlahos
GORDON E. SAWYER AWARD
66TH ACADEMY AWARDS
1993

From Cinefex

Credit: F. Durand

Traditional blue screen matting

- Alternatively, assume that blue *b* and green *g* channels of the foreground respect $b <= a_2 g$ for a_2 typically between 0.5 and 1.5
- $\alpha = 1 - a_1(b - a_2 g)$
  - clamped to 0 and 1
  - a_1 and a_2 are user parameters
  - Note that $\alpha = 1$ where assumption holds



Credit: F. Durand

Blue/Green screen matting issues

- Color limitation
  - Annoying for blue-eyed people
- Blue/Green spilling
  - The background illuminates the foreground, blue/green at silhouettes
  - Modify blue/green channel, e.g. set to min (b, a_2g)
- Shadows
  - How to extract shadows cast on background

Credit: F. Durand

Blue/Green screen matting issues

Plate 52 *(b) The element placed into the scene without spill suppression. Note the blue fringes on the subject, particularly in the hair.*

Credit: F. Durand

From the Art & Science of Digital Compositing

Questions?

Credit: F. Durand

Advanced matting techniques

- Bayesian matting
- Poisson matting
  - Jian Sun, Jiaya Jia, Chi-Keung Tang, and Heung-Yeung Shum, SIGGRAPH 2004
- Robust matting
- Soft Scissors
- …

Natural image matting

- Solving complex α, F, B given a single natural image I and a user input trimap

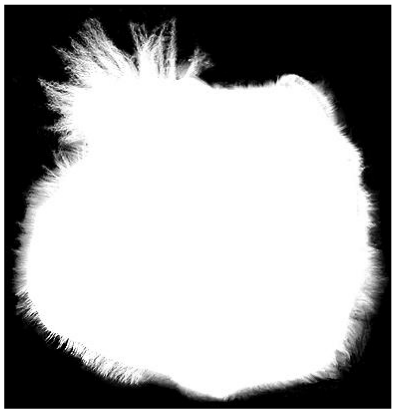
$$\rightarrow \left\{ \begin{matrix} & \alpha & \\ F_r & F_g & F_b \\ B_r & B_g & B_b \end{matrix} \right\}$$

We have only 3 equations for 7 unknowns!

Credit: J. Sun

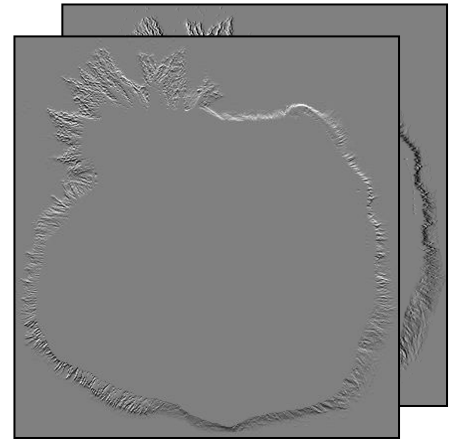
Gradient Manipulation: Poisson Matting

$$\mathbf{g} = -\nabla \alpha$$



α Matte (Potential)

$$\Delta \alpha = div(\mathbf{g})$$



$\mathbf{g}$ Matte Gradient

$$\Delta \equiv \frac{\partial^2}{\partial^2 x} + \frac{\partial^2}{\partial^2 y} \qquad div(\mathbf{g}) \equiv \frac{\partial g_x}{\partial x} + \frac{\partial g_y}{\partial y}$$

Credit: J. Sun

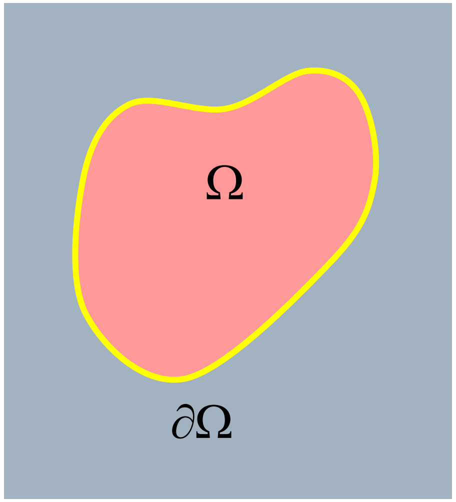
Poisson Equation

Given the destination matte gradient *v*, the optimization problem becomes:

$$\min_{\alpha} \iint_{\Omega} |\nabla \alpha - v|^2 \text{ with } \alpha|_{\partial\Omega} = \alpha^*|_{\partial\Omega}$$

$$\Downarrow$$

$$\Delta \alpha = div(\mathbf{g}) \quad s.t. \ \alpha|_{\partial\Omega} = \alpha^*|_{\partial\Omega}$$



Credit: J. Sun

Global Poisson Matting

- From matting equation:

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

- Taking partial derivatives:

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

- Case I: foreground and background have much smaller gradient values

$$\nabla I \approx (F - B)\nabla \alpha$$

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

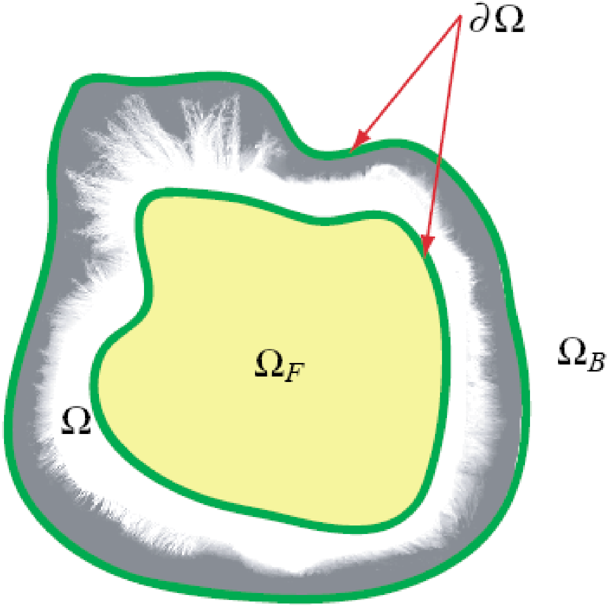
  - Other cases can be handled similarly

Credit: J. Sun

Solving Matting Poisson Equations

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

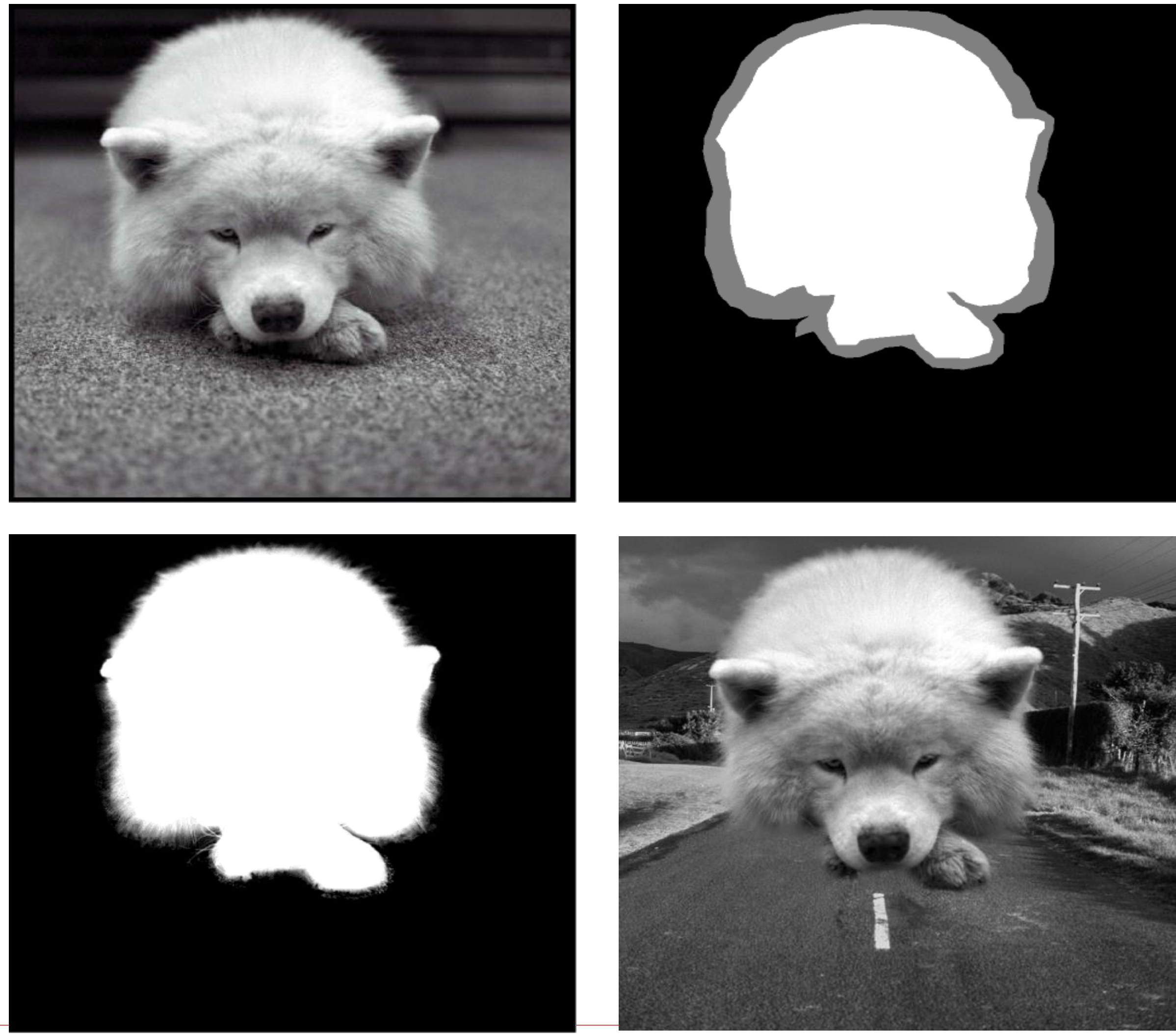
is a guidance field, an approximation of matte gradient.



$$\Delta \alpha = div\left(\frac{\nabla I}{F - B}\right) \quad \text{s.t.}\ \alpha|_{\partial\Omega} = \begin{cases} 1 & \mathbf{x} \in \Omega_F \\ 0 & \mathbf{x} \in \Omega_B \end{cases}$$

Credit: J. Sun

Global Poisson matting result



http://www.cse.cuhk.edu.hk/~leojia/all_project_webpages/Poisson%20matting/Poissonmatting.mov

Credit: J. Sun

Student paper presentation

Learning to See in the Dark

C. Chen, Q. Chen, J. Xu and V. Koltun
IEEE CVPR 2018

Presenter: Mcgowan, Travis

Student paper presentation

Video Tapestries with Continuous Temporal Zoom

C. Barnes, D. Goldman, E. Shechtman,
and A. Finkelstein
SIGGRAPH 2010

Presenter: McKinney, Drew

Next Time

- Video stabilization
- Student paper presentations
  - 05/12: Rojas, Casey
    - Poisson image editing. P. Pérez, M. Gangnet, and A. Blake, SIGGRAPH 2003
  - 05/12: Smith, Cassaundra
    - Intelligent scissors for image composition. E. Mortensen and W. Barrett. SIGGRAPH 1995