ENGN 8501

Week#4: Computational Photography-2:

Natural Image Matting

2021 S2

Project proposal due date → week-6

On some of your request, the project proposal/team forming deadline has been deferred by one week until Thursday Week-6, to mitigate impact of the sudden covid lock down.

However, regardless this, you should start to prepare or WORK on your project from NOW.

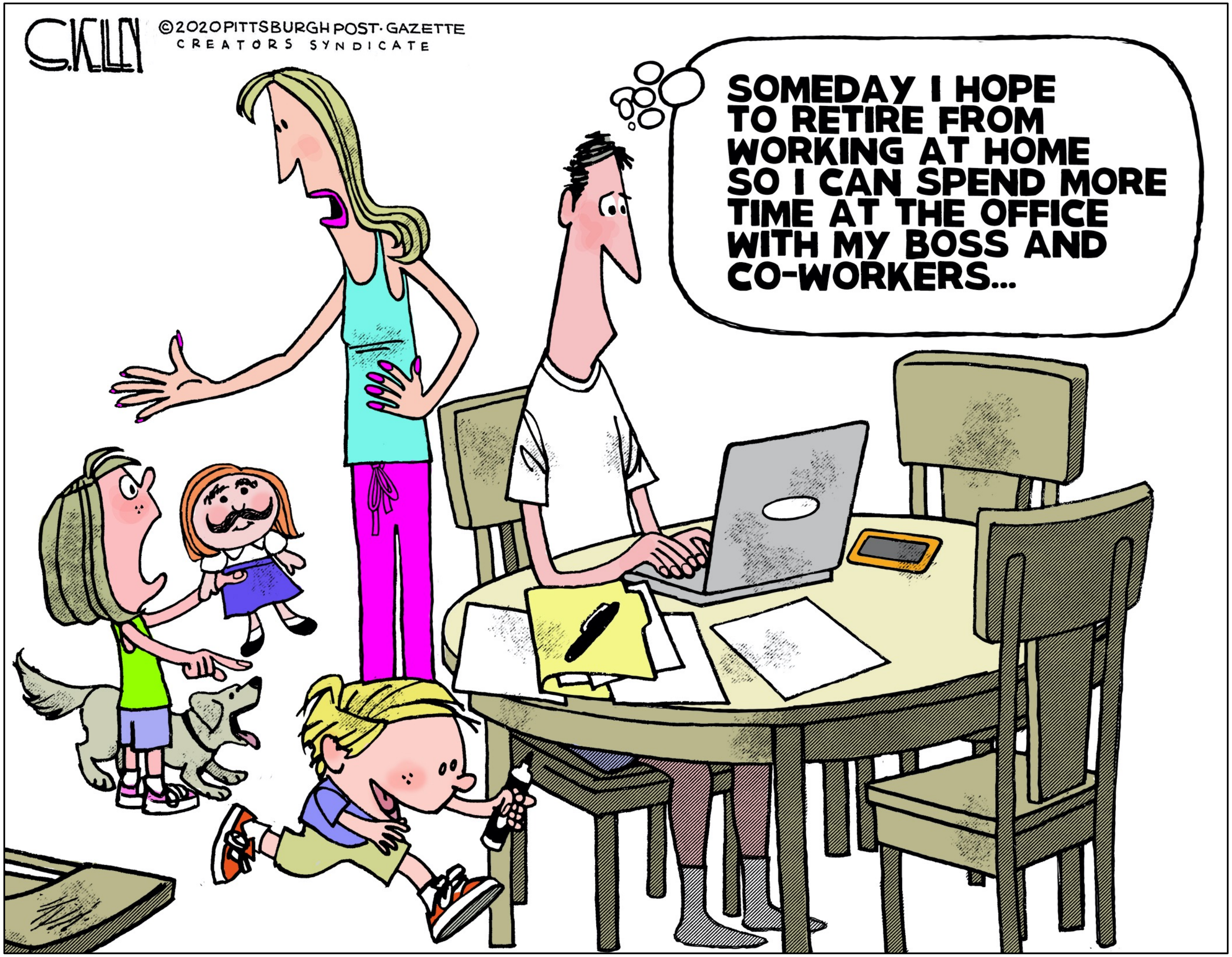
The google-spreadsheet link for registering Project teams (and paper) will be posted on Wattle (under "Research Project" topic).

From next week onward

Resume to normal timetable (Monday lecture, Thursday tute).

However, all activities will be online zoom-based, until further notice.

We are back to "**working from home**" again.. in ACT.


S.KELLEY
©2020 PITTSBURGH POST-GAZETTE
CREATORS SYNDICATE
SOMEDAY I HOPE TO RETIRE FROM WORKING AT HOME SO I CAN SPEND MORE TIME AT THE OFFICE WITH MY BOSS AND CO-WORKERS...

Today’s plan

First one hour: Paper reading session on **Natural Image Matting**

Then, (a short) breakout room session (discuss paper #2) + report exercise (20 minutes)

Finally, the last 30 minutes: **Research Project Q&A session**

General Introduction:

What is Image Matting ?

How does Superman fly?

Super powers ?

OR

Image Matting ?

Play with Zoom’s “virtual background”

“Pulling a Matte” in film/movie industry

Problem Definition:

- The separation of an image C into
  - A foreground object image C_F,
  - a background image C_B,
  - and an alpha matte α
- C_F and α can then be used to composite the foreground object into a different image

Hard problem

- Even if alpha is binary, this is hard to do automatically (image segmentation problem)
- For movies/TV, manual segmentation of each frame is infeasible
- Need to make a simplifying assumption…

Blue Screen matting

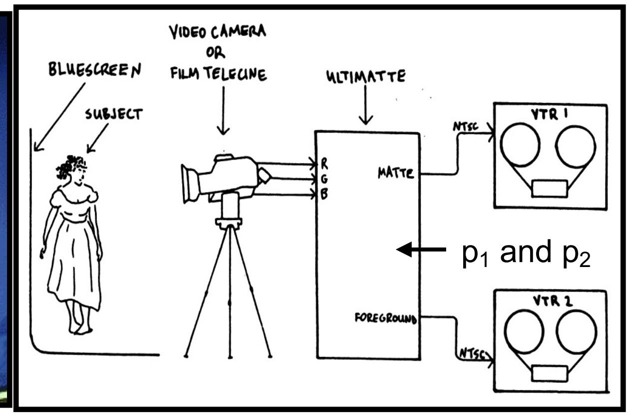
Most common form of matting in TV studios & movies

Petros Vlahos invented blue screen matting in the 50s. His Ultimatte® is still the most popular equipment. He won an Oscar for lifetime achievement.

A form of background subtraction:

- Need a known background
- Compute alpha as SSD(C,Cb) > threshold
  - Or use Vlahos' formula: $\alpha = 1\text{-}p_1(B\text{-}p_2G)$
- Hope that foreground object doesn't look like background
  - no blue ties!
- Why blue?
- Why uniform?

Blue/Green Screen



Color difference


Blue/Green Screen

Which movie is this ?

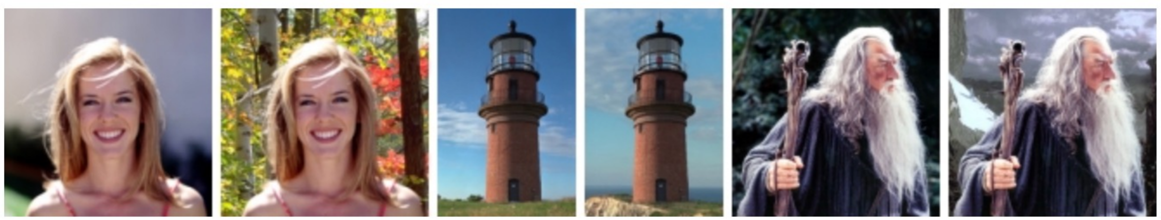
From Cinefex

Paper #1 to read today : Bayesian matting

A Bayesian Approach to Digital Matting

Yung-Yu Chuang[1] Brian Curless[1] David Salesin[1,2] Richard Szeliski[2]

[1]University of Washington [2]Microsoft Research



Paper #2 to read today: background matting v1

https://grail.cs.washington.edu/projects/background-matting/

Background Matting: The World is Your Green Screen

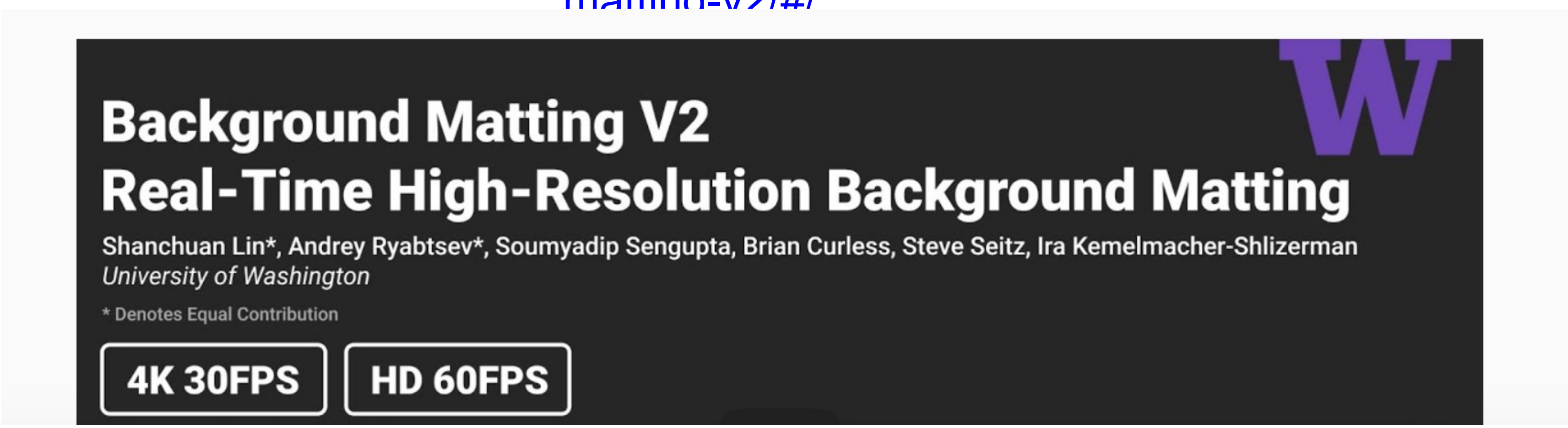
We capture 2 images, with and without the subject. Captured Image and Background Predicted Alpha Matte Composite Image

By Soumyadip Sengupta, Vivek Jayaram, Brian Curless, Steve Seitz, and Ira Kemelmacher-Shlizerman

This paper will be presented in IEEE CVPR 2020.

Paper #3 to read today: **Background Matting -v2**

https://grail.cs.washington.edu/projects/background-matting-v2/#/



Paper#1: Bayesian Matting

A Bayesian Approach to Digital Matting

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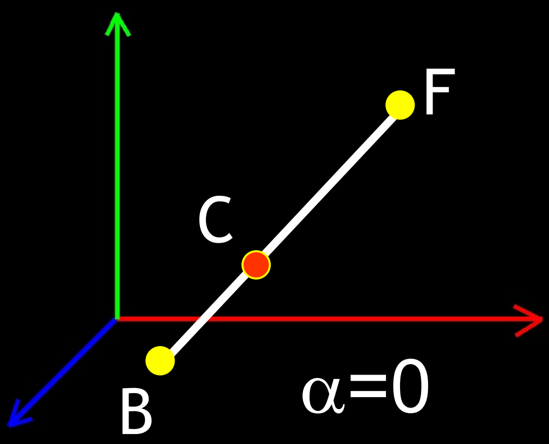
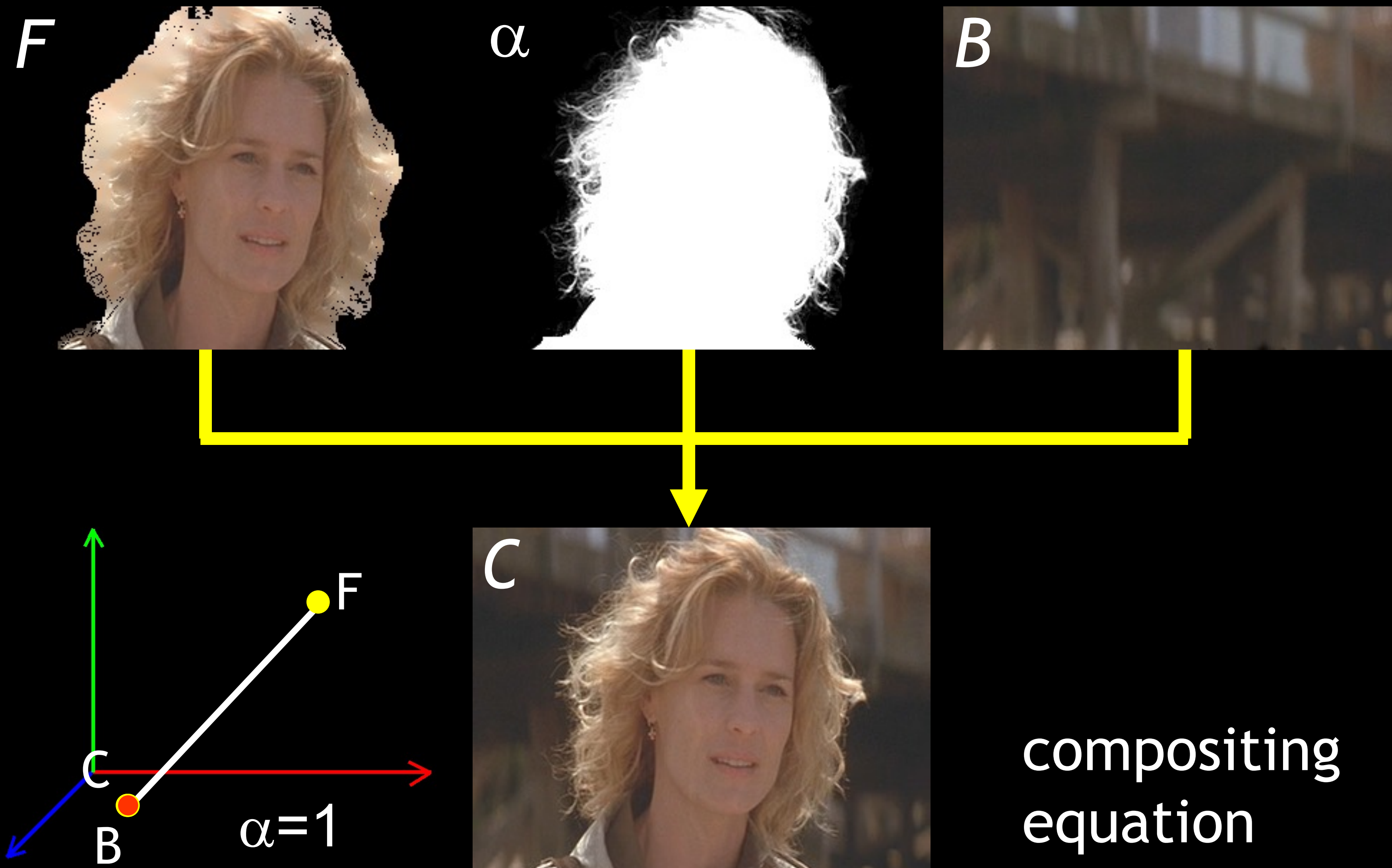
α

foreground color alpha matte background plate



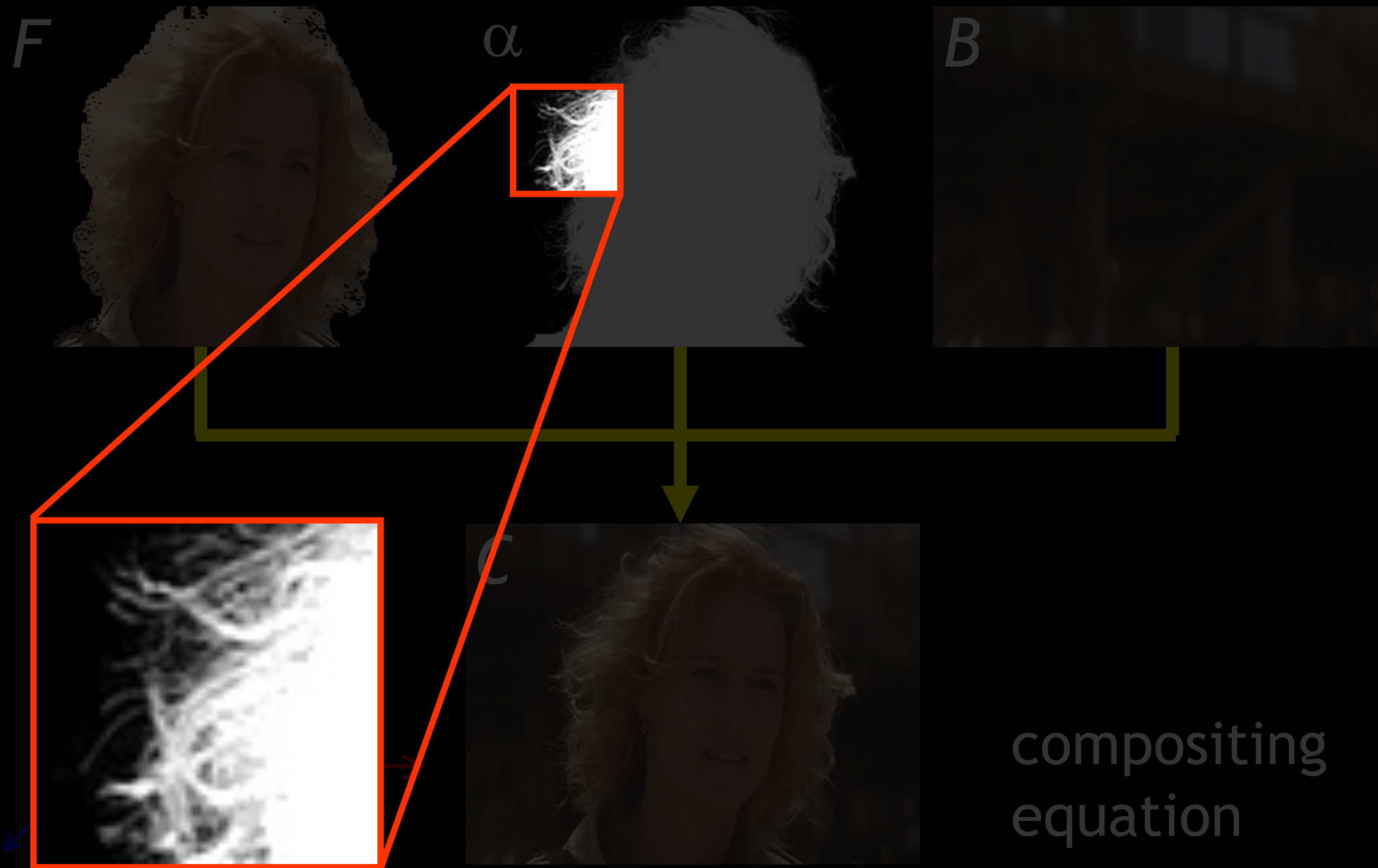
compositing equation

Compositing



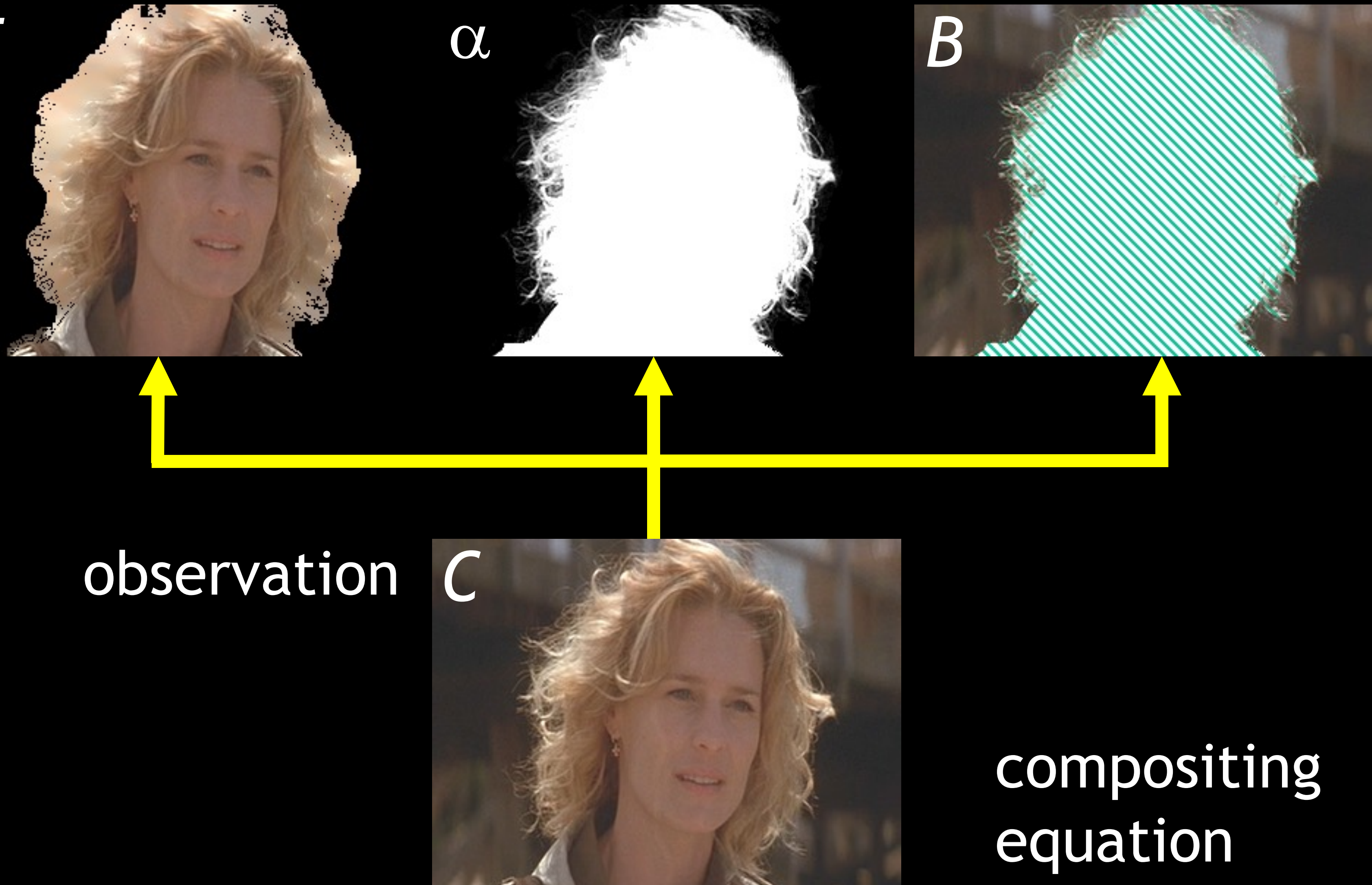
compositing
equation

Compositing



compositing
equation

Compositing



Matting

The matting Equation

$$I_i = \alpha_i F_i + (1 - \alpha_i) B_i$$

How many unknowns versus eqs?

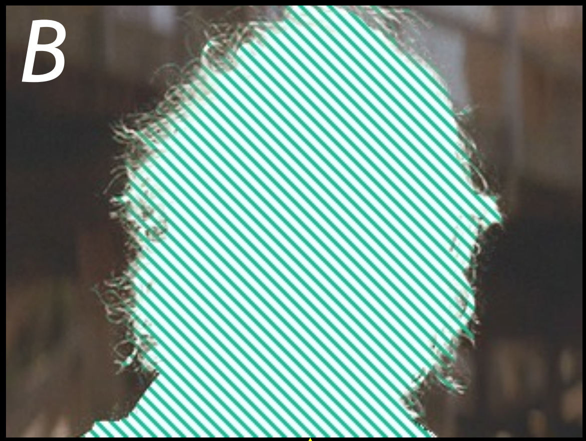
$$I_i = \alpha_i F_i + (1 - \alpha_i) B_i$$

$$I^R{}_i = \alpha_i F_i{}^R + (1 - \alpha_i) B_i{}^R$$

$$I^G{}_i = \alpha_i F_i{}^G + (1 - \alpha_i) B_i{}^G$$

$$I^B{}_i = \alpha_i F_i{}^B + (1 - \alpha_i) B_i{}^B$$

Matting is ill posed: 7 unknowns but 3 constraints per pixel



Three approaches:

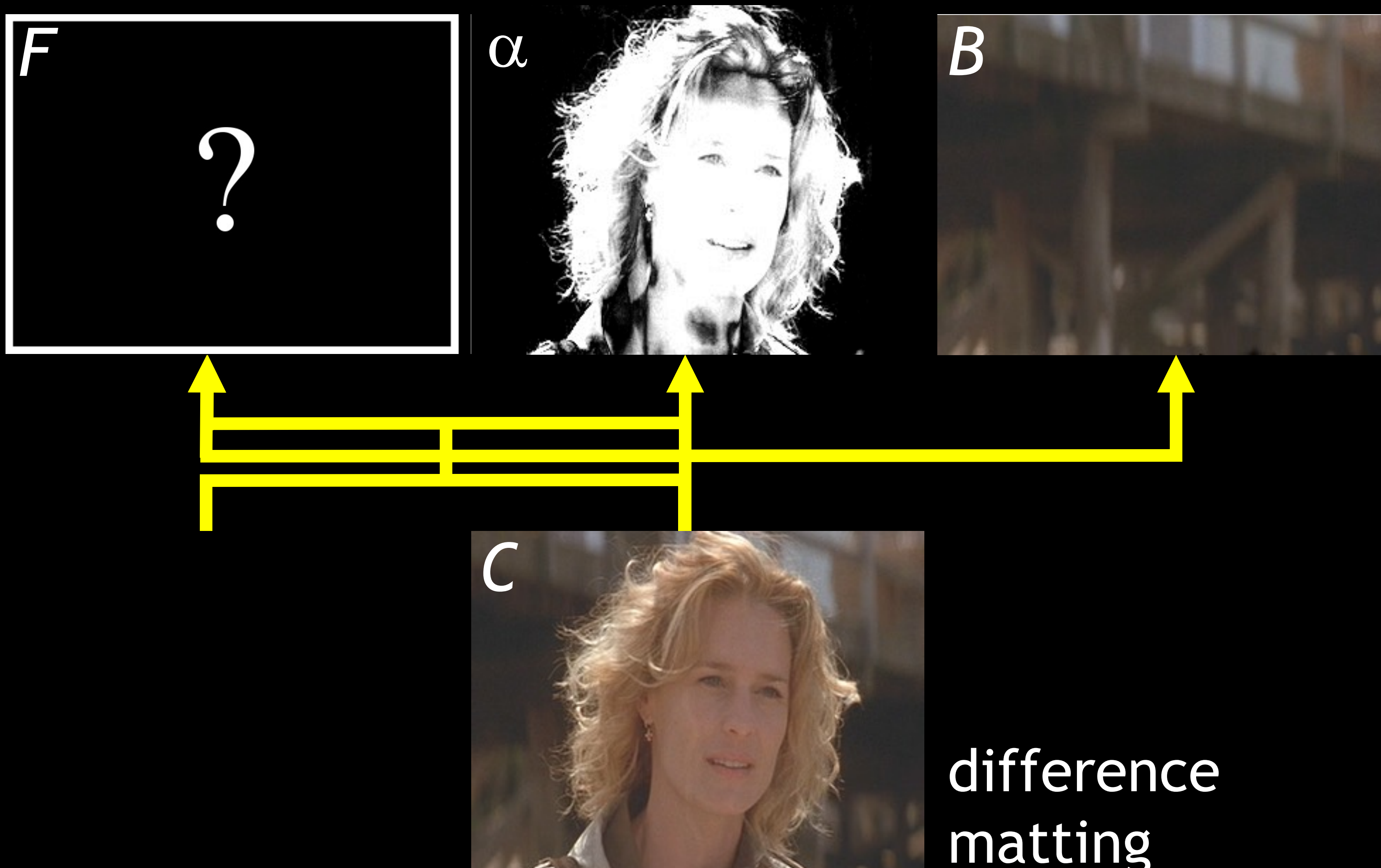
1 reduce #unknowns

2 add observations

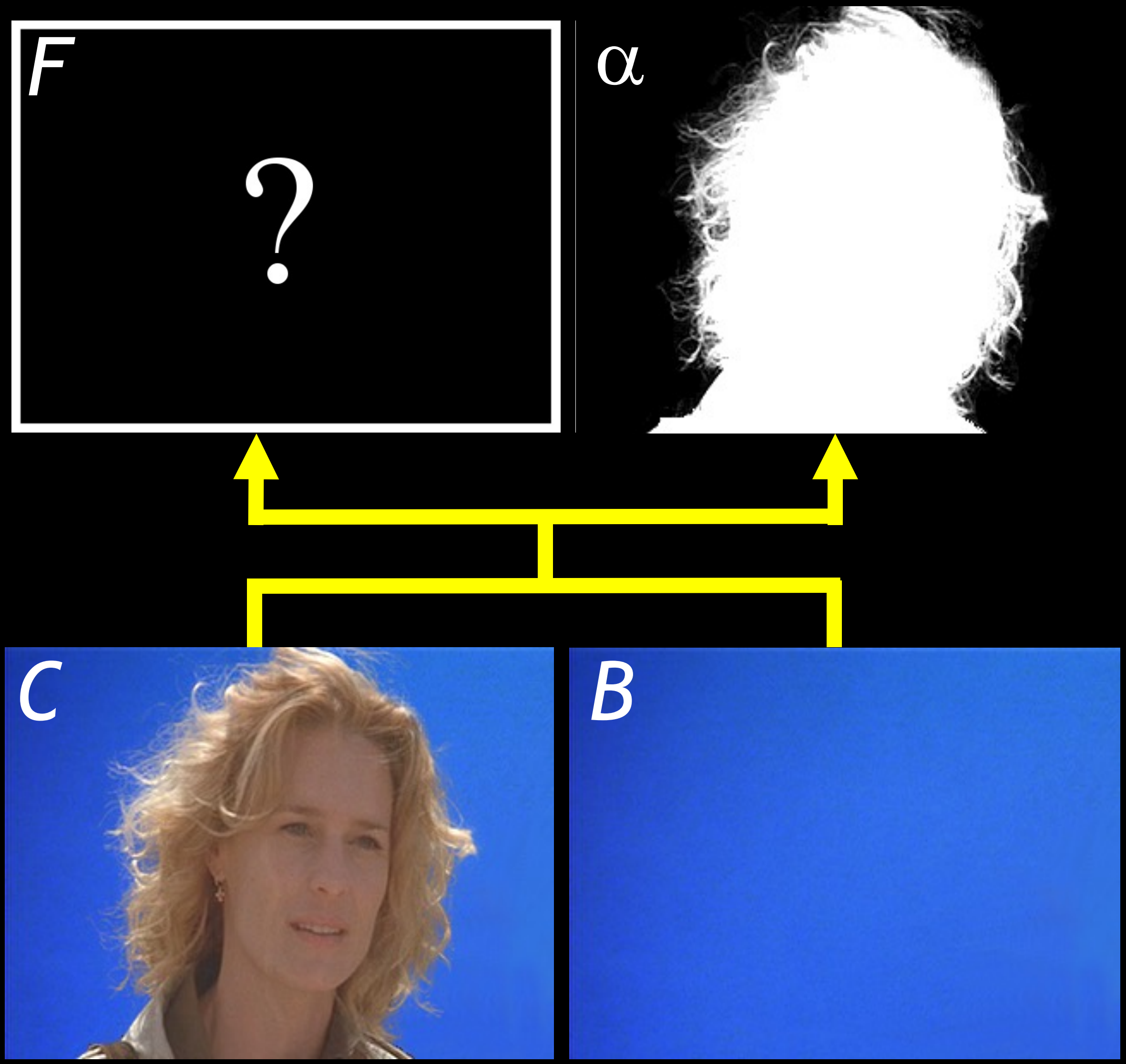
3 add priors

compositing equation

Matting



Matting (reduce #unknowns)

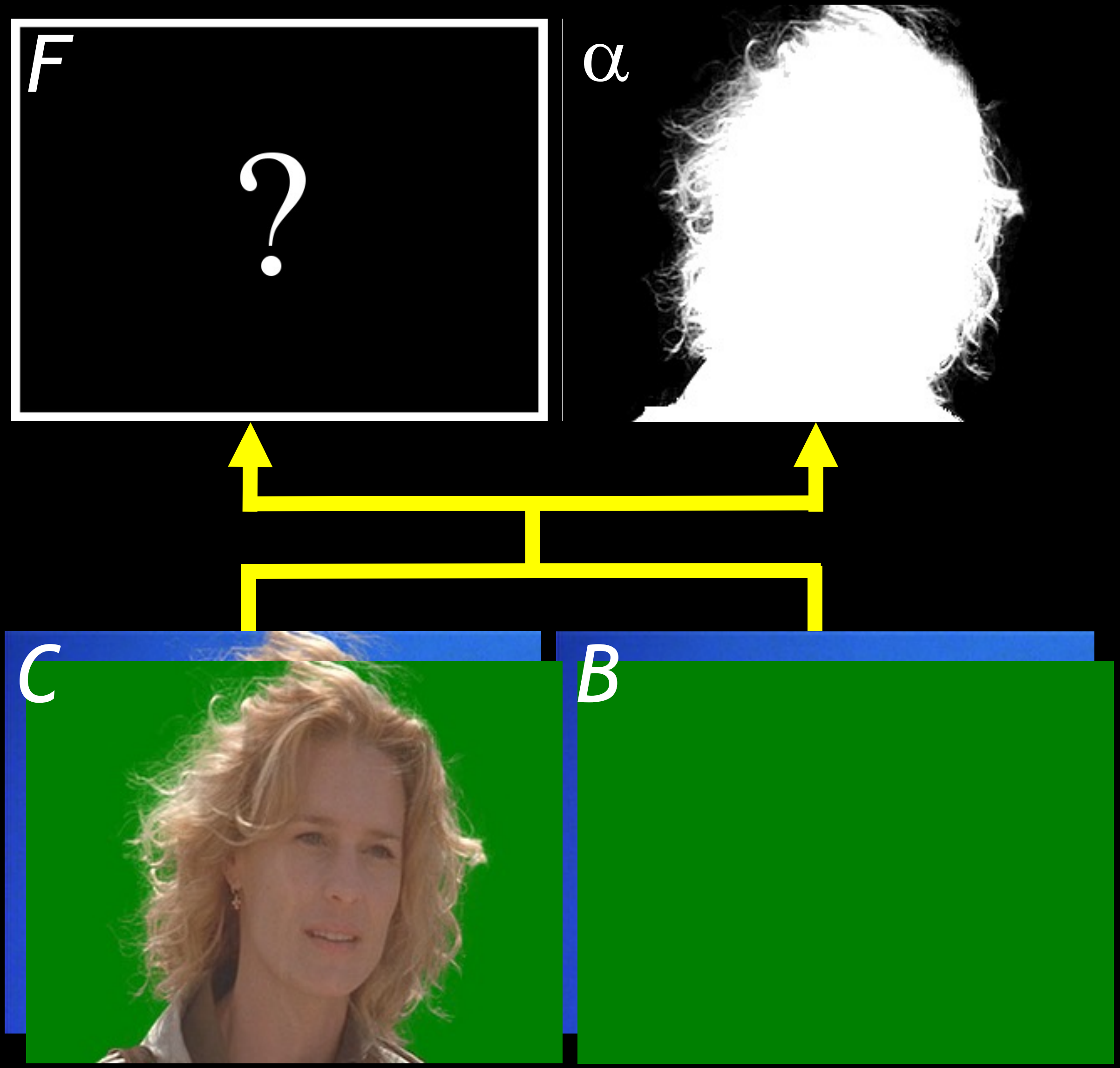


blue screen
matting

Matting (reduce #unknowns)

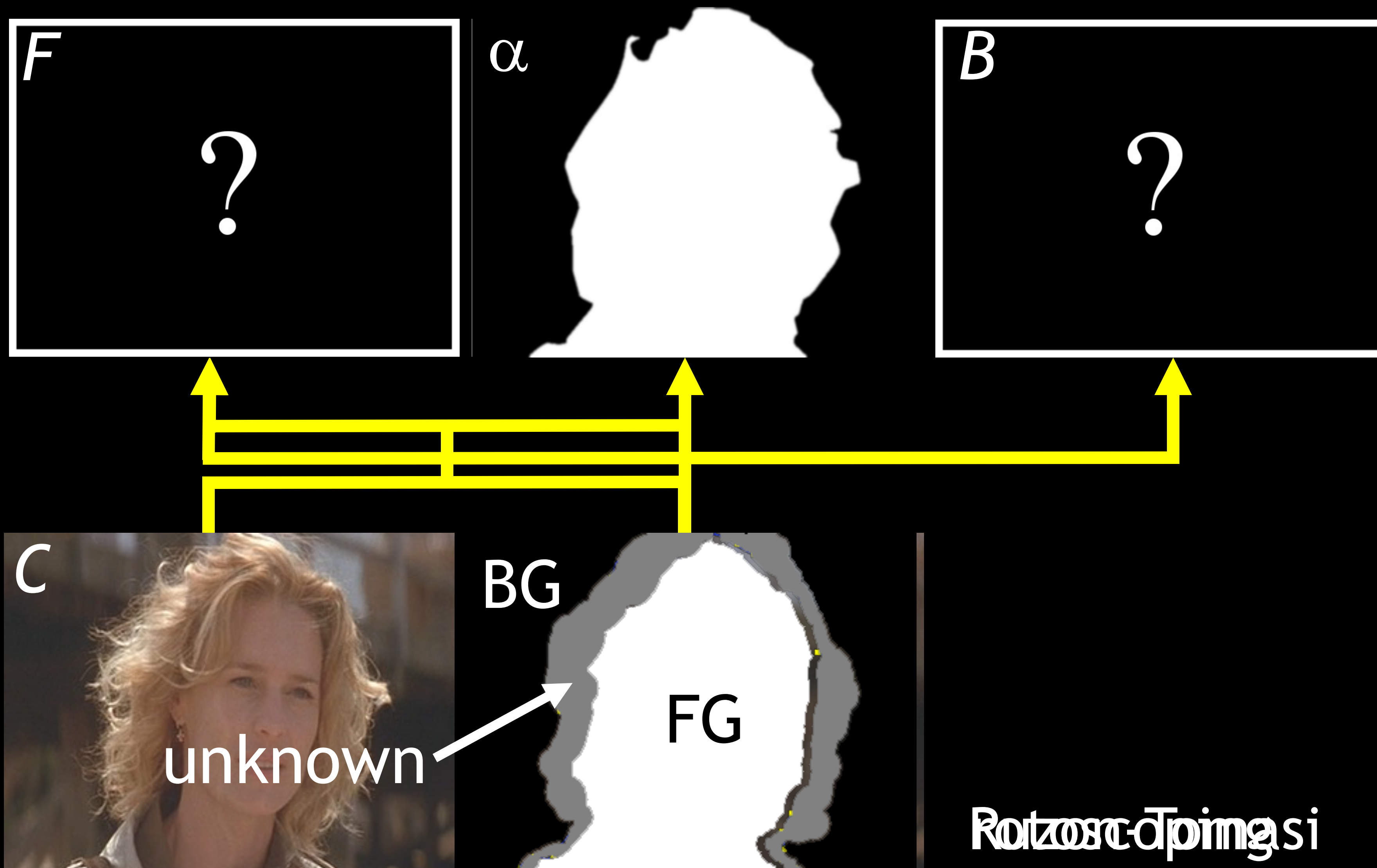
Problems with color difference

Background color is usually not perfect! (lighting, shadowing…)



Smith & Blinn, 96

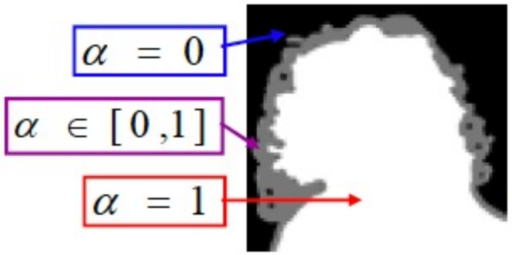
Matting (add observations)



Matting (add priors)

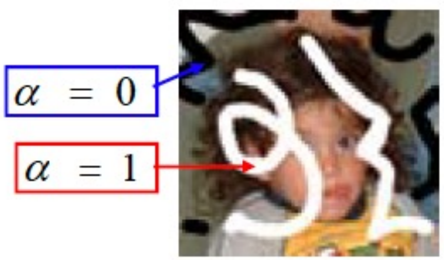
User input

User interfaces



The trimap interface:

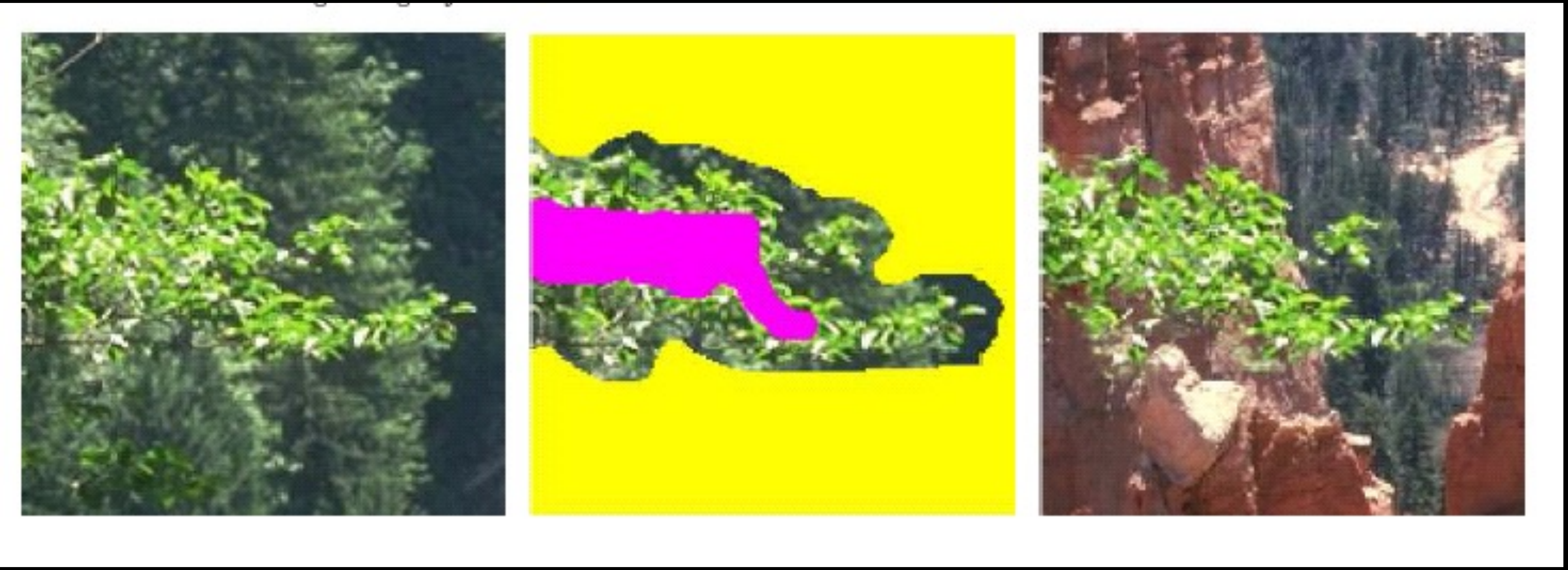
- **Bayesian Matting (Chuang et al, CVPR01)**
- **Poisson Matting (Sun et al SIGGRAPH 04)**
- **Random Walk (Grady et al 05)**



Scribbles interface:

- **Wang&Cohen ICCV05**
- **Levin et al CVPR06**

Example: Tri-map user input



para-meters $z \longrightarrow \boxed{f(z)+\varepsilon} \longrightarrow y$ observed signal

Example:
super-resolution
de-blurring
de-blocking
…

Bayesian framework

para-
meters

$z \rightarrow \boxed{f(z)+\varepsilon} \rightarrow y$

observed
signal

data
evidence

a-priori
knowledge

Bayesian framework

posterior probability

likelihood

priors

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

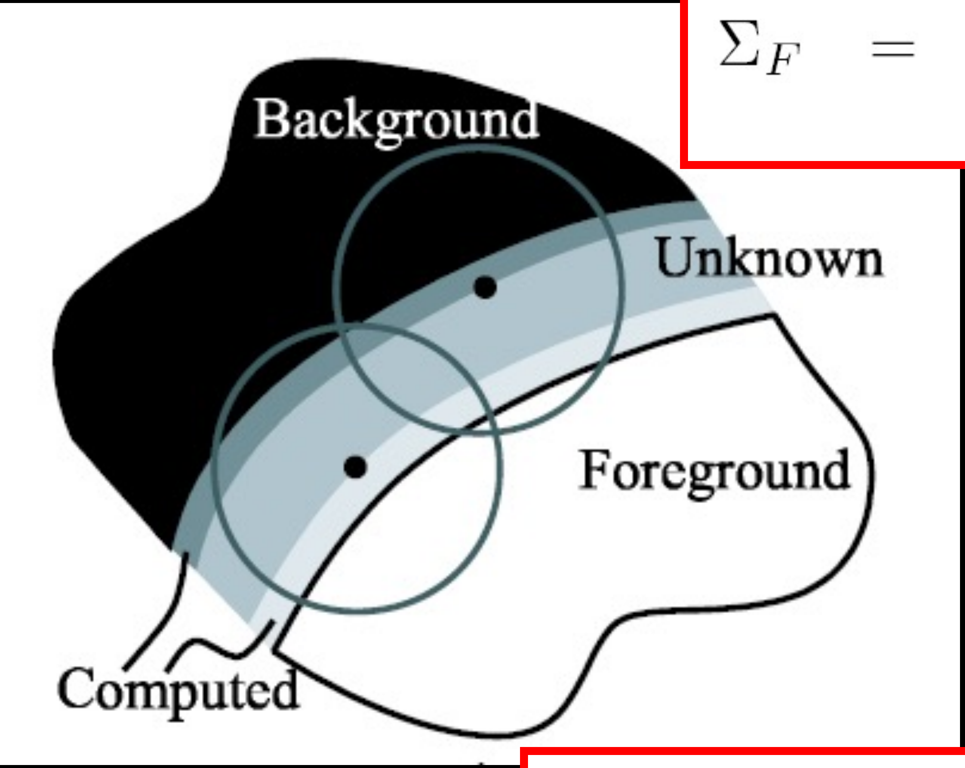
$$= \arg\max_{F,B,\alpha} \boxed{P(C \,|\, F,B,\alpha)}\, \boxed{P(F)\, P(B)\, P(\alpha)} \,/\, P(C)$$

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

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

$$\arg\max_{F,B,\alpha} L(C \mid F, B, \alpha) + L(F) + L(B)$$

$$\begin{aligned}\arg\max_{F,B,\alpha} & -\|C - \alpha F - (1-\alpha)B\|^2 / \sigma_C^2 \\ & -\left(F - \overline{F}\right)^T \Sigma_F^{-1} \left(F - \overline{F}\right) / 2 \\ & -\left(B - \overline{B}\right)^T \Sigma_B^{-1} \left(B - \overline{B}\right) / 2\end{aligned}$$

Bayesian matting

repeat

1. fix alpha

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

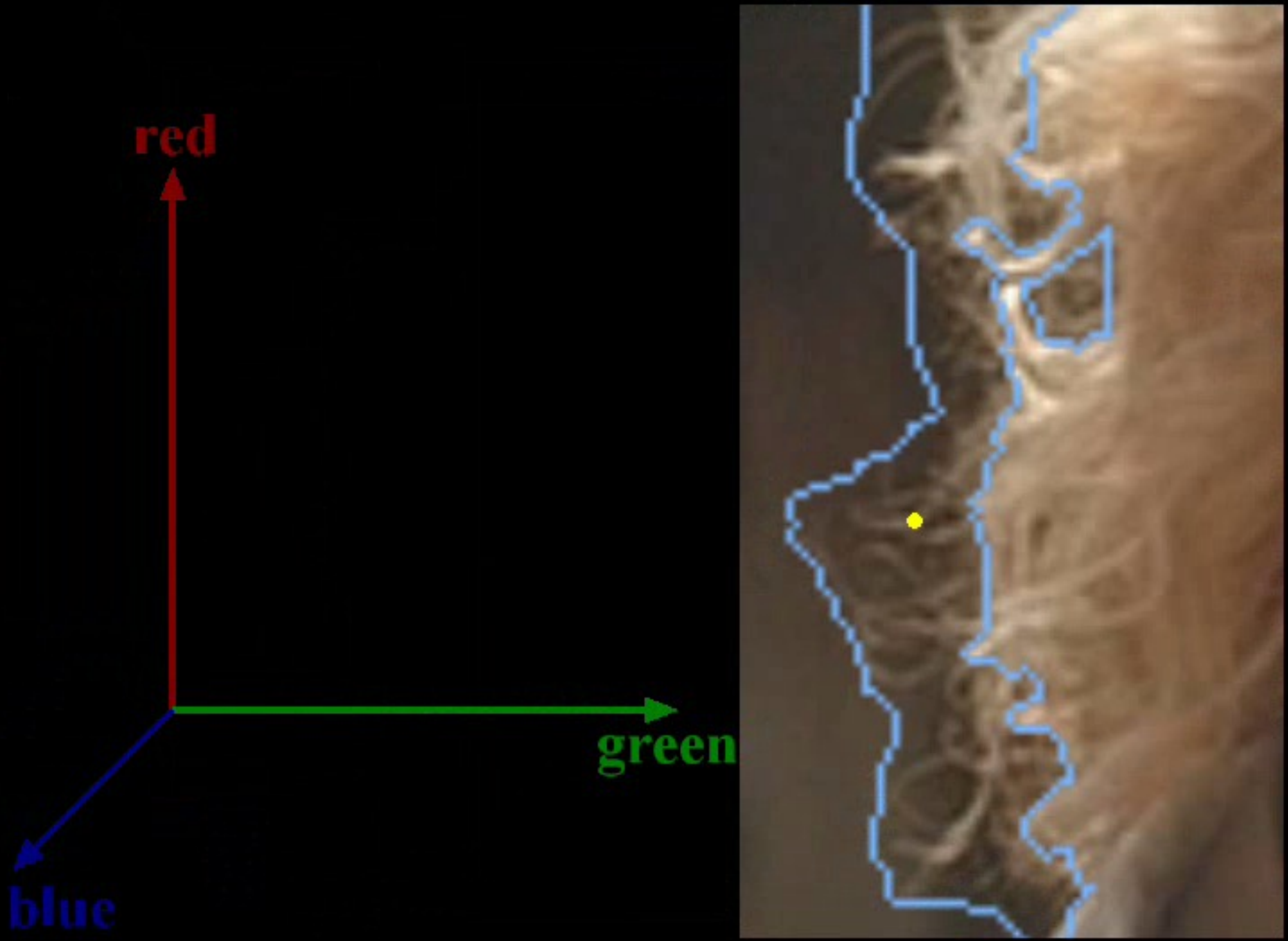
2. fix F and B

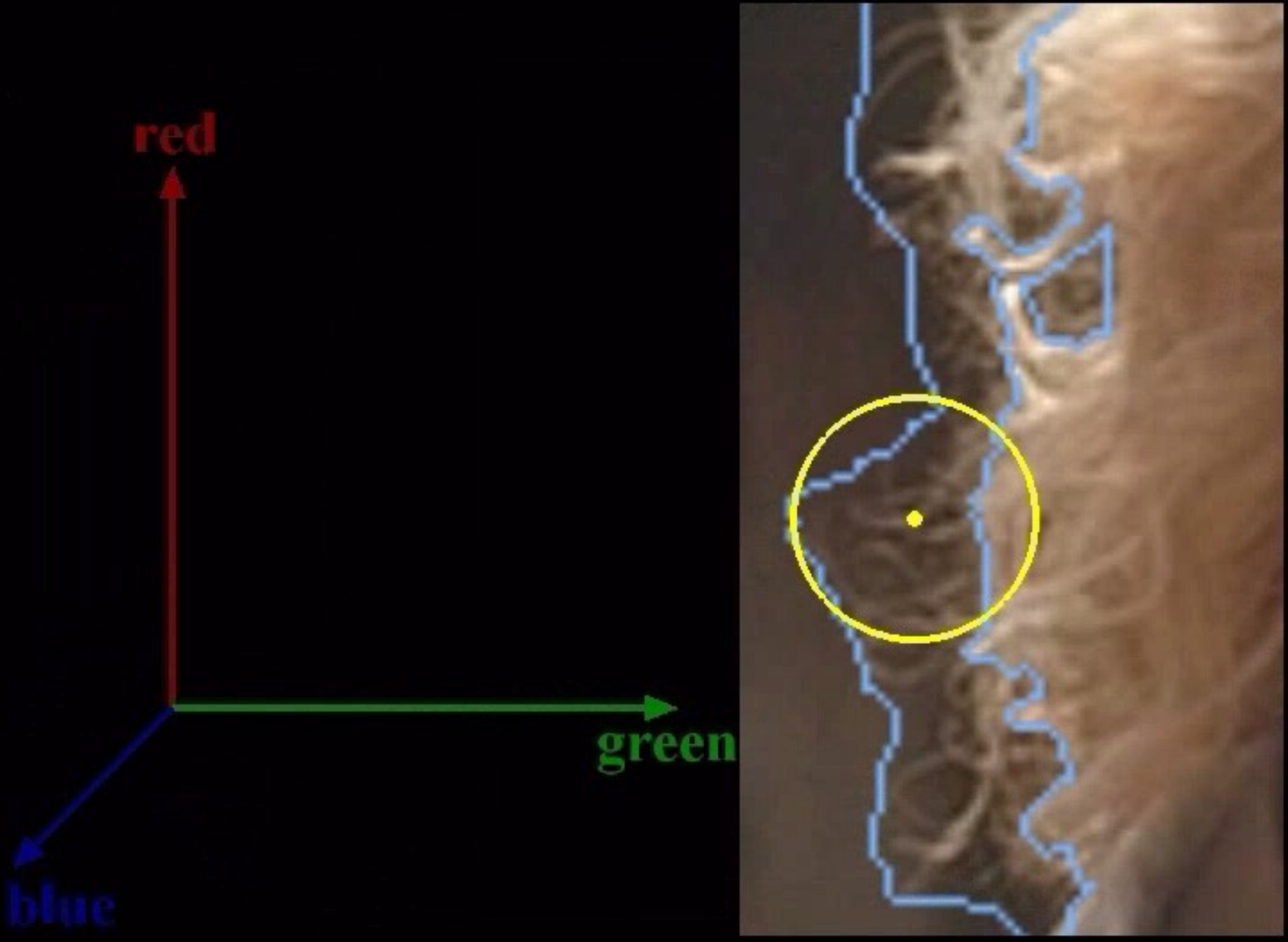
$$\alpha = \frac{(C-B)\cdot(F-B)}{\|F-B\|^2}$$

until converge

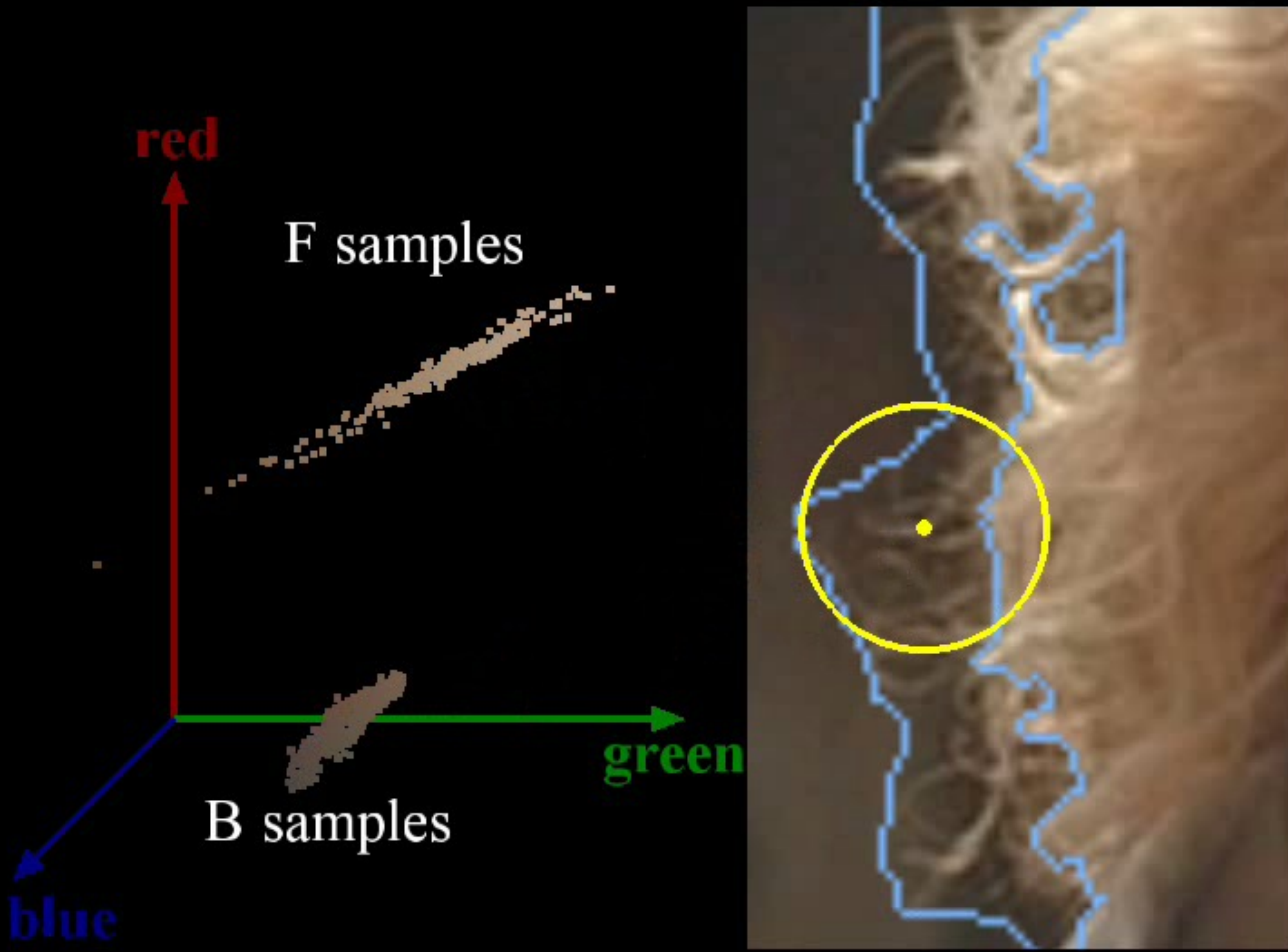
Optimization

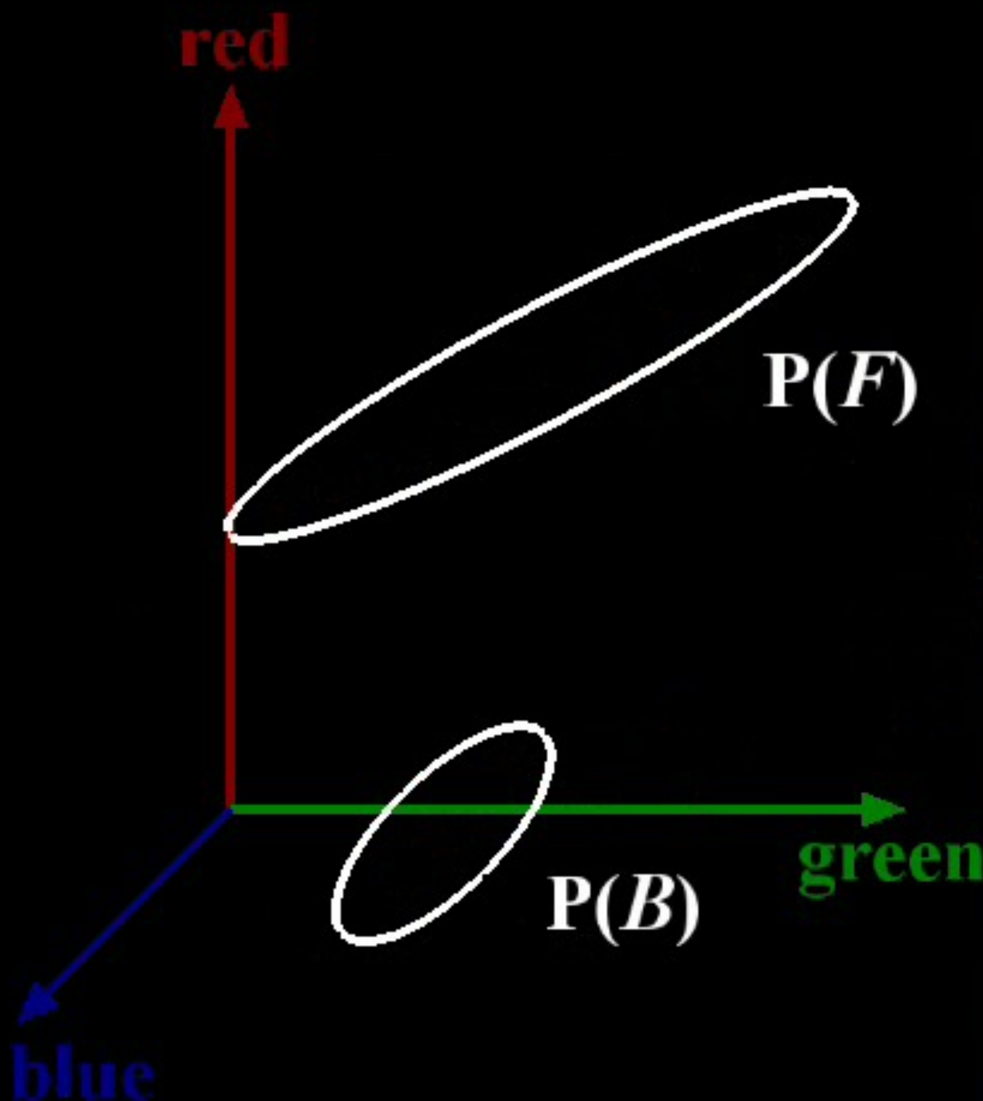
Bayesian image matting

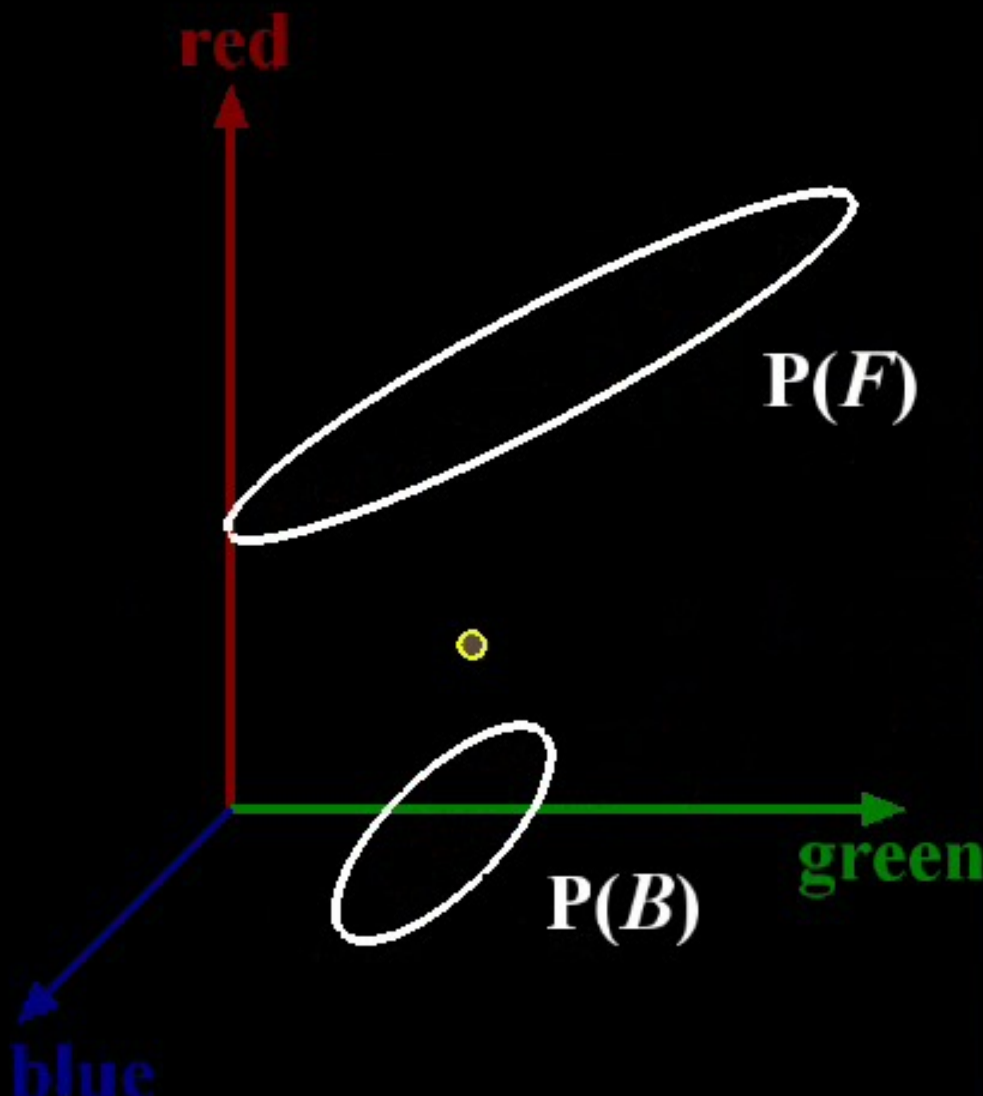

red
green
blue

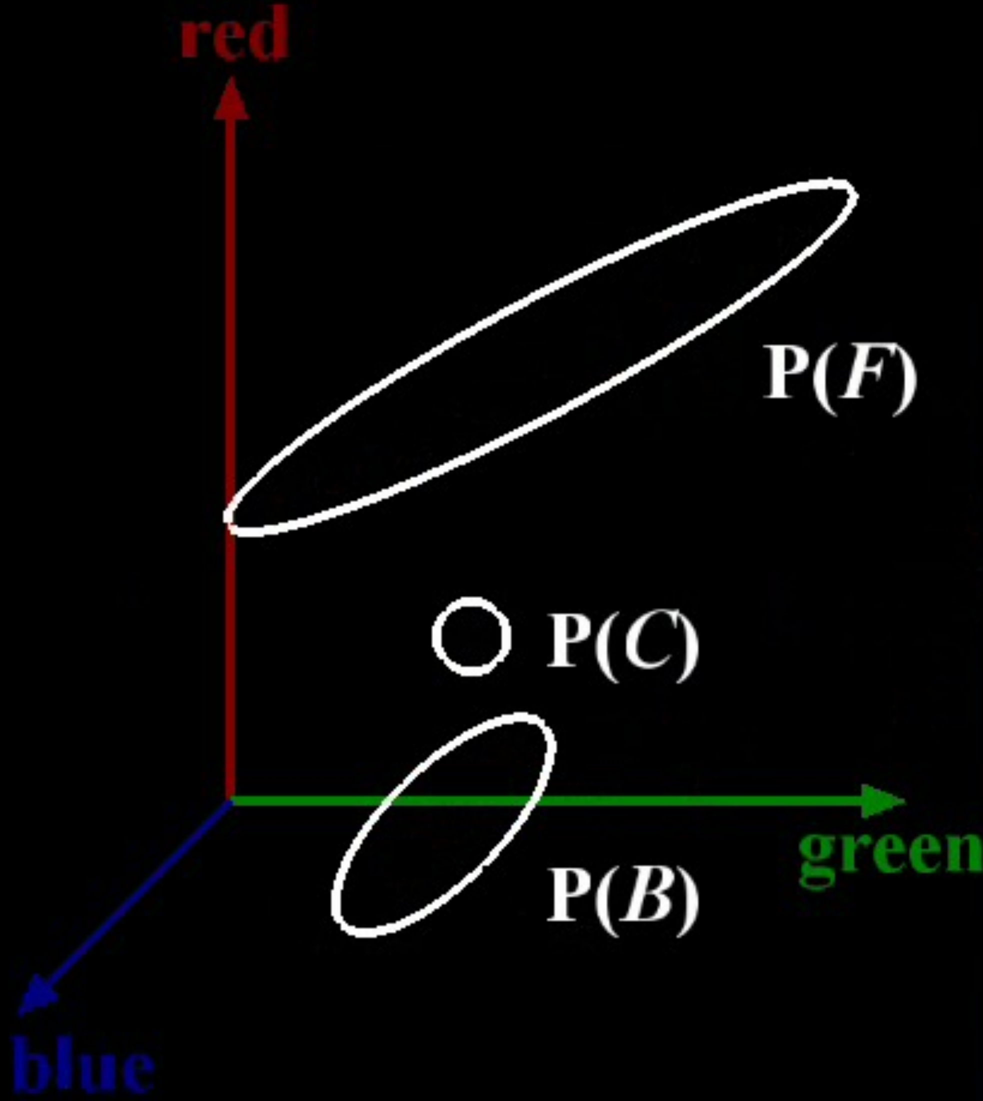


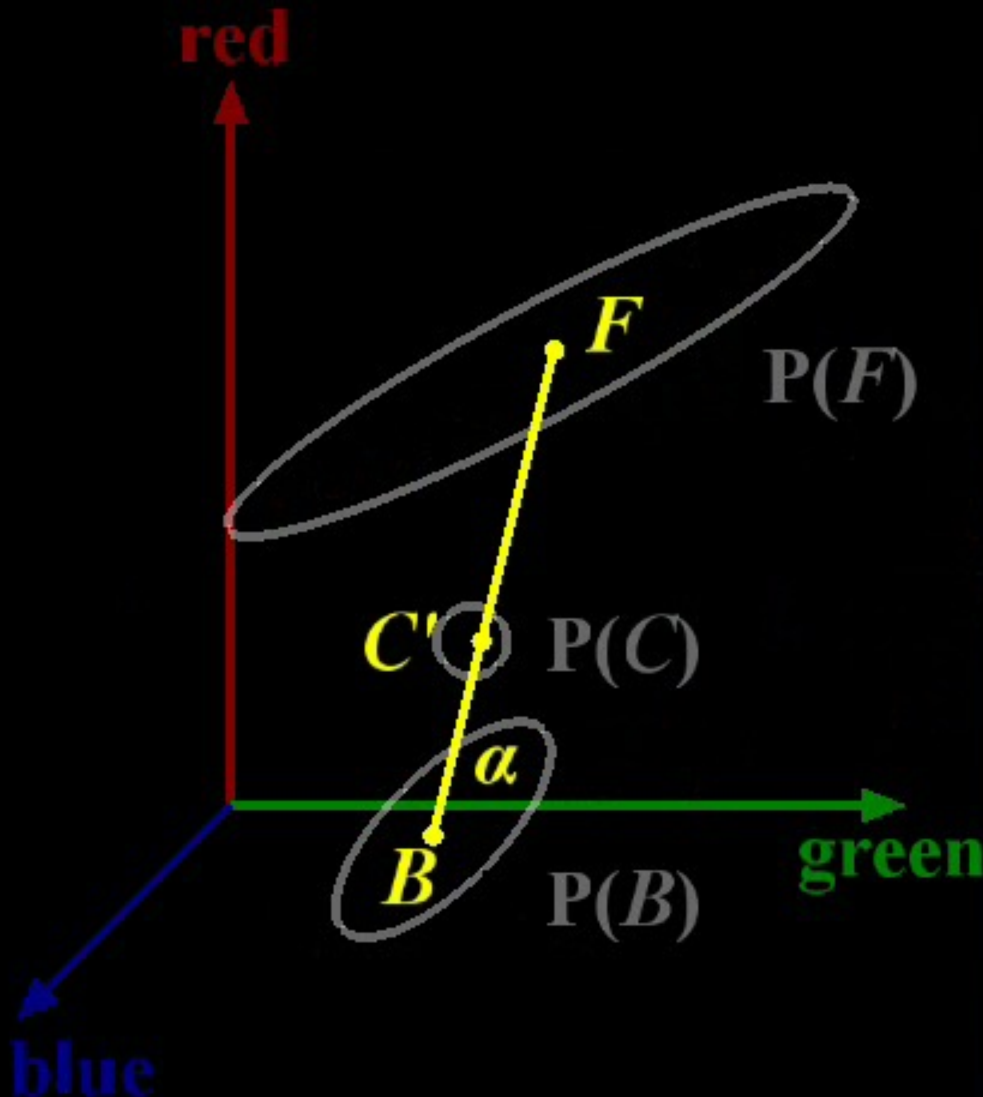
red
green
blue


red
F samples
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



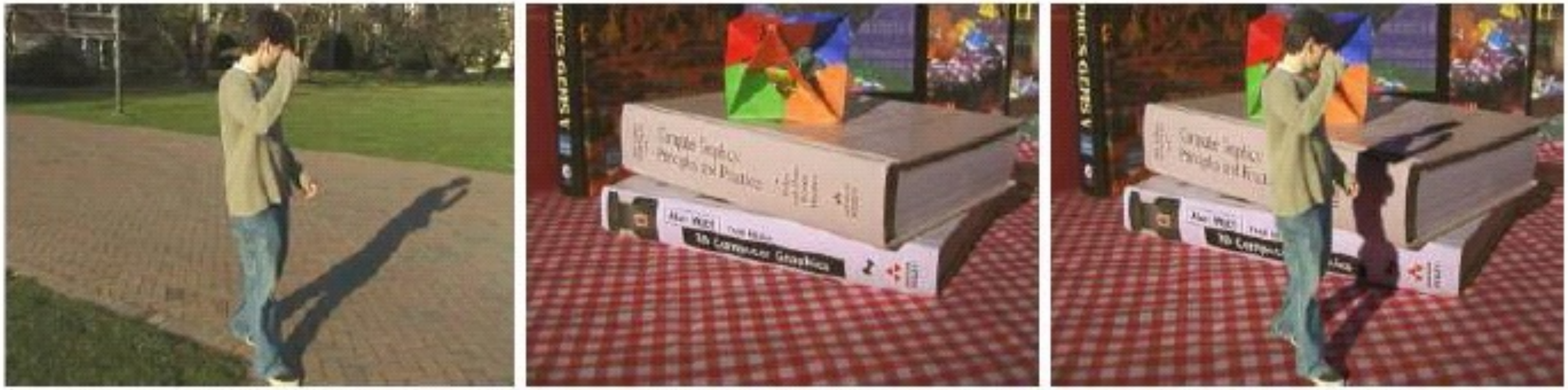
red
F
P(F)
C'
P(C)
α
B
P(B)
green
blue

alpha

input

composite

Image Composition



(a) Source frame (b) Target frame (c) Composite

Paper #2 to read today: background matting v1

https://grail.cs.washington.edu/projects/background-matting/

Background Matting: The World is Your Green Screen

We capture 2 images, with and without the subject. Captured Image and Background Predicted Alpha Matte Composite Image

By Soumyadip Sengupta, Vivek Jayaram, Brian Curless, Steve Seitz, and Ira Kemelmacher-Shlizerman

This paper will be presented in IEEE CVPR 2020.

Network structure

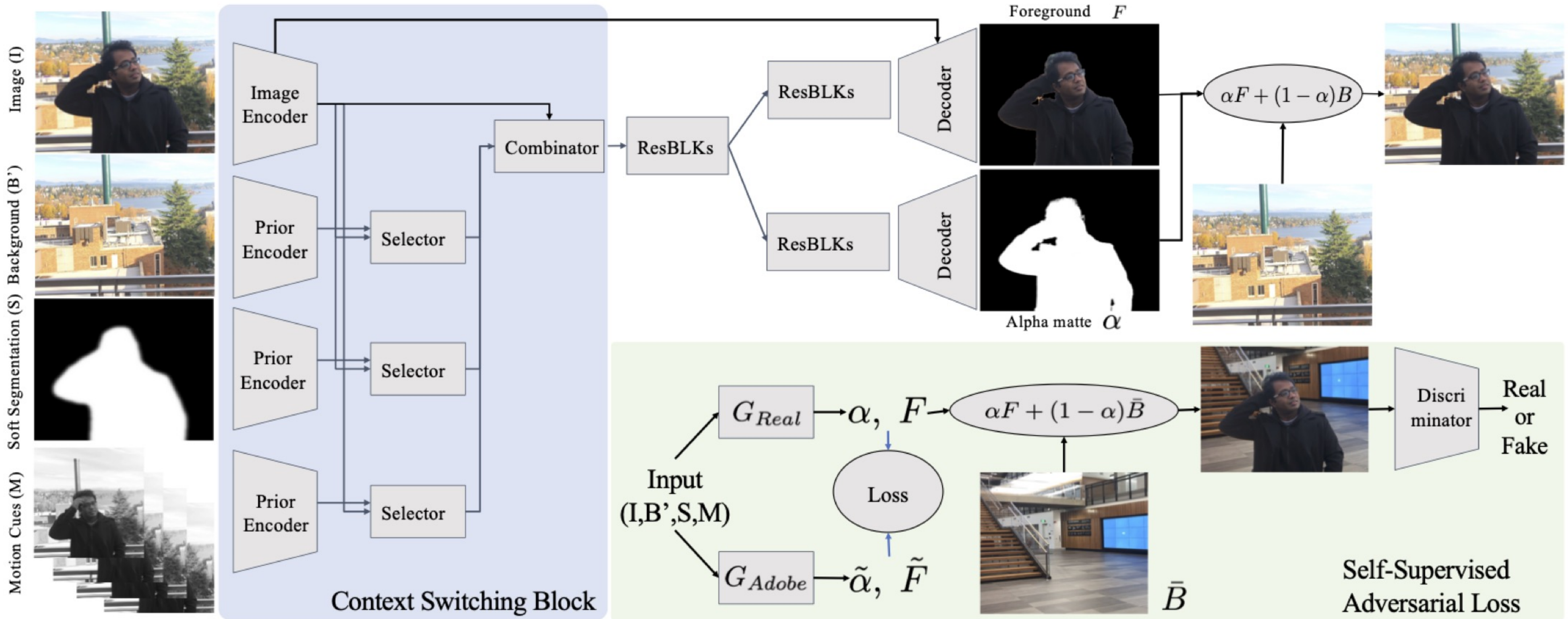
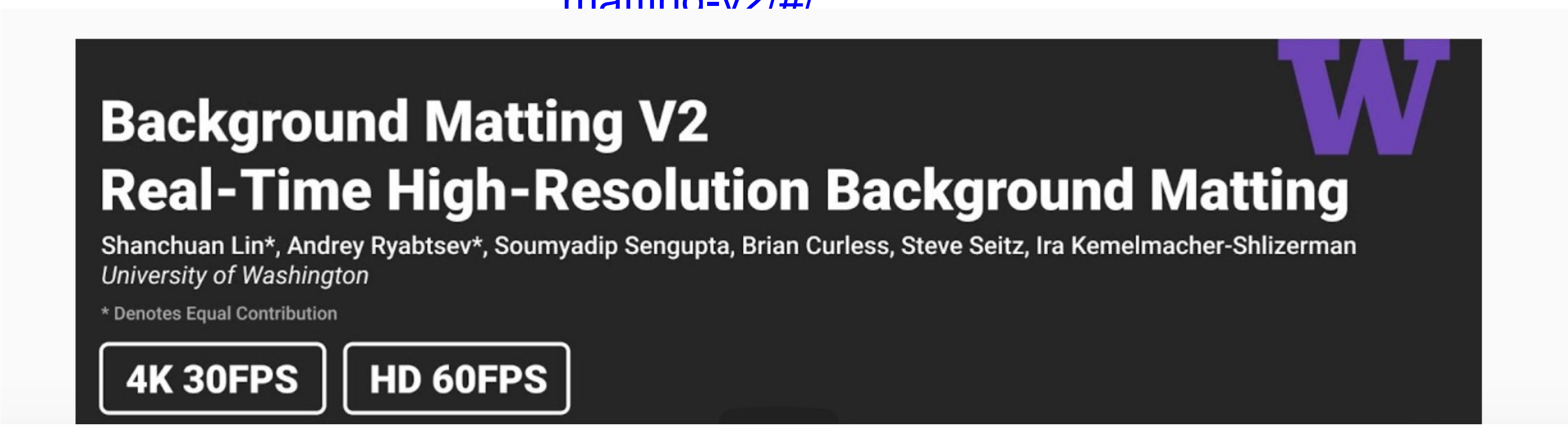


Figure 2: **Overview of our approach.** Given an input image I and background image B', we jointly estimate the alpha matte α and the foreground F using soft segmentation S and motion prior M (for video only). We propose a Context Switching Block that efficiently combines all different cues. We also introduce self-supervised training on unlabelled real data by compositing into novel backgrounds.

Paper #3 to read today: **Background Matting -v2**

https://grail.cs.washington.edu/projects/background-matting-v2/#/



Network structure

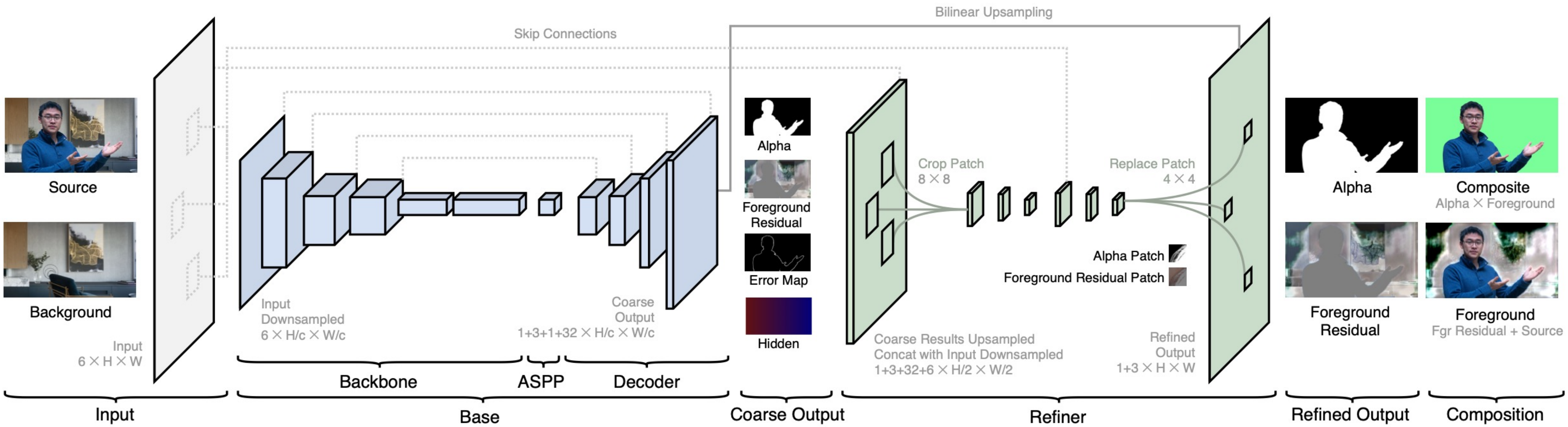


Figure 3: The base network G_{base} (blue) operates on the downsampled input to produce coarse-grained results and an error prediction map. The refinement network G_{refine} (green) selects error-prone patches and refines them to the full resolution.

Other related works

Deep Image Matting

Ning Xu[1,2], Brian Price[3], Scott Cohen[3], and Thomas Huang[1,2]

[1]Beckman Institute for Advanced Science and Technology
[2]University of Illinois at Urbana-Champaign
[3]Adobe Research

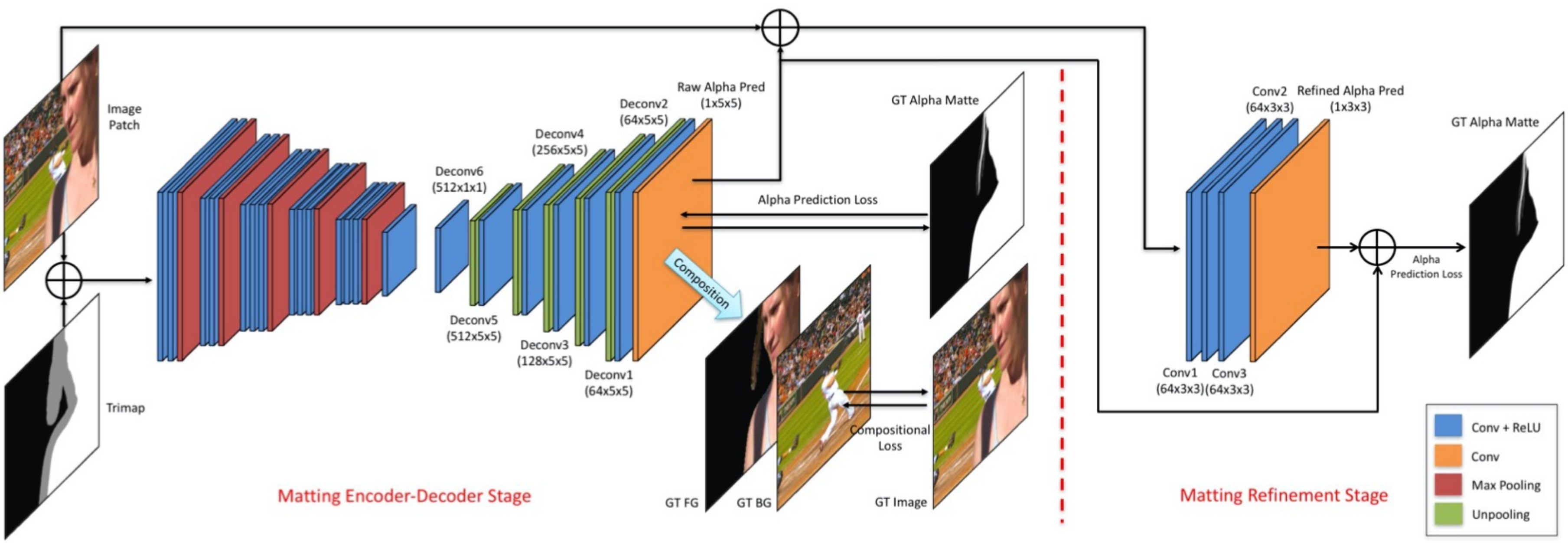


Figure 3. Our network consists of two stages, an encoder-decoder stage (Sec. 4.1) and a refinement stage (Sec. 4.2)

Other related works

Deep Automatic Portrait Matting

Xiaoyong Shen(✉), Xin Tao, Hongyun Gao, Chao Zhou, and Jiaya Jia

The Chinese University of Hong Kong, Sha Tin, Hong Kong

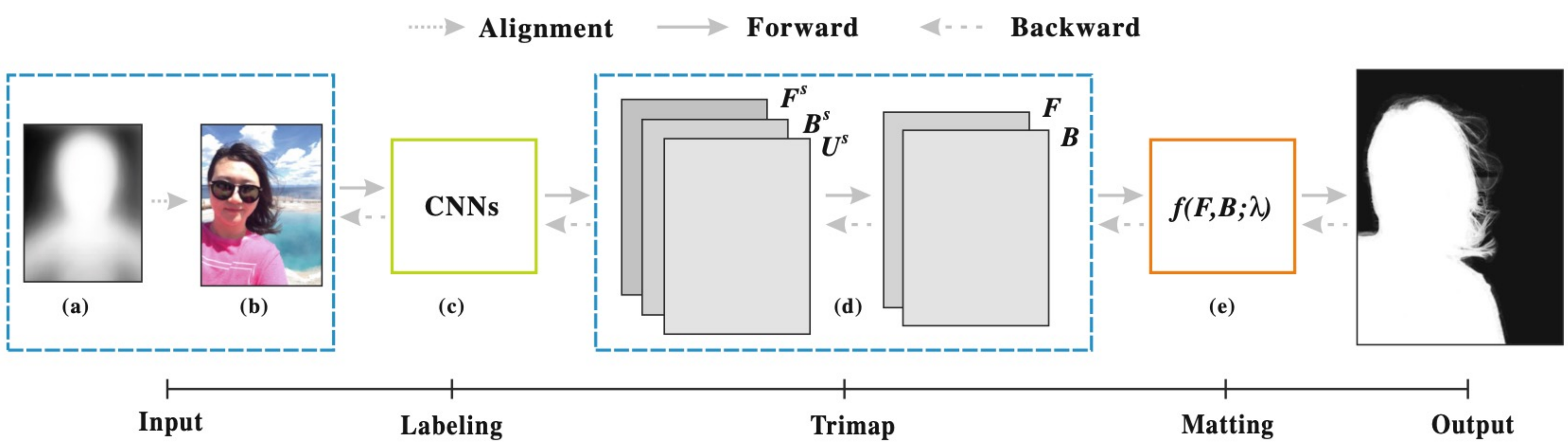
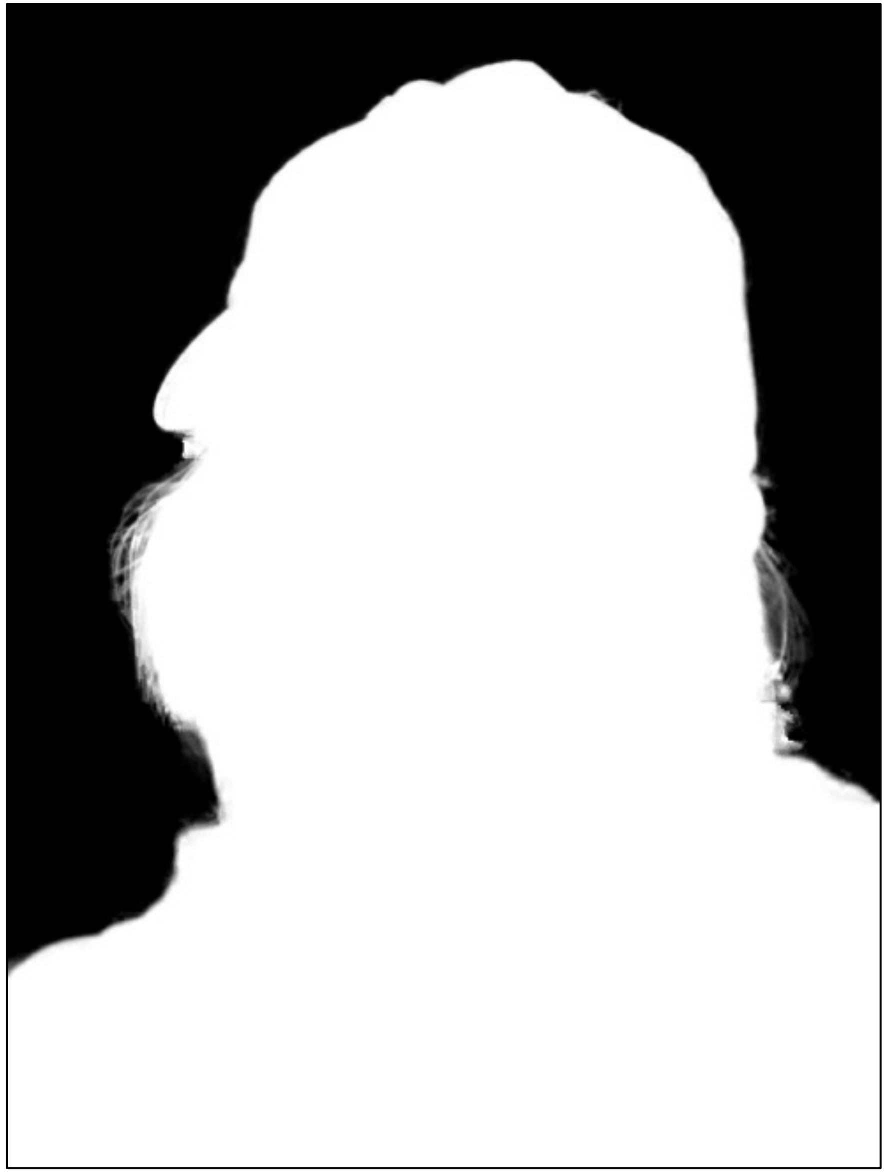


Fig. 3. Pipeline of our end-to-end portrait image matting network. It includes trimap labeling (c) and image matting (e). They are linked with forward and backward propagation functions.

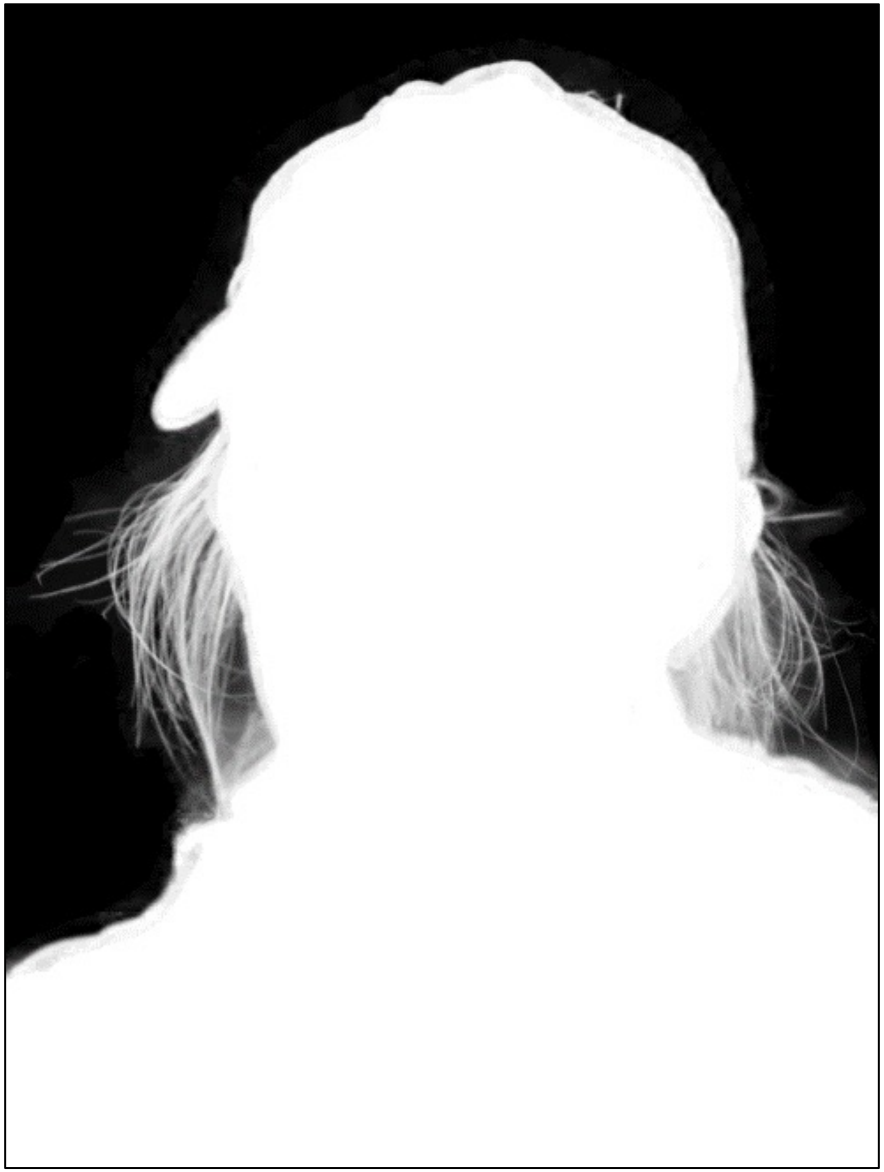
More SOTA results of deep matting: input

Graph-cut Trimap

FCN Trimap



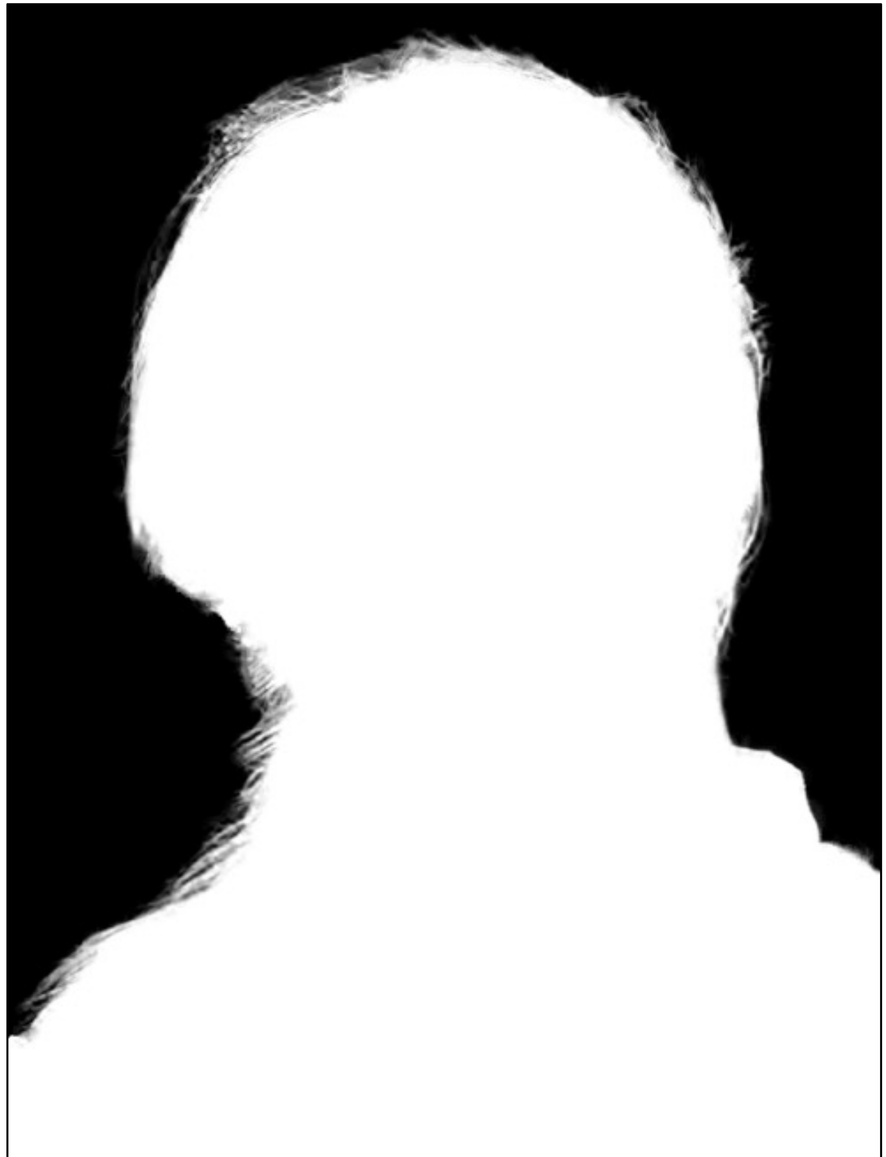
Ours



Input

Graph-cut Trimap

FCN Trimap



Ours

More Results

More Results

Now it is your turn

A short Breakout room session (15 minute + 10 minutes)

Reading Paper #2, and discuss:

Background Matting: The World is Your Green Screen, S. Sengupta, et al.

Breakout room: Now it is your turn.

Breakout room group discussion & report:

Check your name on Zoom

Take note: breakout room ID, room members, “Mr/Ms speaker”.

Your task:

- Recorded your Room ID, and room members’ names, and nominate a “Speaker”.
- Together you discuss and pick one paper, either (1) the ”coded aperture”, or (2) the “coded shutter”;

- Quickly re-read it for about 5 minutes.
- Discuss their limitations/drawbacks, for another 10 minutes.

- Try to answer the following “critical analysis” questions → page turn ..
- Report back in 3 minutes by the “Mr/Ms speaker”. Tutor may record your report.

Critical Analysis

5.1. Are the paper's contributions significant?

Are the contribution/improvement trivial, incremental?
Why previous efforts failed ?

5.2. Are the authors' main claims valid?

Have they convincingly validated their main idea?
Any hole in their arguments, derivation, experiments ?

5.3. Limitation and weaknesses

Any limitation/weakness of their method? What can be done to improve the work ?

What would you do to address/overcome their weaknesses?

5.4. Extension and future work

What *extra* experiments that you would suggest the authors to conduct in order to strengthen the result ?

Can you think of other possible applications of the method/ideas (assuming valid) presented in the paper?

What are possible future works?

5.5. Is the paper stimulating or inspiring ?

Many papers (even those published ones) are dull, while some are exciting. What is your opinion about this paper and why?

5.6. Conclusion and personal reflection

First, draw a short conclusion about this paper.

Then, if you were tasked to solve the research problem, what would you do differently? an alternative solution ?

Finally, in one sentence, summarize what you have learn from reading this paper.

→ Now we move to
“Research Project Tutorial”