# CS 194/294-26: Image Manipulation and Computational Photography

Instructor: Alexei Efros
GSIs: Rachel Albert
Weilun Sun
UC Berkeley, Fall 2015

© Quint Buchholz

# Today

Introductions

Why Computational Photography?

Overview of the course

Administrative stuff

# A bit about me

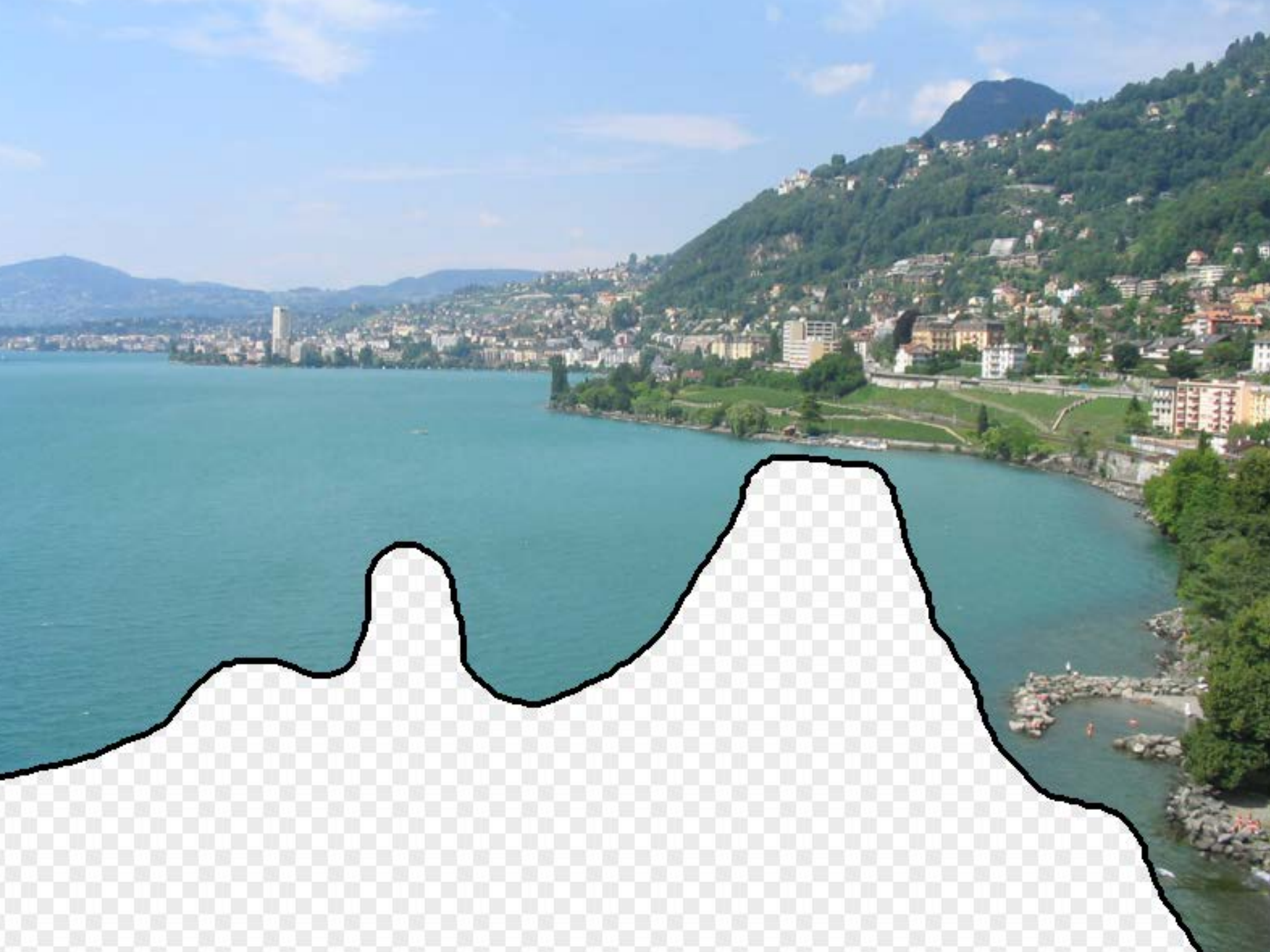
- Alexei (Alyosha) Efros
  - Moved (back) to UC Berkeley in 2013, after decade at CMU
  - (also work with colleagues in Paris)
- Teaching
  - The plan is to have fun and learn cool things, both you and me!
  - Social warning: I don’t see well
- Research
  - Computer Vision, Computer Graphics, Machine Learning, Visual Perception

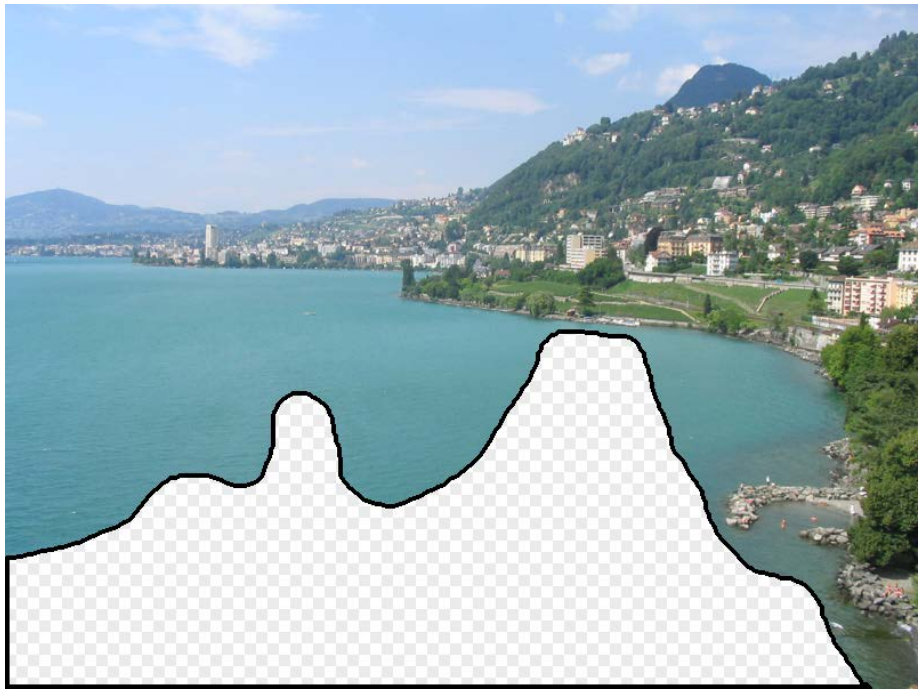
# PhD 2003 on Texture and Action Synthesis

*Inspired Photoshop's **"Context-aware Fill"** and Microsoft **"Smart Erase"*** buttons:

© Antonio Criminisi

# Other works…





# im2GPS

## (using 6 million GPS-tagged Flickr images)

Query Photograph

**Im2gps [Hays & Efros, CVPR'08]**

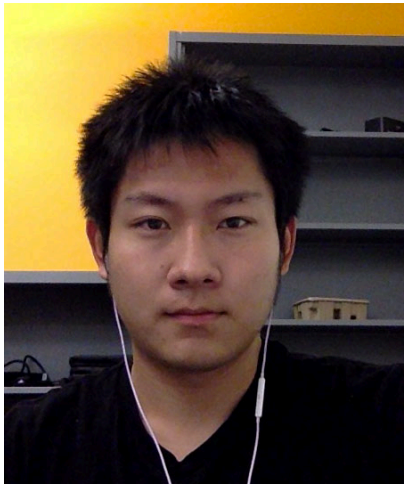
# Amateur Photographer

# GSIs

## Rachel Albert

- PhD candidate in Vision Science + MS in Computer Science
- Expert in human vision, graphics, and photography
- http://www.rachelalbert.com/index.html

## Weilun Sun



- PhD candidate in Computer Science
- Hard-core rendering geek
- http://sunweilun.github.io/

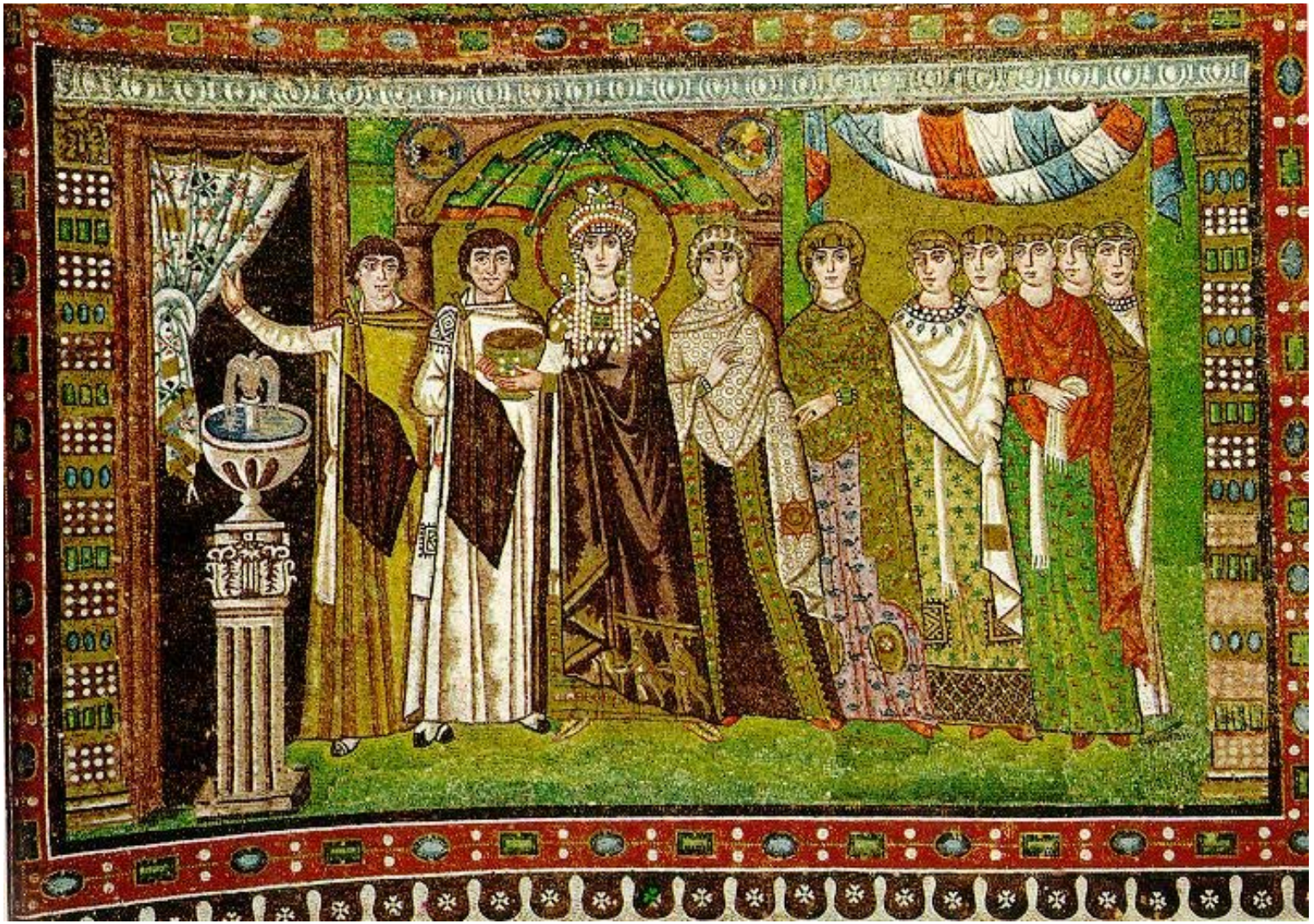
# Why Computational Photography?

A Brief History of the Visual Media

# Depicting Our World: The Beginning

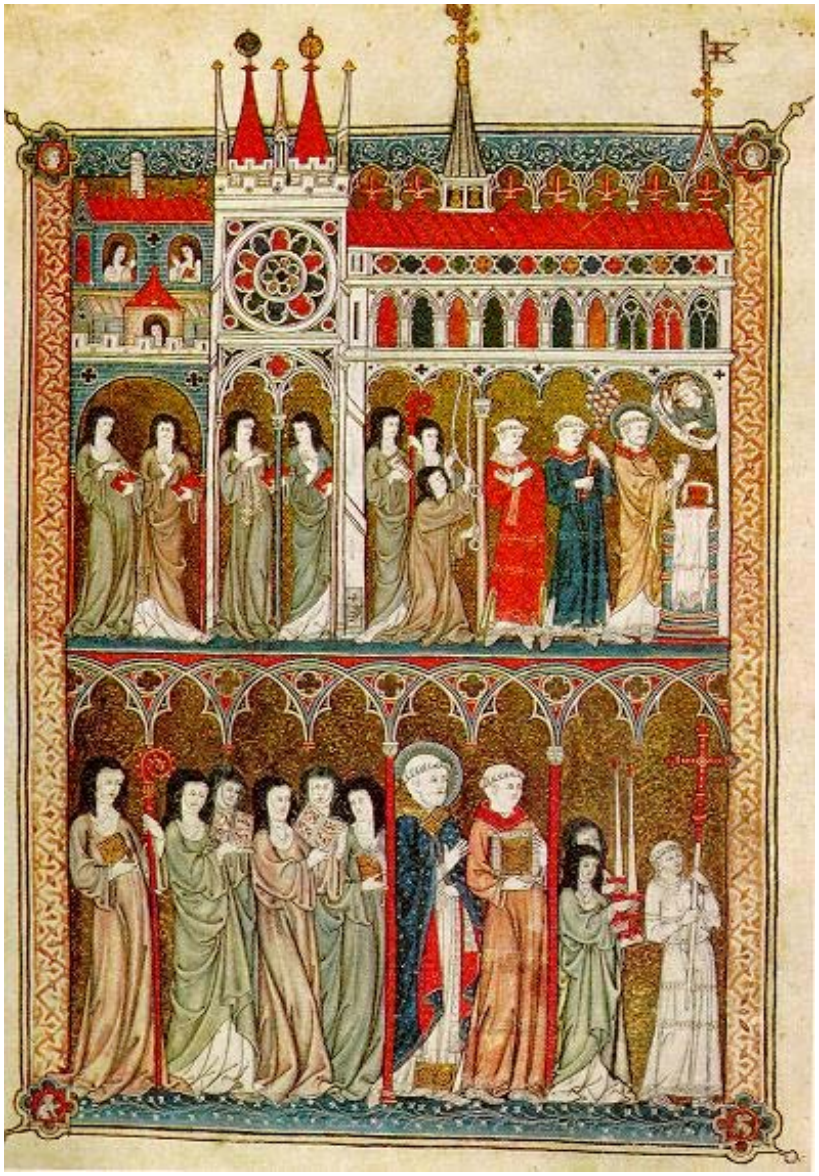
Prehistoric Painting, Lascaux Cave, France
~ 13,000 -- 15,000 B.C.

# Depicting Our World: Middle Ages



The Empress Theodora with her court.
Ravenna, St. Vitale 6th c.

# Depicting Our World: Middle Ages



Nuns in Procession. French ms. ca. 1300.

# Beginnings of the Renaissance

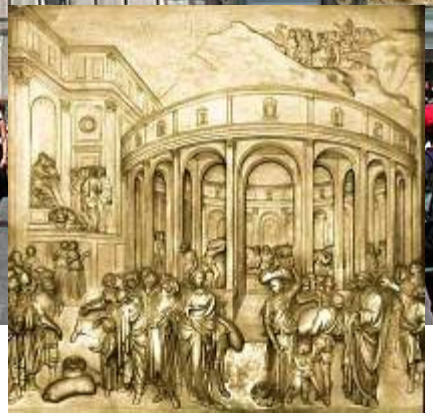
**Giotto, *The Mourning of Christ*, c.1305**

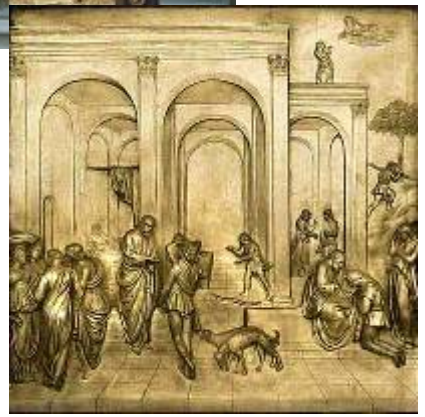
# Depicting Our World: Renaissance

North Doors (1424)

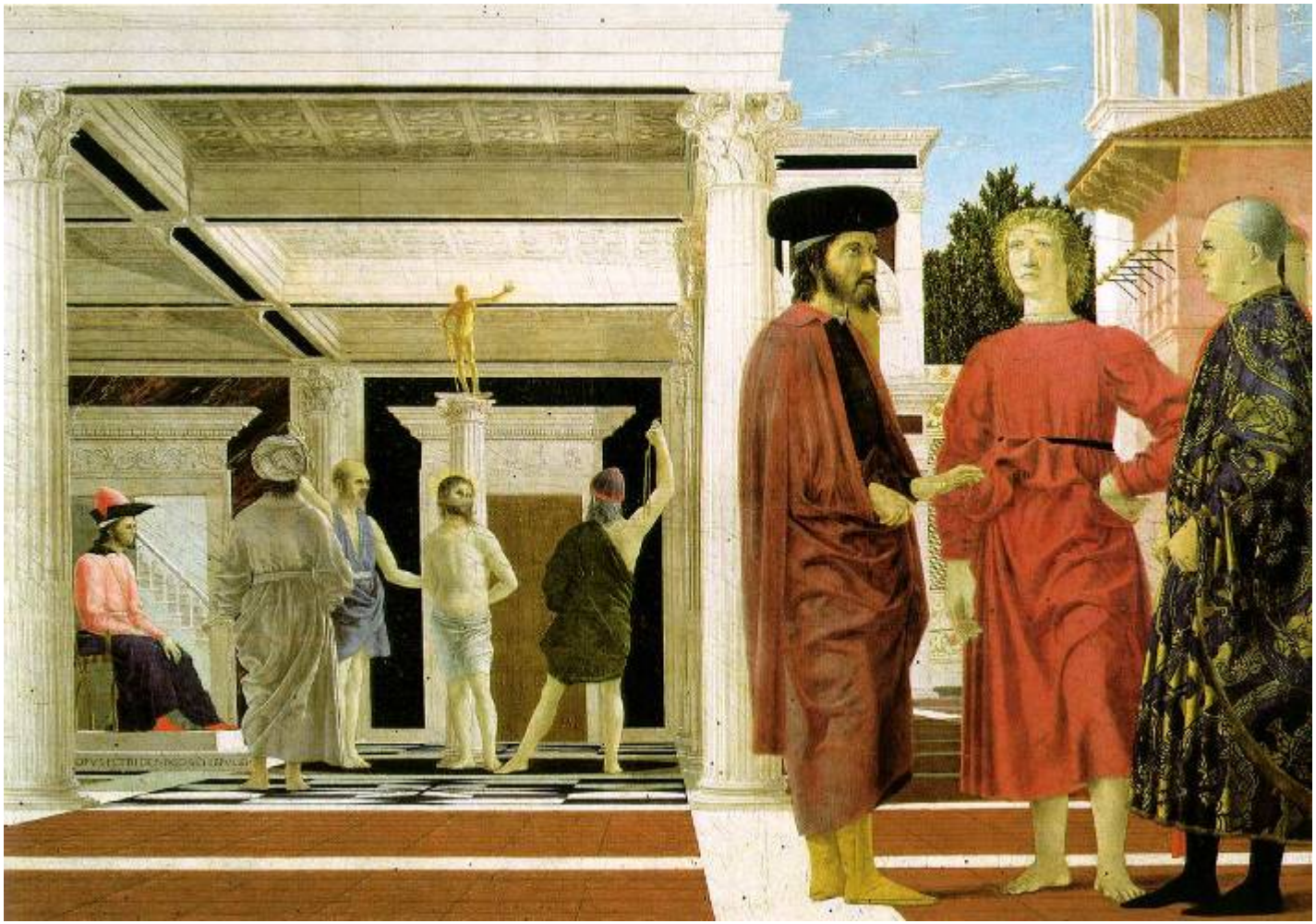
Lorenzo Ghiberti (1378-1455)

East Doors (1452)



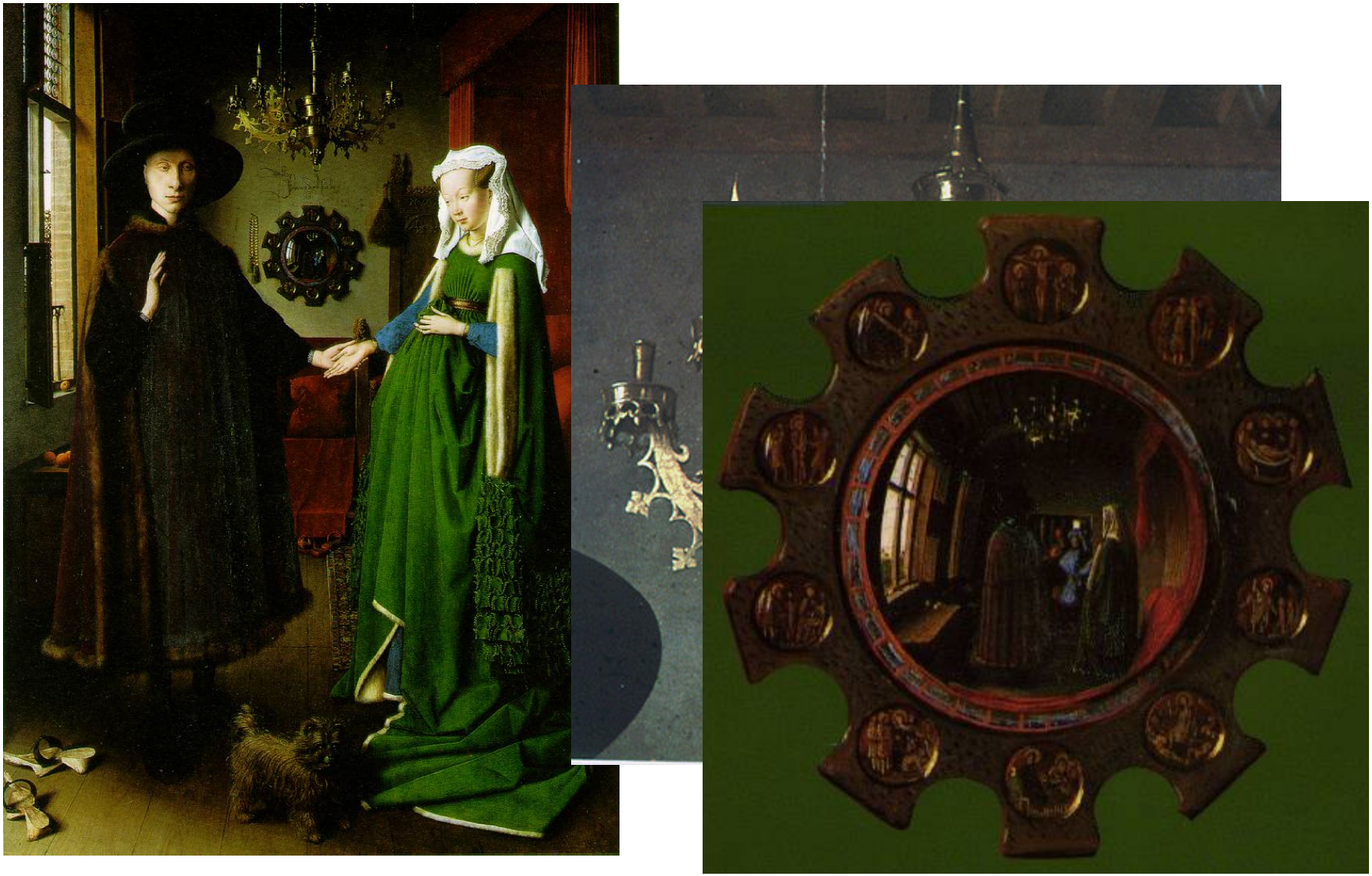


# Depicting Our World: Renaissance



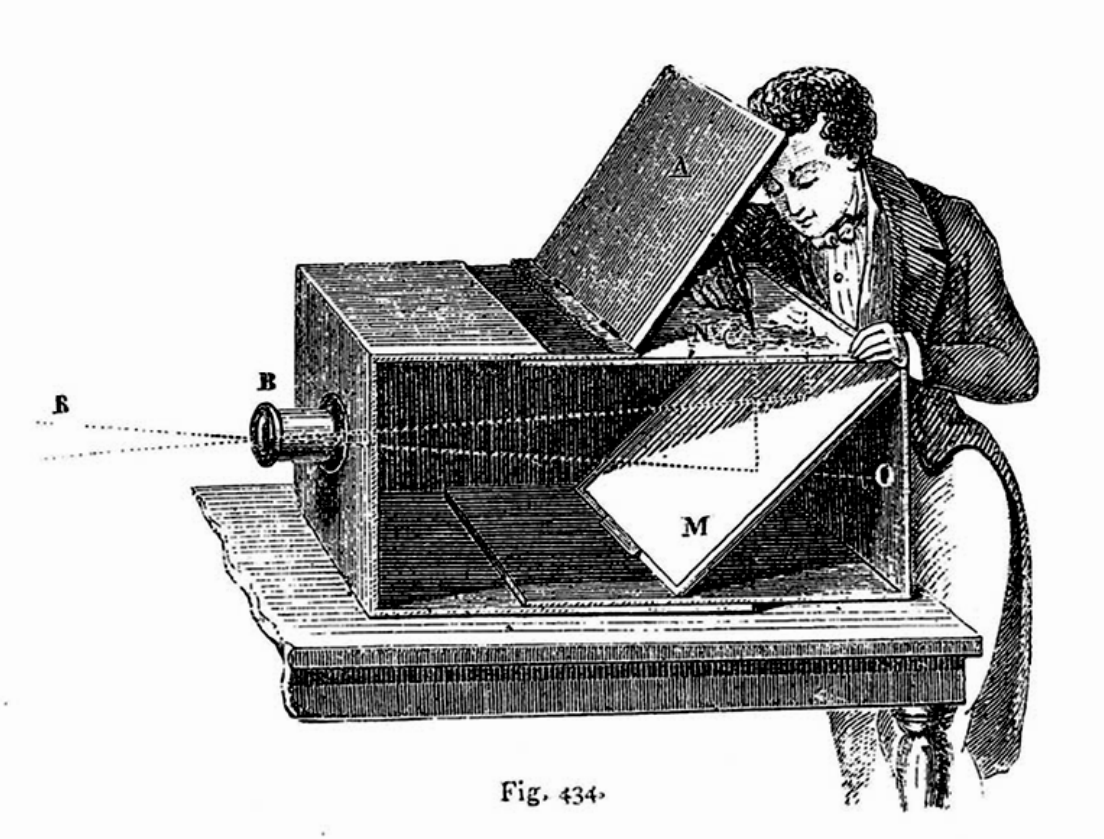
***Piero della Francesca,***
*The Flagellation* (c.1469)

# Depicting Our World: Toward Perfection



**Jan van Eyck,** *The Arnolfini Marriage (c.1434)*

# Depicting Our World: Toward Perfection

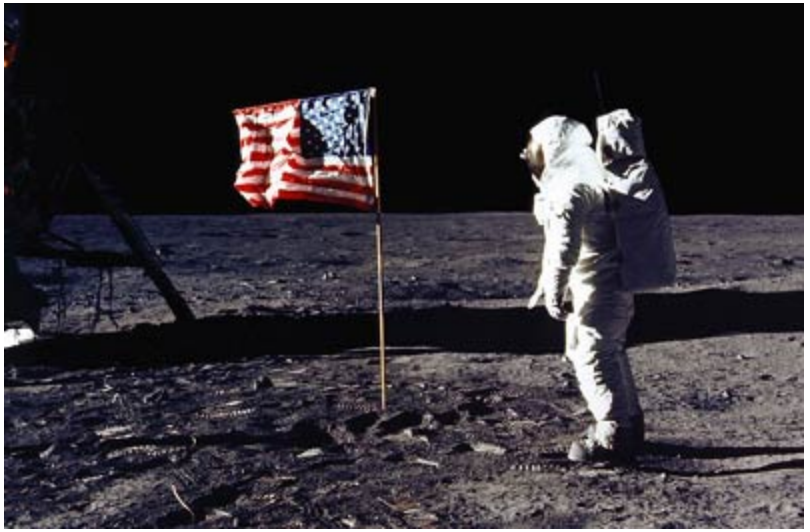



Lens Based Camera Obscura, 1568

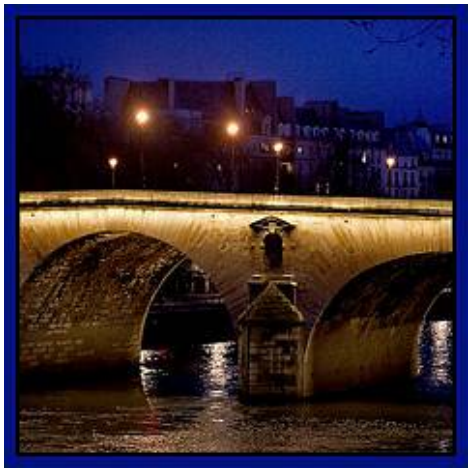
# Depicting Our World: Perfection!

*Still Life*, Louis Jaques Mande Daguerre, 1837

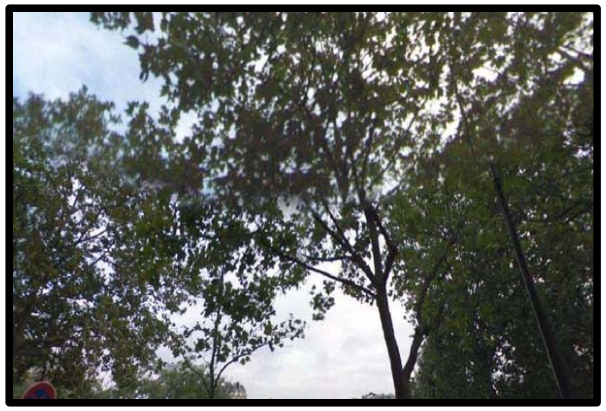
# Depicting Our World:  Realism?

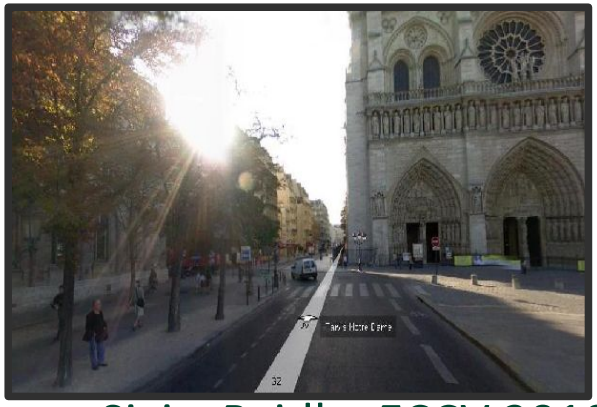


# Paris, according to Flickr



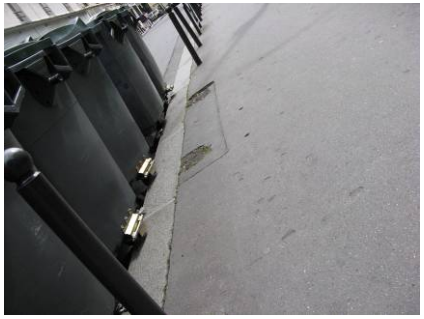
# Paris, according to Google StreetView





Knopp, Sivic, Pajdla, ECCV 2010

# Paris, according to me



# After realism…

Monet,
La rue Montorgueil

# Depicting Our World: Ongoing Quest

Pablo Picasso

David Hockney

# Better than realism?

**David Hockney, Place Furstenberg, (1985)**

# Which one is right?

**Multiple viewpoints**

**David Hockney,**
**Place Furstenberg, 1985**

**Single viewpoint**

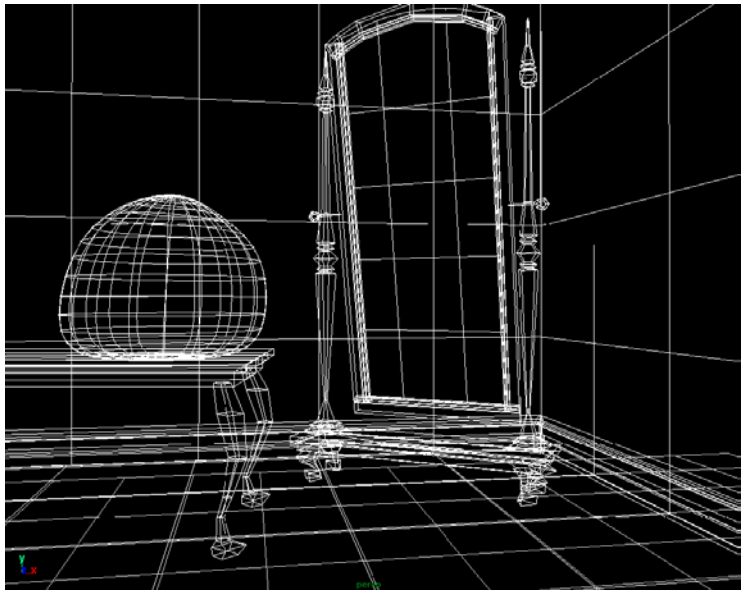
**Alyosha Efros**
**Place Furstenberg, 2009**

# Depicting Our World: Ongoing Quest

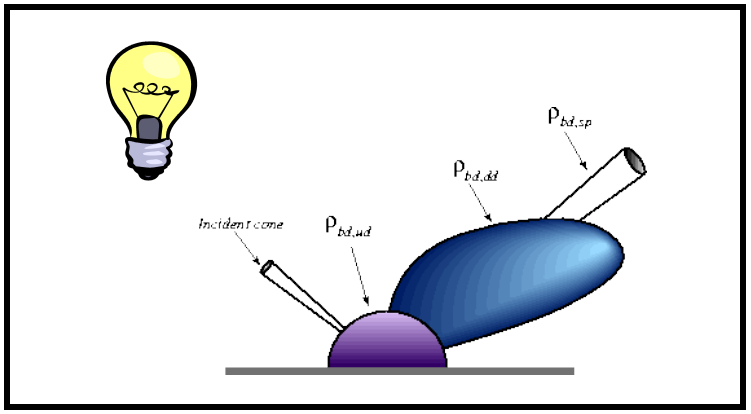
Antonio Torralba & Aude Oliva (2002)

Enter Computer Graphics...

# Traditional Computer Graphics



3D geometry




physics

projection

Simulation

GRAPHICS

# Modern Computer Graphics

- Amazingly real
- But so sterile, lifeless, *futuristic (why?)*

# The richness of our everyday world

Photo by Svetlana Lazebnik

# Beauty in complexity

University Parks, Oxford

# Which parts are hard to model?

Photo by Svetlana Lazebnik

# People

From “Final Fantasy”

On the Tube, London

# Faces / Hair

From “Final Fantasy”

Photo by Joaquin Rosales Gomez

# Hyper-humans

# Creating Realistic Imagery

## Computer Graphics

+ great creative possibilities

+ easy to manipulate objects/viewpoint

-Tremendous expertise and effort to obtain realism

## Computational Photography

Realism
Manipulation
Ease of capture

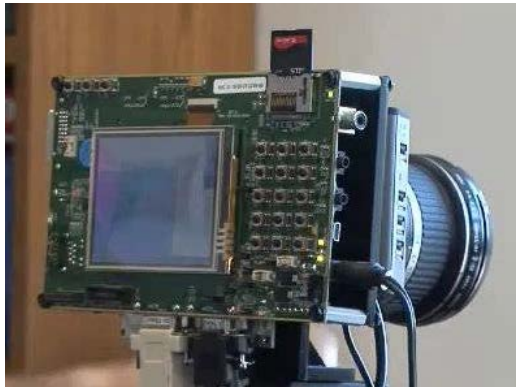
## Photography

+ instantly realistic

+ easy to aquire

- very hard to manipulate objects/viewpoint

# Computational Photography

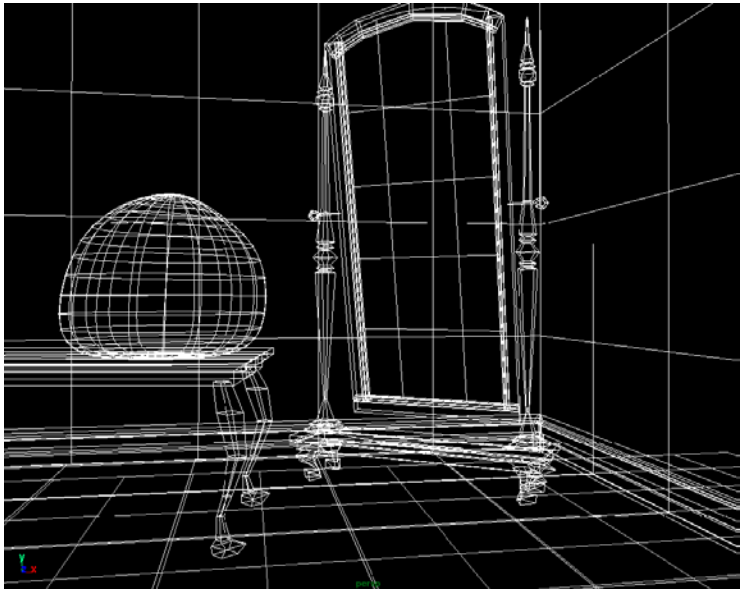


How can I use computational techniques to capture light in new ways?

How can I use computational techniques to breathe new life into the photograph?

How can I use computational techniques to visualize, organize, and navigate the captured visual world?

# Relationship to Vision and Graphics



**3D Model**

**2D image**

**Computer Graphics**: Models to Images

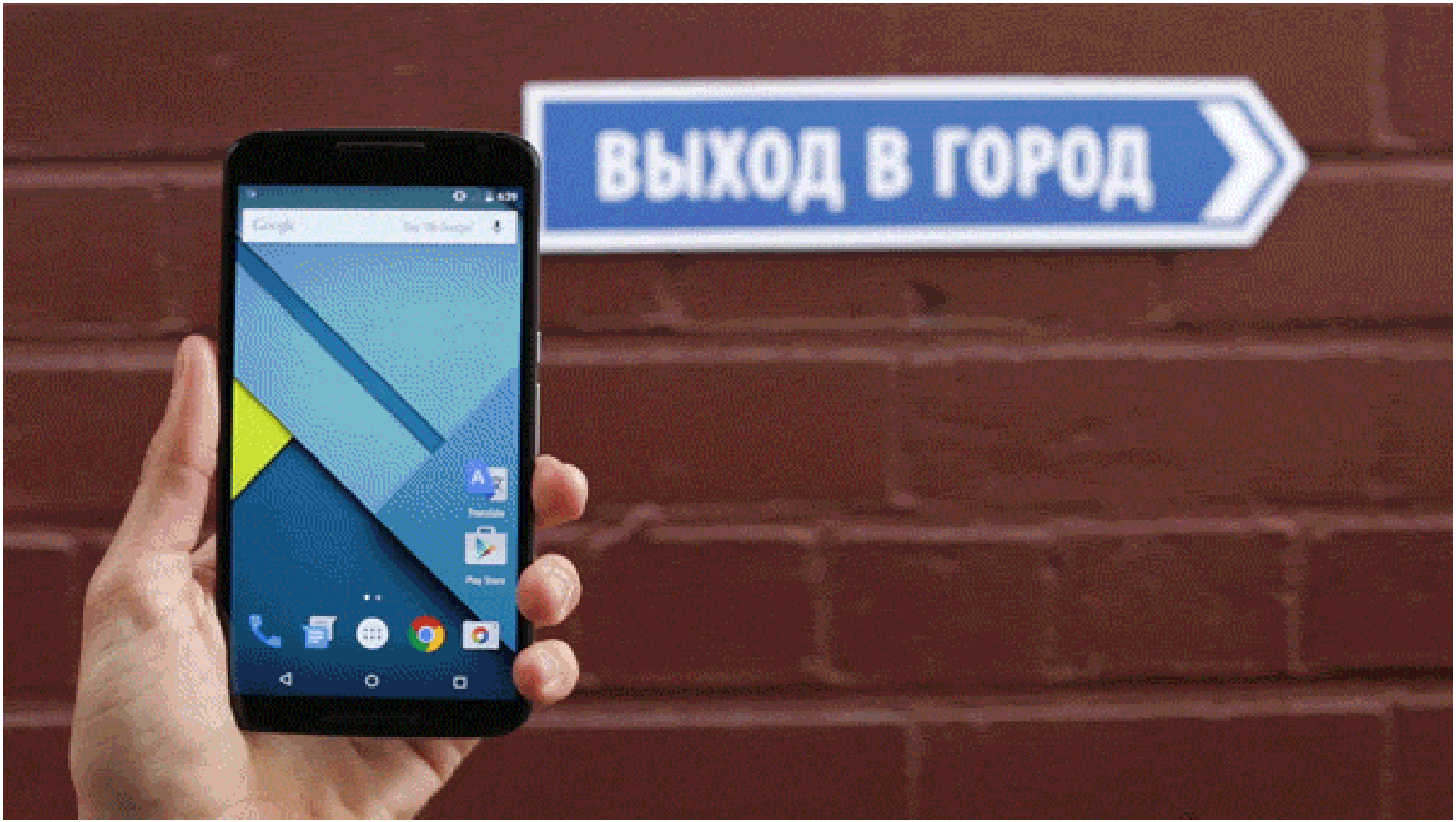
**Computer Vision:** Images to Models

**Comp. Photography:** Images to Images

# Google Photosphere

https://www.youtube.com/watch?v=ZIsRPqcv0Cw

# WordLens / Google Translate



# Fyuse

https://www.youtube.com/watch?v=9rTjaCcwX6o

# Virtual Real World

Campanile Movie

http://www.debevec.org/Campanile/

# Course objectives

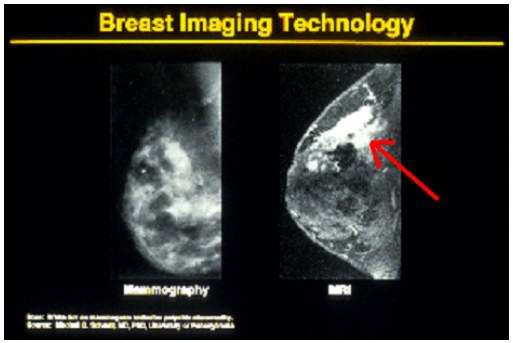
1. You will have new abilities for visual creation.

Graphic by James Hays

# Course objectives

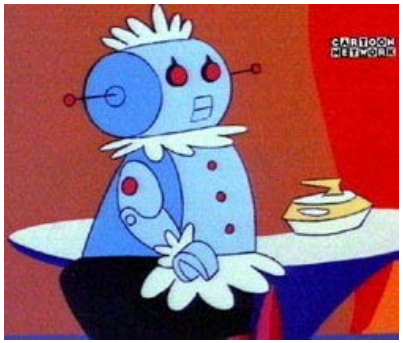
2. You will get a foundation in computer vision.

Safety



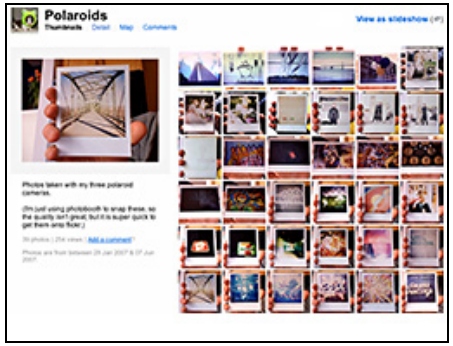

Health

Security




Comfort

Fun

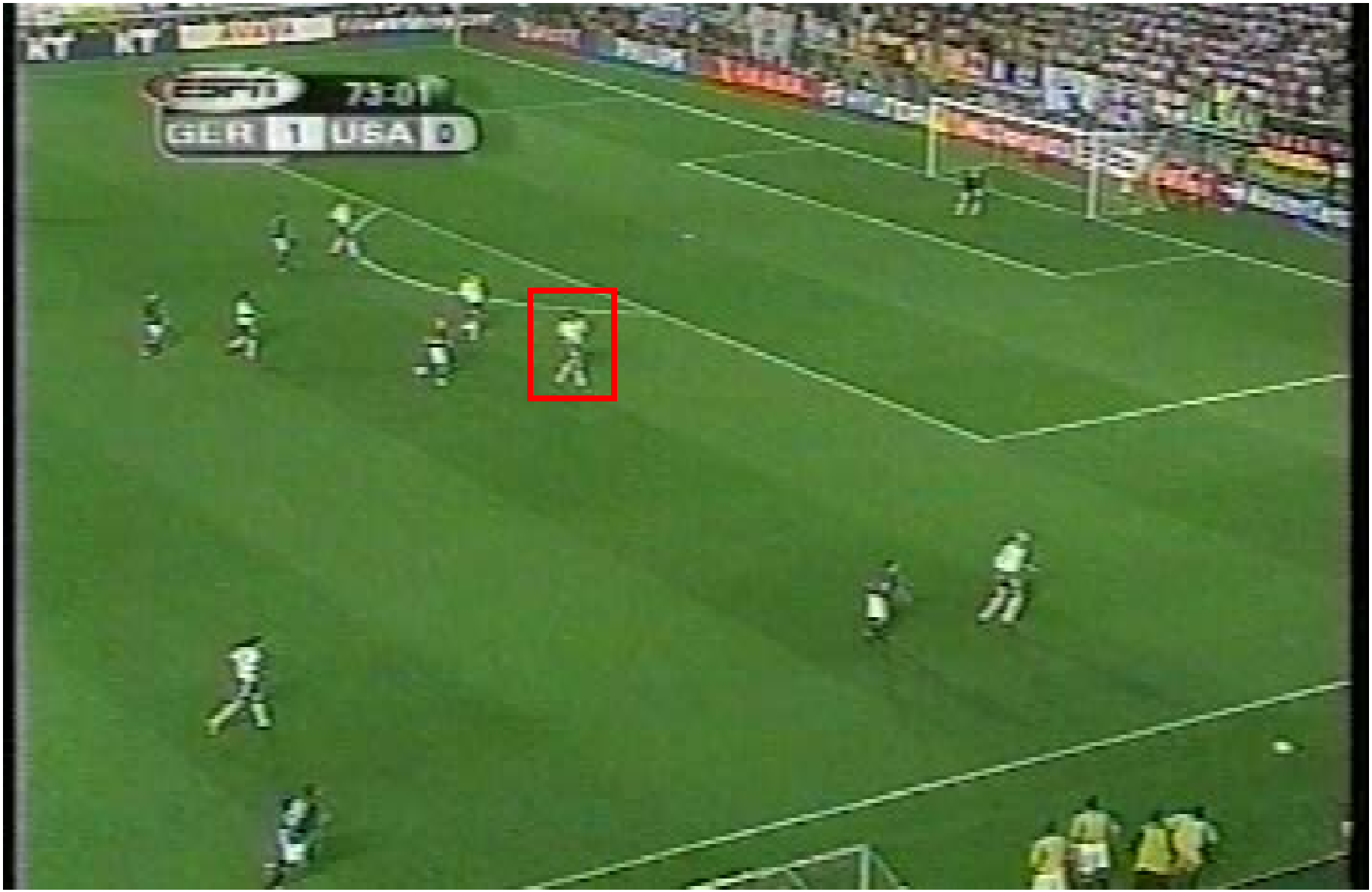



Access

# Course objectives

3. You'll better appreciate your own visual ability.

# Seeing less than you think…



# Seeing less than you think…

Video by Antonio Torralba (starring Rob Fergus)

# But actually…

Video by Antonio Torralba (starring Rob Fergus)

# Course objectives

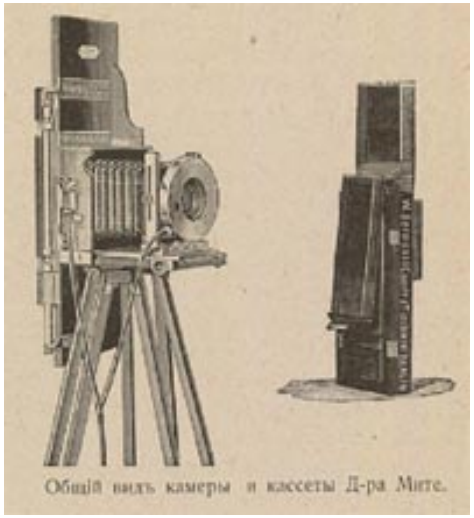
4. You will get a more intuitive understanding of important mathematical and computational concepts
   - Convolutions, filtering
   - Gradients
   - Change of basis, interpolation, extrapolation, PCA
   - Furrier Transforms
   - Dynamic programming, recursion
   - …

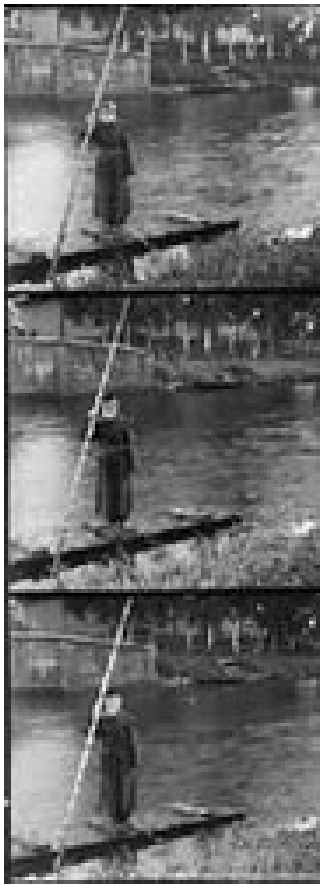
# Course objectives

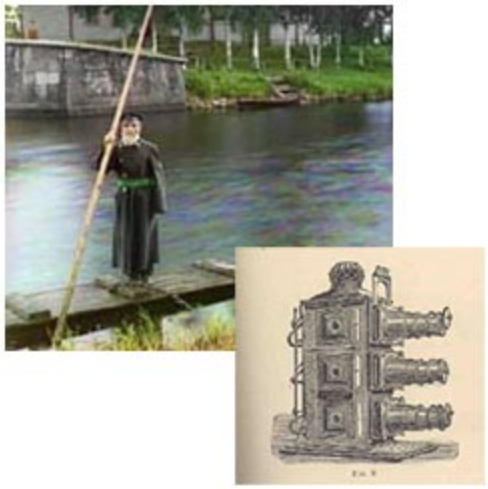
5. You'll have fun doing cool stuff!

# Programming Project #1

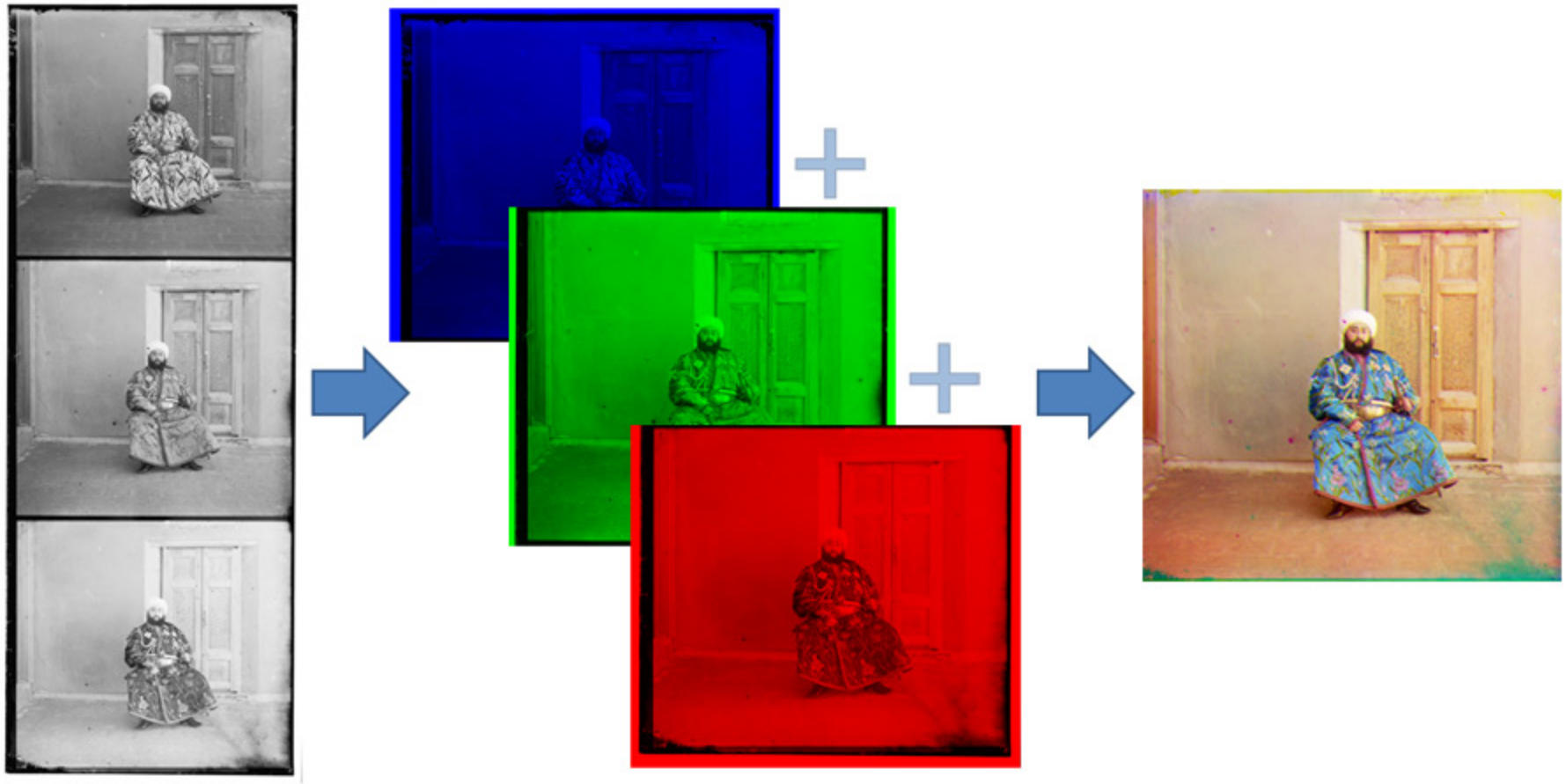
**Prokudin-Gorskii's Color Photography (1907)**





# Programming Project #1



# Programming Project #1

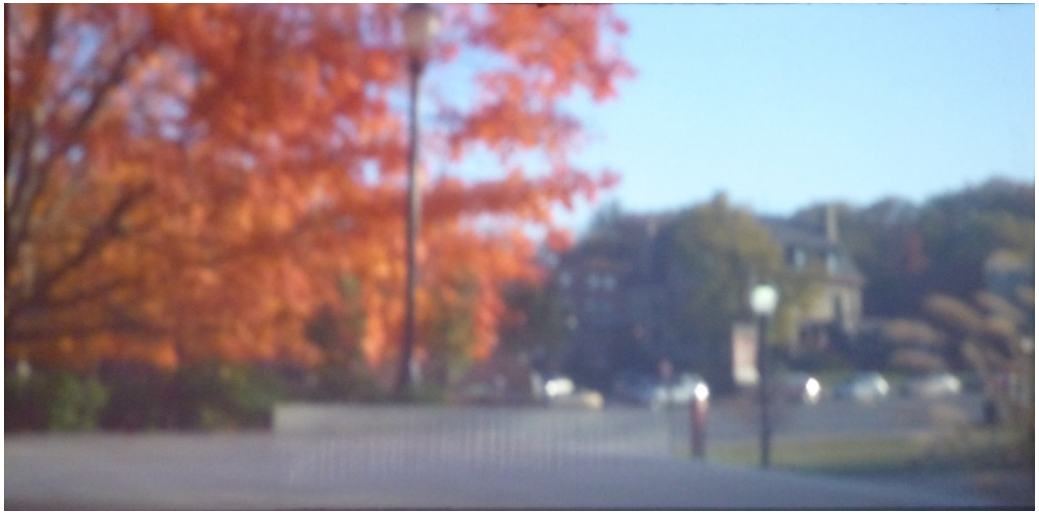
- How to compare R,G,B channels?
- No right answer
  - Sum of Squared Differences (SSD):

$$ssd(u,v) = \sum_{(x,y)\in N} \left[ I(u+x, v+y) - P(x,y) \right]^2$$

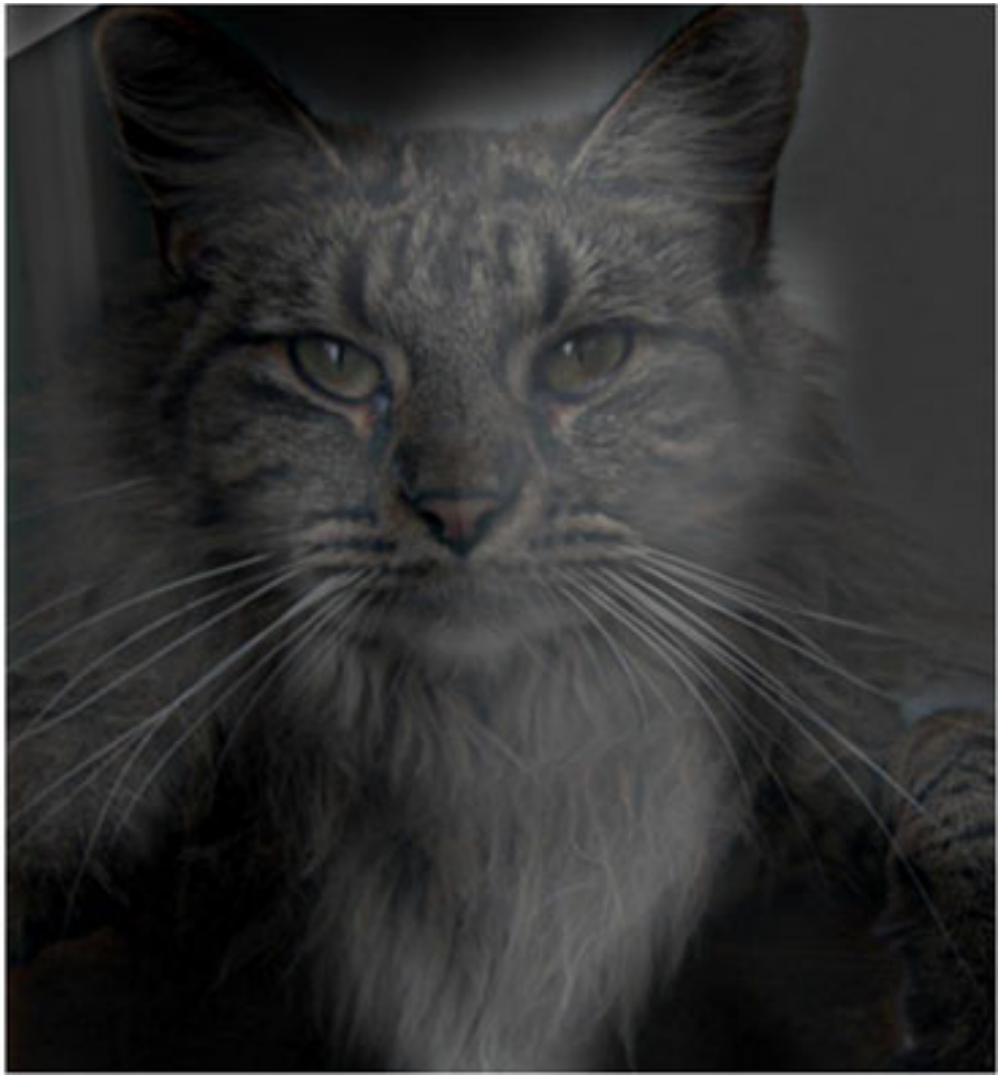
  - Normalized Correlation (NCC):

$$ncc(u,v) = \frac{\sum_{(x,y)\in N} \left[ I(u+x, v+y) - \bar{I} \right] \left[ P(x,y) - \bar{P} \right]}{\sqrt{\sum_{(x,y)\in N} \left[ I(u+x, v+y) - \bar{I} \right]^2 \sum_{(x,y)\in N} \left[ P(x,y) - \bar{P} \right]^2}}$$

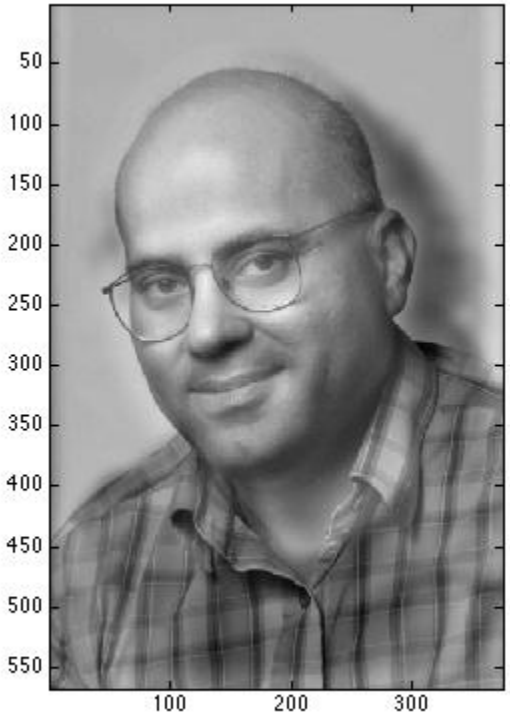
# Project 2:  Building a Camera Obscura



# Project 3: Fun with frequencies



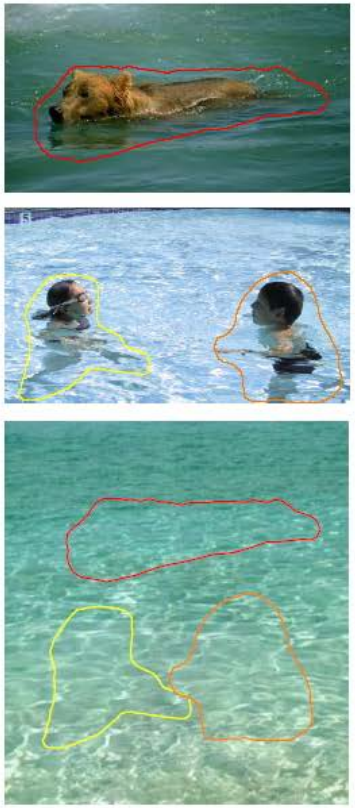
# Project 3: Fun with frequencies




**Prof. Christos Papadimalik**

© Riyaz Faizullabhoy

# Project 4: Gradient Domain Editing



sources/destinations

cloning

seamless cloning

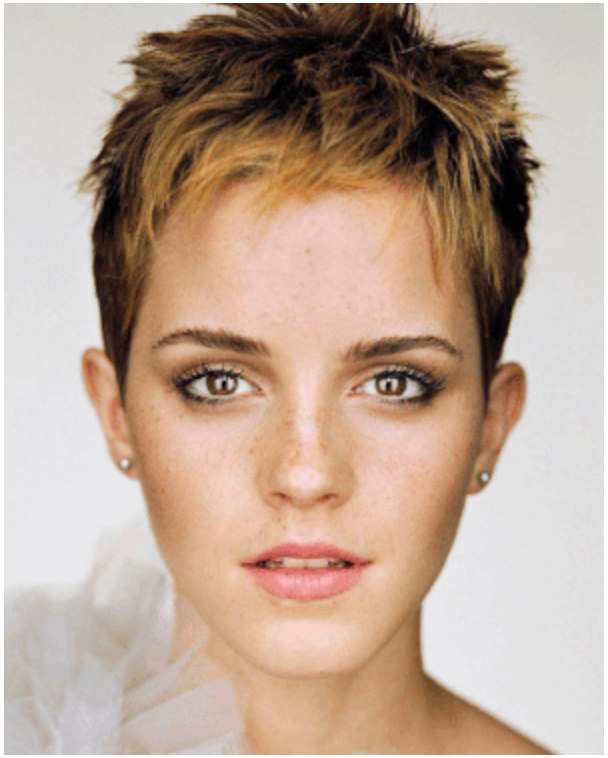
# Project 4: Gradient Domain Editing

© Weilun Sun

# Project 5: Face morphing and caricatures

# Project 5: Face morphing and caricatures

The Beatles



Polyjuice Potion

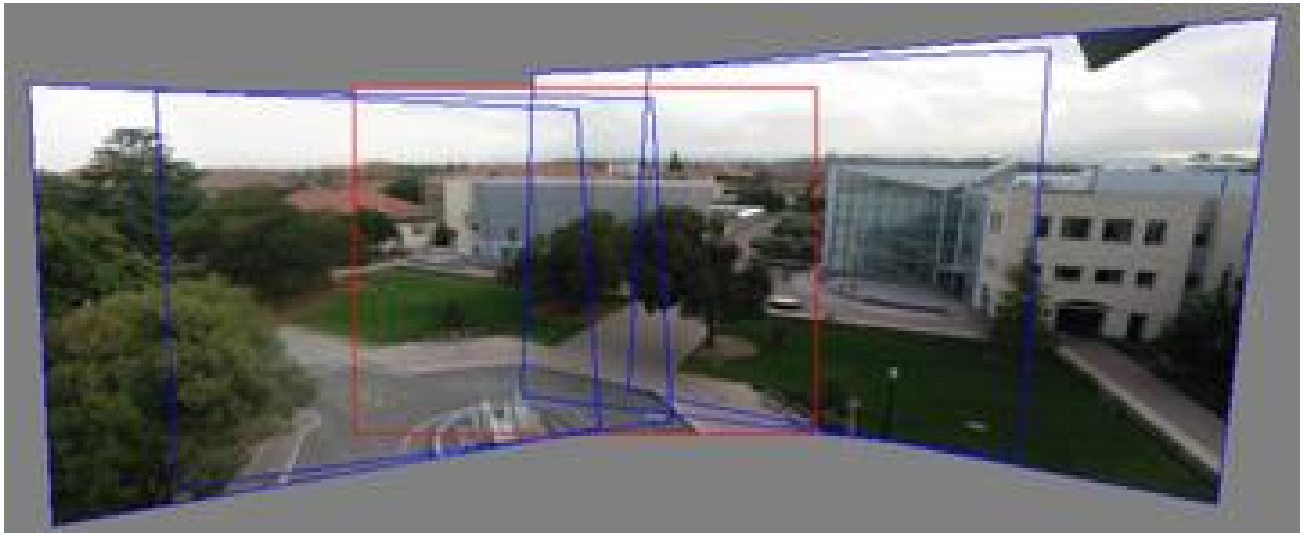
© Rachel Albert

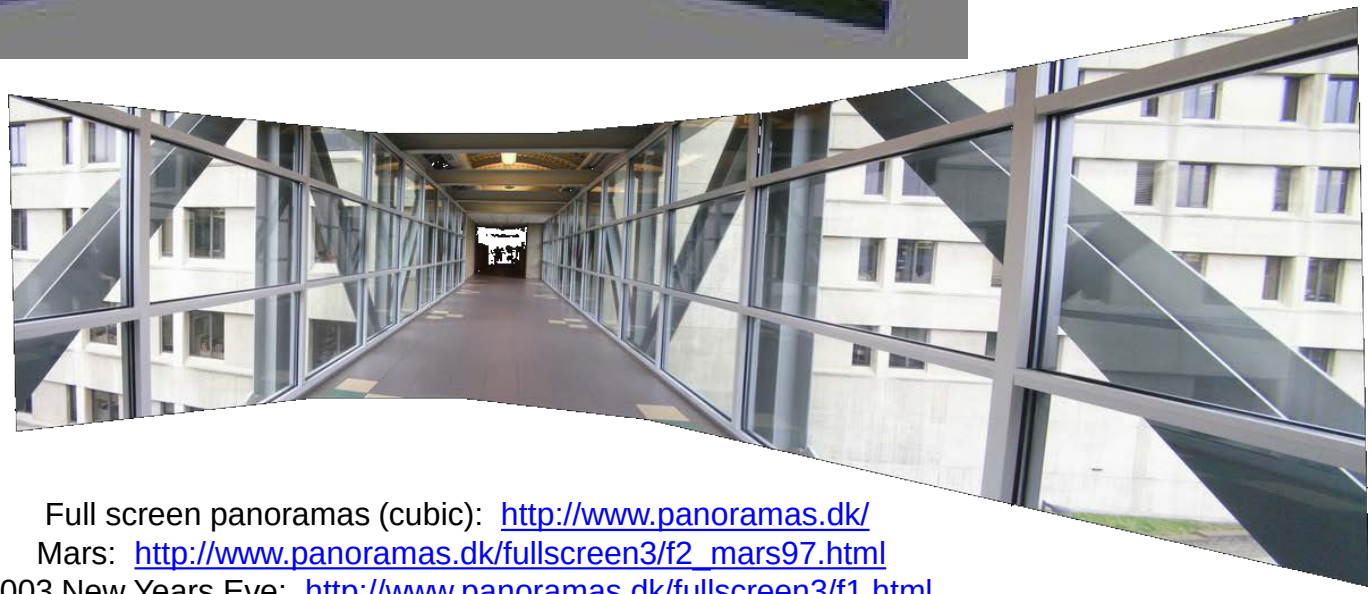
# Project 6: Playing with Lightfields

© Riyaz Faizullabhoy

# Project 7: Automatic Mosaic Stitching

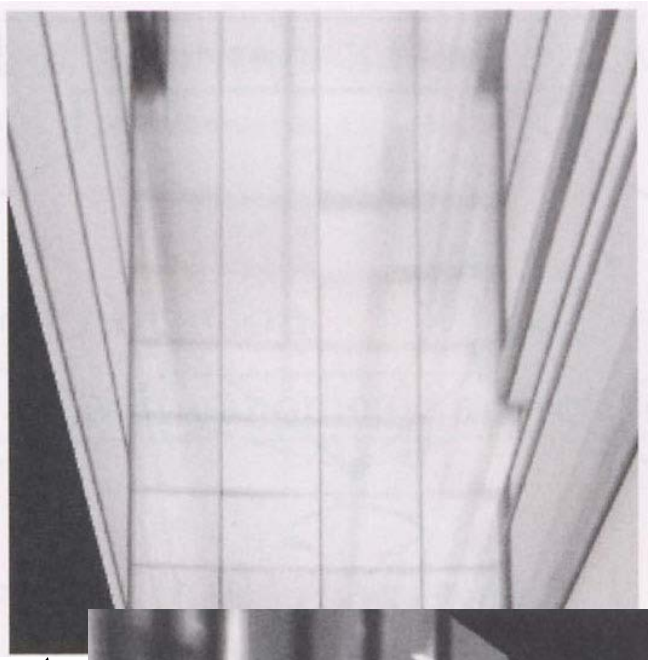
## Photo Mosaics





Full screen panoramas (cubic): http://www.panoramas.dk/
Mars: http://www.panoramas.dk/fullscreen3/f2_mars97.html
2003 New Years Eve: http://www.panoramas.dk/fullscreen3/f1.html

# Image warping with homographies



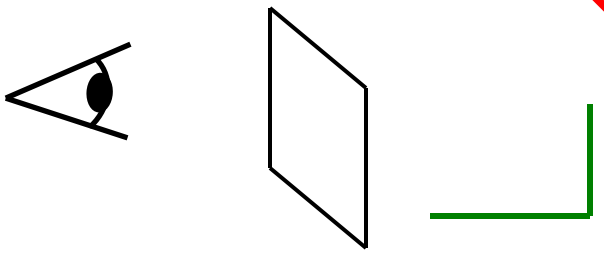
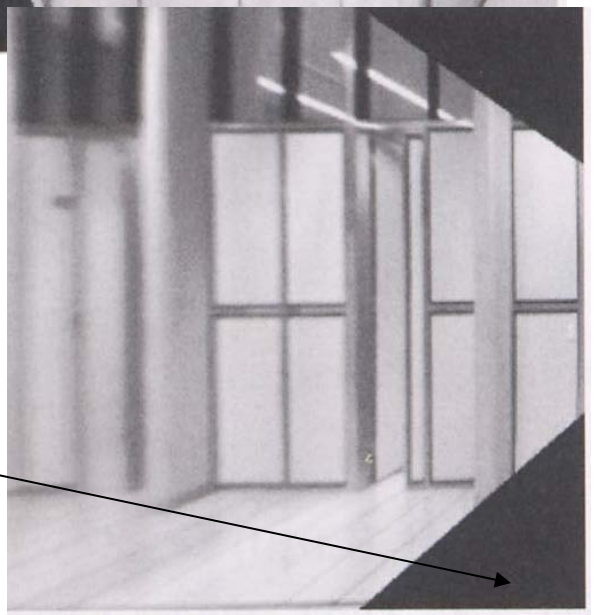


image plane in front



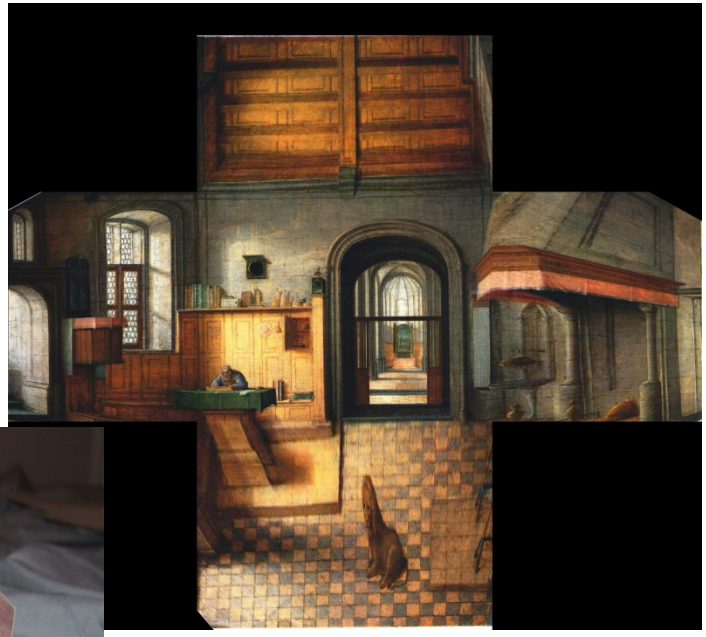
black area
where no pixel
maps to

# Project 7(g)

Tour Into the Picture

# Paper Pop-up

Step 1: define planes



p 2: rectify each plane

Step 3: compute 3D box coords

# Final Project

Something cool!!!

- We will have some pre-canned projects
- Will also have some suggestions, cool datasets, etc
- Or you can do whatever you want!

(can be done in groups of 2 or 3)

# Sample Project

# For each project:

Implement stuff from scratch and apply it to your own photos

Every person does their own project (except final projects and camera obscura)

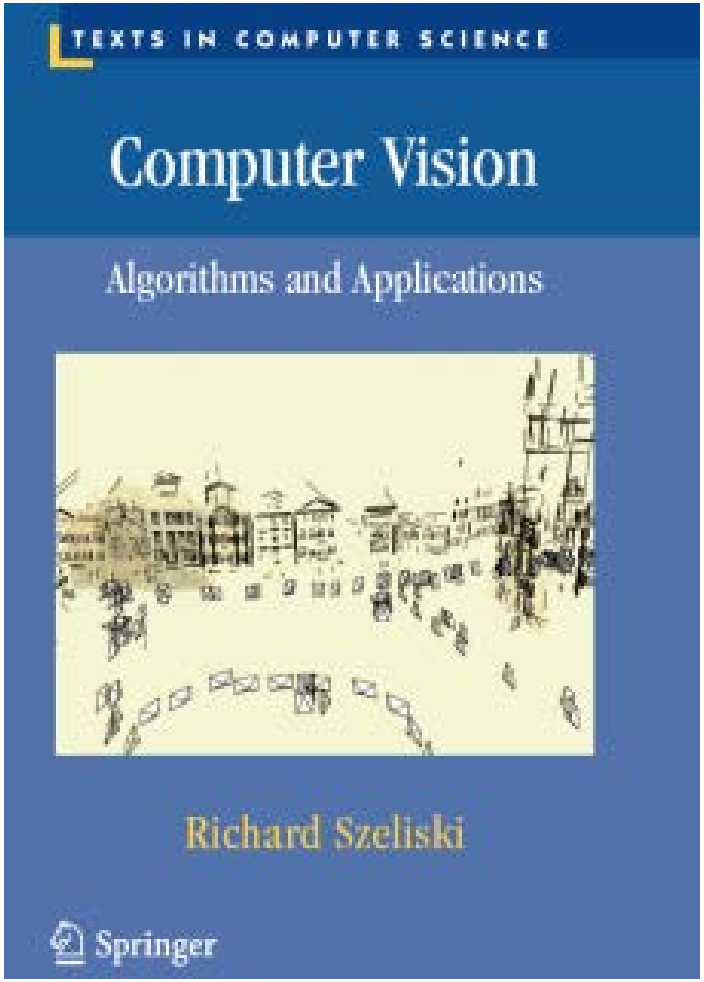
Reporting via web page (plus submit code)

Afterwards, vote for class favorite(s)!

Programming Language:

- Matlab (or Python)
- you can use other languages, but you are on your own

# Textbook




**http://szeliski.org/Book/**

# General Comments

Prerequisites

- Linear algebra!!!
- Good programming skills (at least CS61B)
- Some computer graphics, vision, or image processing is useful, but not required.

Emphasis on programming projects!

- Building something from scratch

Graduate Version:

- Need to do more on each project, plus a final paper

“No Screens” Policy:

- No laptops, no cell phones, no smartphones, etc.

# Getting help outside of class

**Course Web Page**

- http://inst.eecs.berkeley.edu/~cs194-26/

**Discussion board**:

- piazza.com

**Office hours**

- TBA… see webpage and piazza

# Administrative Stuff

## Grading

- Programming Project (60%)
- Exam (20%)
- Final Project (20%)
- Class Participation: priceless

## Late Policy

- Five emergency late days for semester, to be spent wisely
- Max 10% of full credit afterwards

## Cheating

- Let’s not embarrass ourselves

# Academic Integrity

Can discuss projects, but don’t share code

Don’t look up code or copy from a friend

If you’re not sure if it’s allowed, ask

Acknowledge any inspirations

If you get stuck, come talk to us

# Why you should NOT take this class

- Project-based class
  - No canned problem sets
  - Not theory-heavy (but will read a few research papers)
  - No clean rubrics
  - Open-ended by design
- Need time to think, not just hack
  - **Creativity** is a class requirement
- Lots of work…There are easier classes if
  - you just need some units
  - you care more about the grade than about learning stuff
- Not worth it if you don’t enjoy it

# Now… reasons TO take this class

- It’s your reward after 3 grueling years ☺
- You get to create pictures, unleash your creative potential
- Interested in grad school? ☺

# Questions?