



# 计算摄影学

章国锋、陶煜波



# 拍摄的苦恼

- 如何拍出完美的照片，俘获心仪女生的欢心？

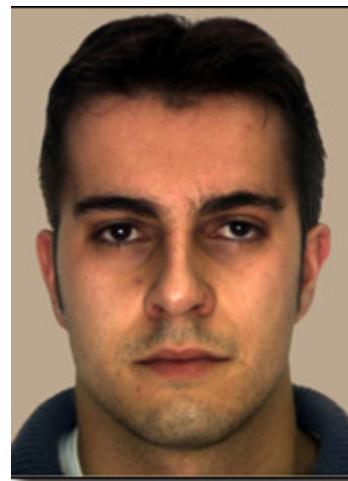
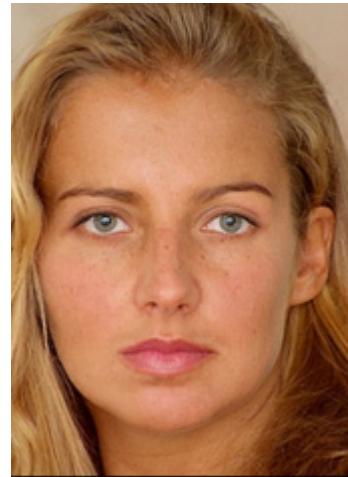
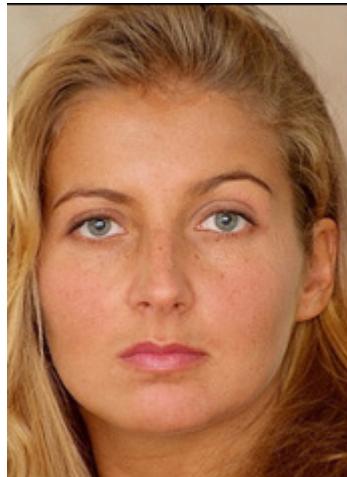


# 拍摄的苦恼

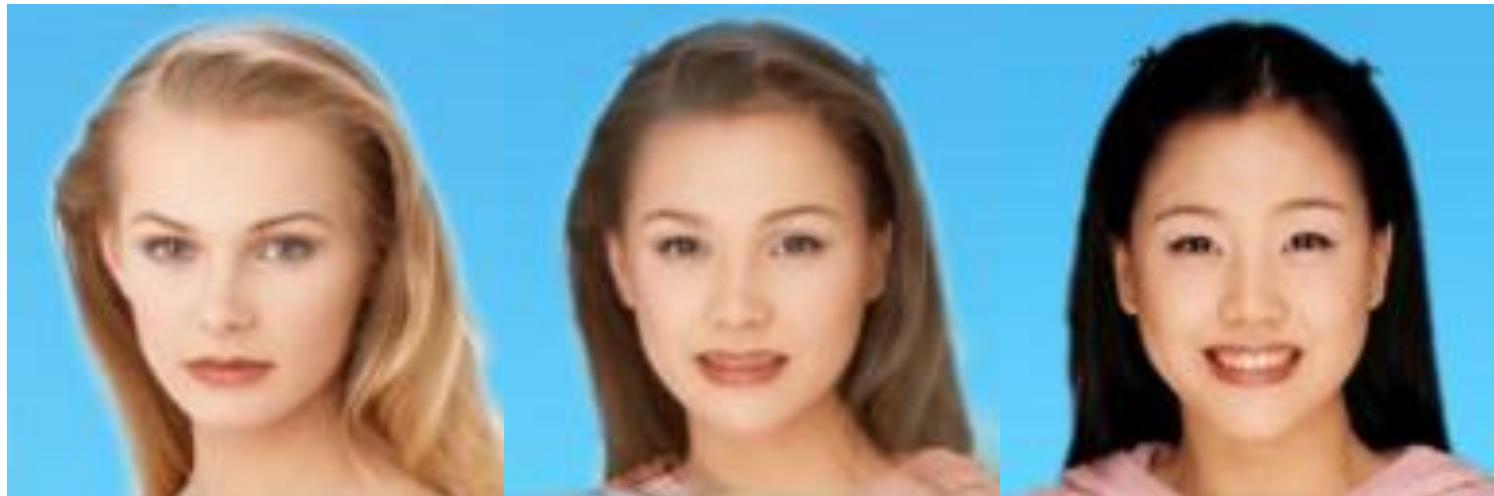
- 如何拍出完美的照片，俘获心仪女生的欢心？



# 美化照片



# 人脸组合



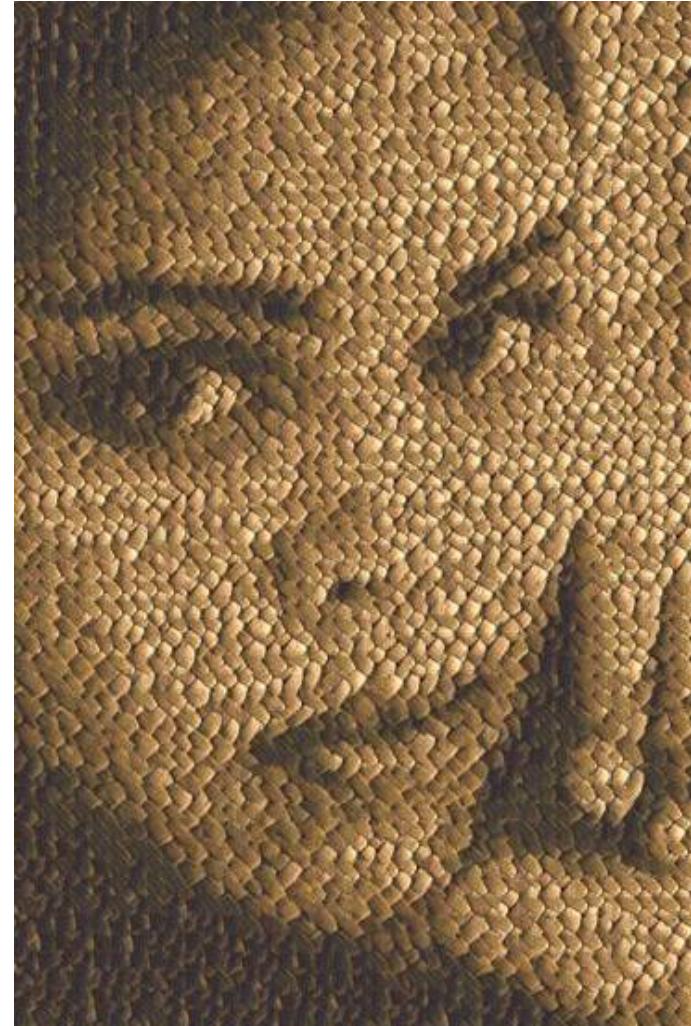
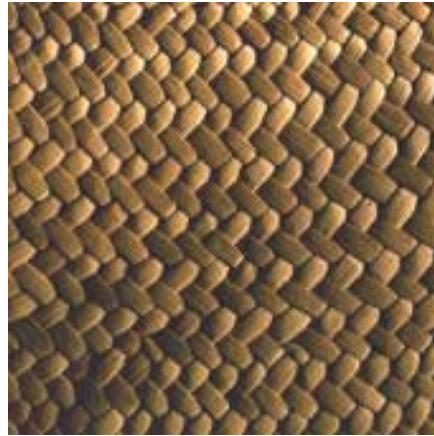
# 人脸组合



# For Fun



# Creating Stylized Images



# Creating unlikely juxtapositions



# Creating unlikely juxtapositions



Jeff Wall, *Flooded Grave*



Scott Mutter, *Escalator*

# Today

- 1) History of Photography
- 2) What is Computational Photography?
- 3) Course Objectives
- 4) Course Overview
- 5) Projects

# A Brief History of 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.

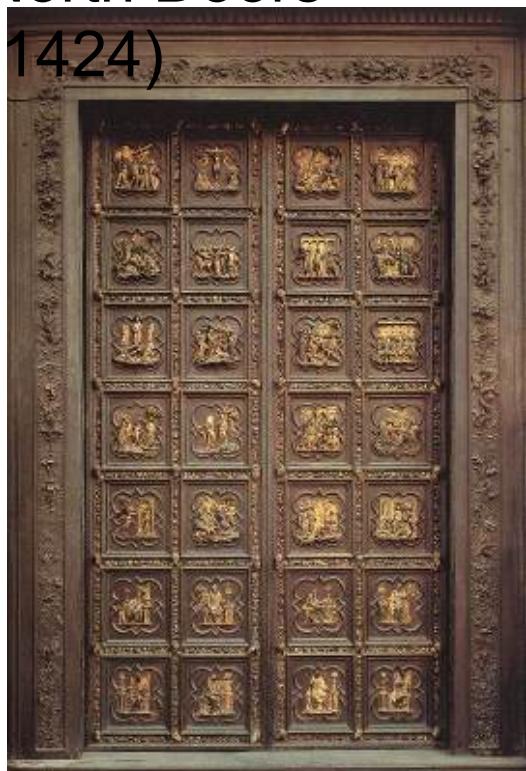
# Depicting Our World: Middle Ages



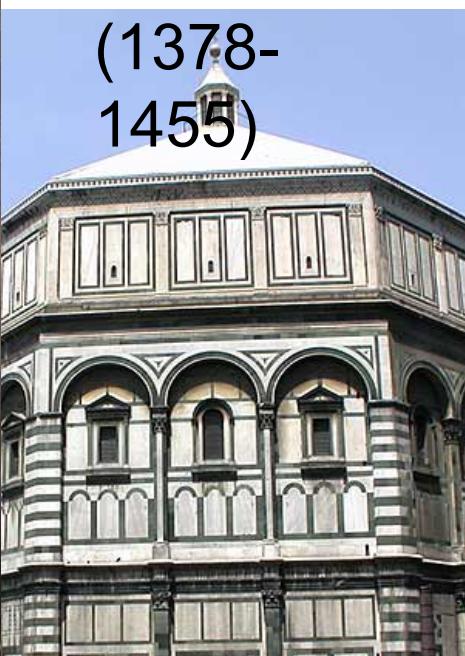
Nuns in Procession. French ms. ca. 1300.

# Depicting Our World: Renaissance

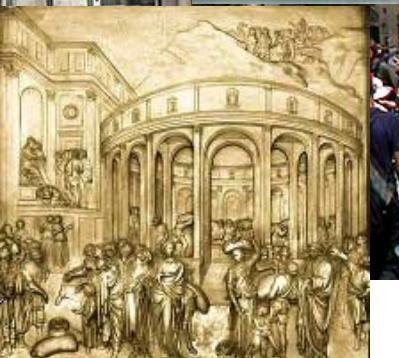
North Doors  
(1424)



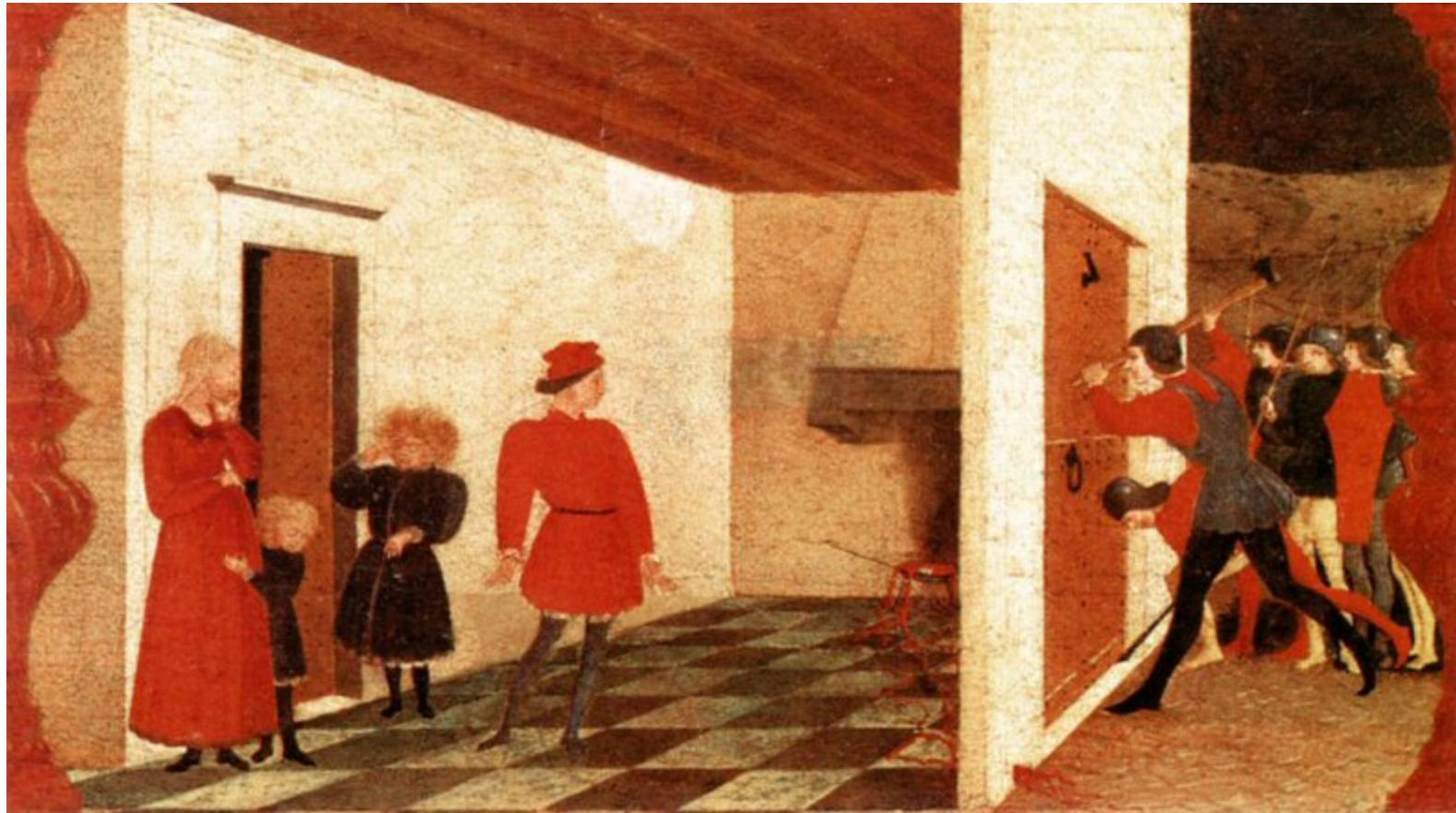
Lorenzo  
Ghiberti  
(1378-  
1455)



East Doors  
(1452)

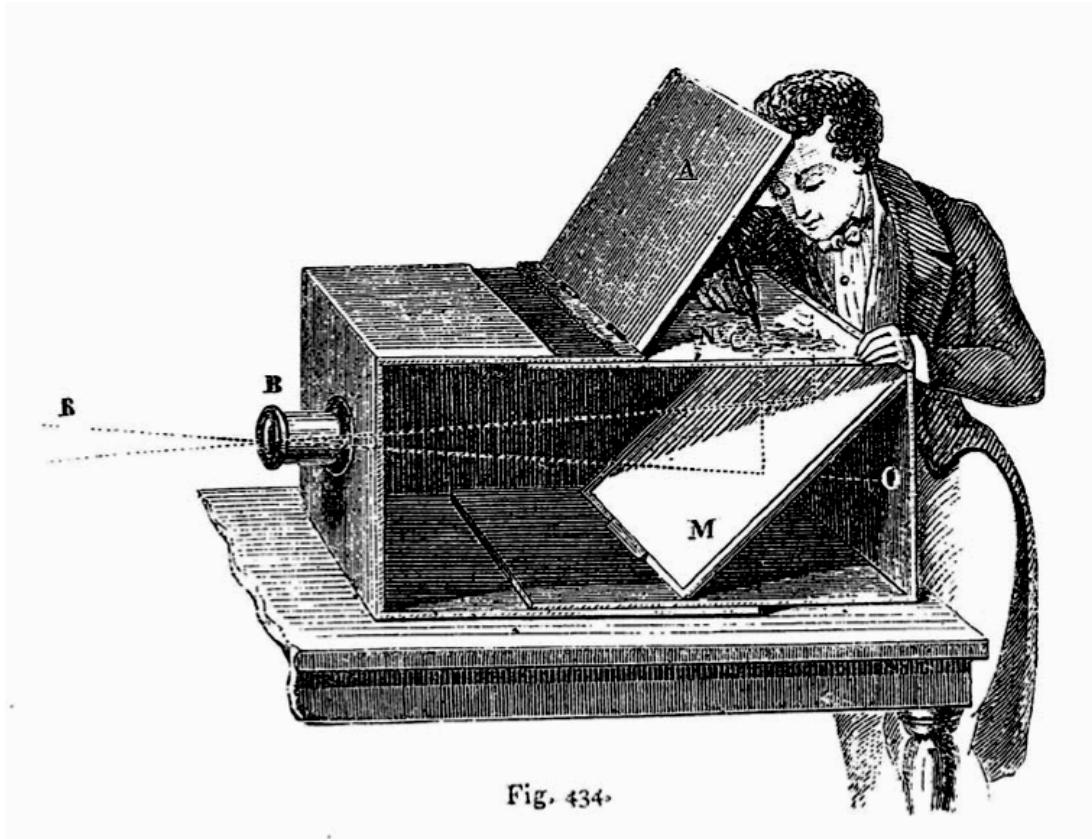


# Depicting Our World: Renaissance



***Paolo Uccello,  
Miracle of the Profaned Host (c.1467-9)***

# Depicting Our World: Toward Perfection



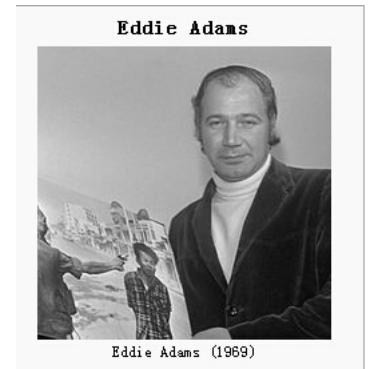
Lens Based Camera Obscura, 1568

# Depicting Our World: Perfection!



*Still Life*, Louis Daguerre, 1837

- ‘Still photographs are the most powerful weapon in the world.’
- Eddie Adams, Pulitzer Prize winning photographer.



What is Computational Photography?  
---from a hardware's perspective

# From a hardware's perspective

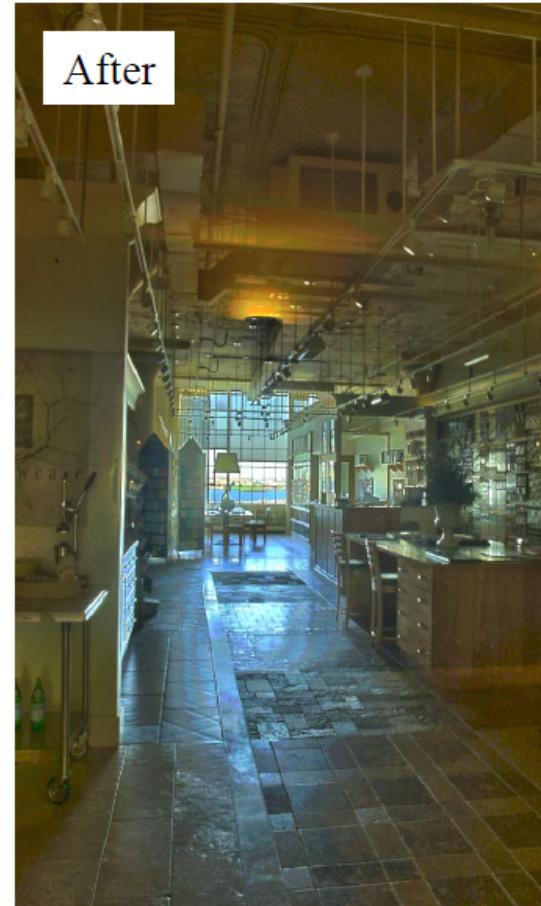
- **Digital photography**
  - Simply replaces traditional sensors and recording by digital technology
  - Involves only simple image processing
- **Computational photography**
  - Camera design that takes computation into account
  - More elaborate image manipulation and computation

# Examples

- **Tone mapping**
- **Defocus Matting**
- **Multi-Modal Imaging**

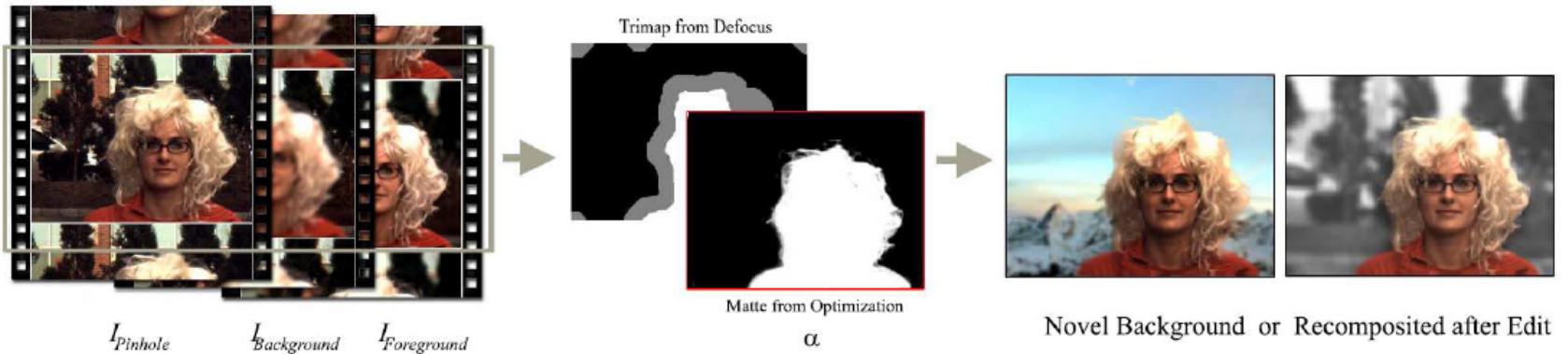
# Tone mapping

Suitable for HDR images

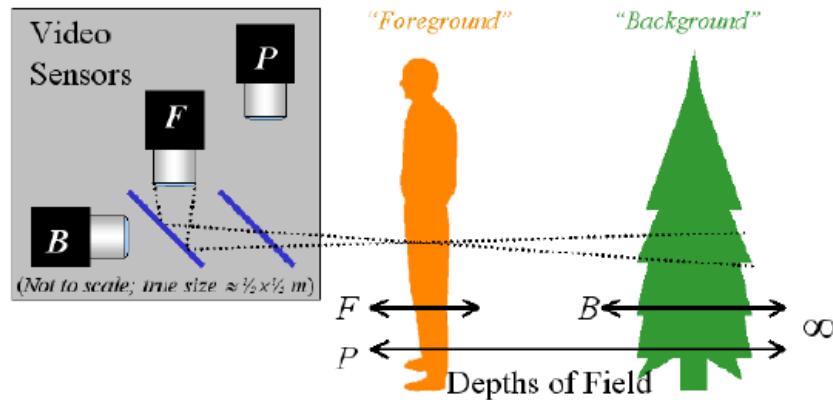


# Defocus Matting

- What can be achieved



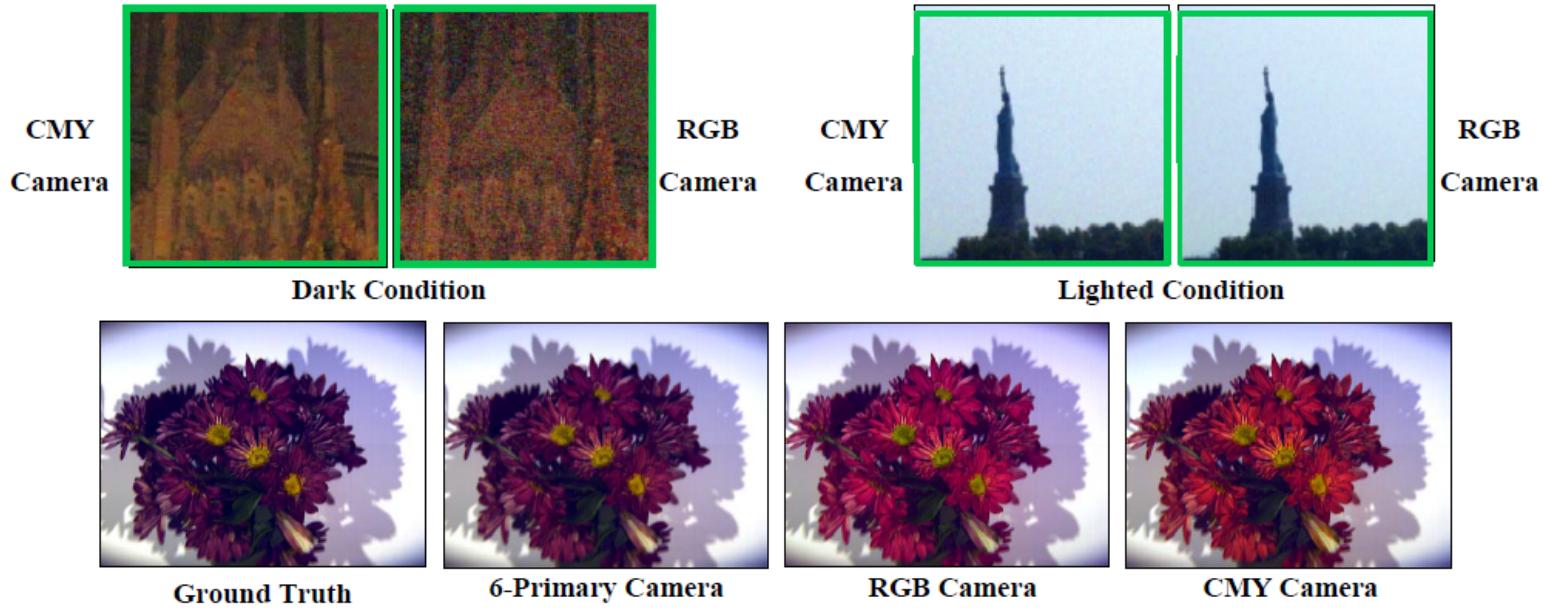
- Design: use 3 streams with different focus



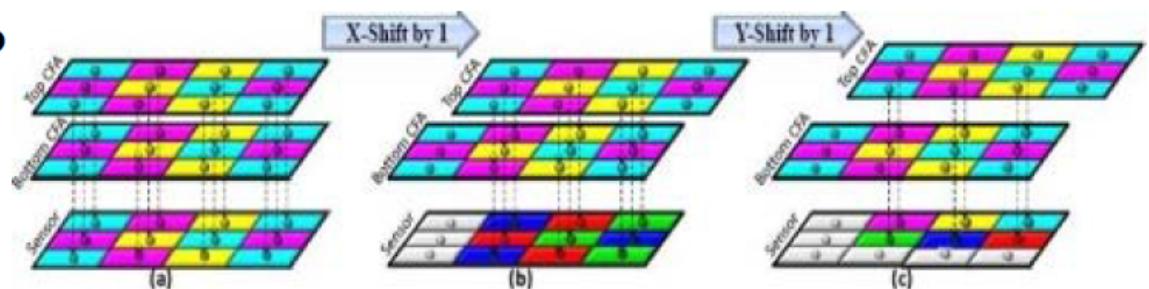
<http://people.csail.mit.edu/wojciech/DefocusVideo/index.html>

# Multi-Modal Cameras

- What can be achieved



- How it works?



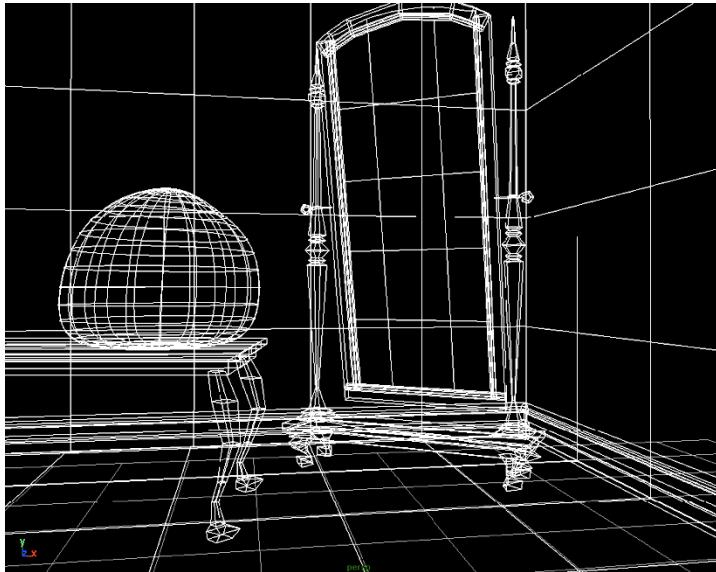
<http://www.ics.uci.edu/~bsajadi/SwitchableCam.html>

What is Computational Photography?  
---from a software's perspective

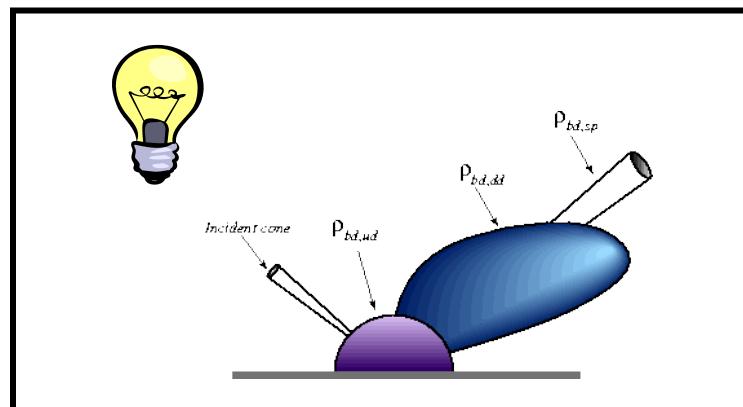
# From a software's perspective

- Definition 1: the use of photographic imagery to create **graphics content**

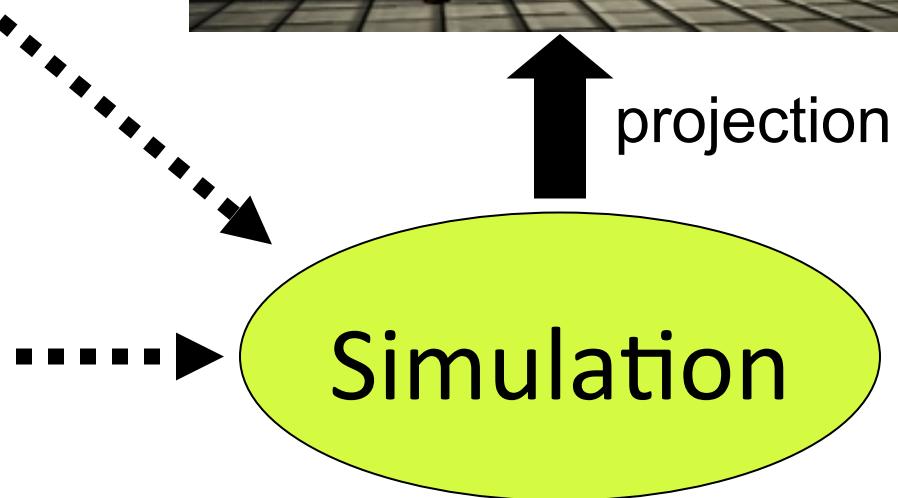
# Traditional Computer Graphics



3D geometry



physics



Simulation

# State of the Art (10 years ago)



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

# The richness of our everyday world



Photo by Svetlana Lazebnik

What are hard to model in Computer  
Graphics?

# 1. People



From "Final Fantasy"

On the Tube, London



## 2. Faces / Hair



From "Final Fantasy"



Photo by Joaquin Rosales Gomez

# 3. Urban Scenes



Photo of I LA



# 4. Nature



River Cherwell,  
Oxford



# Creating Realistic Imagery

## Computer Graphics



- + great creative possibilities
- + easy to manipulate objects/  
viewpoint
- Tremendous expertise and  
work for realism

## Computational Photography

Realism  
Manipulation  
Ease of capture

## Photography



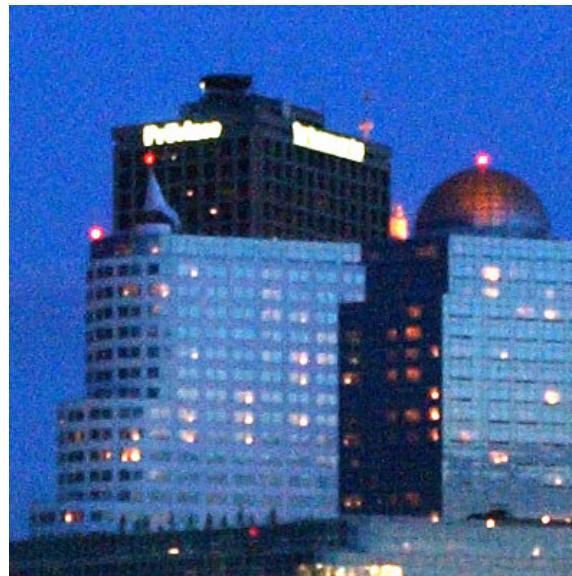
- + instantly realistic
- + easy to acquire
- very hard to manipulate  
objects/viewpoint

# From a software's perspective

- Definition 1: the use of photographic imagery to create **graphics content**
- Definition 2: The use of computational techniques to **overcome limitations of conventional photography**

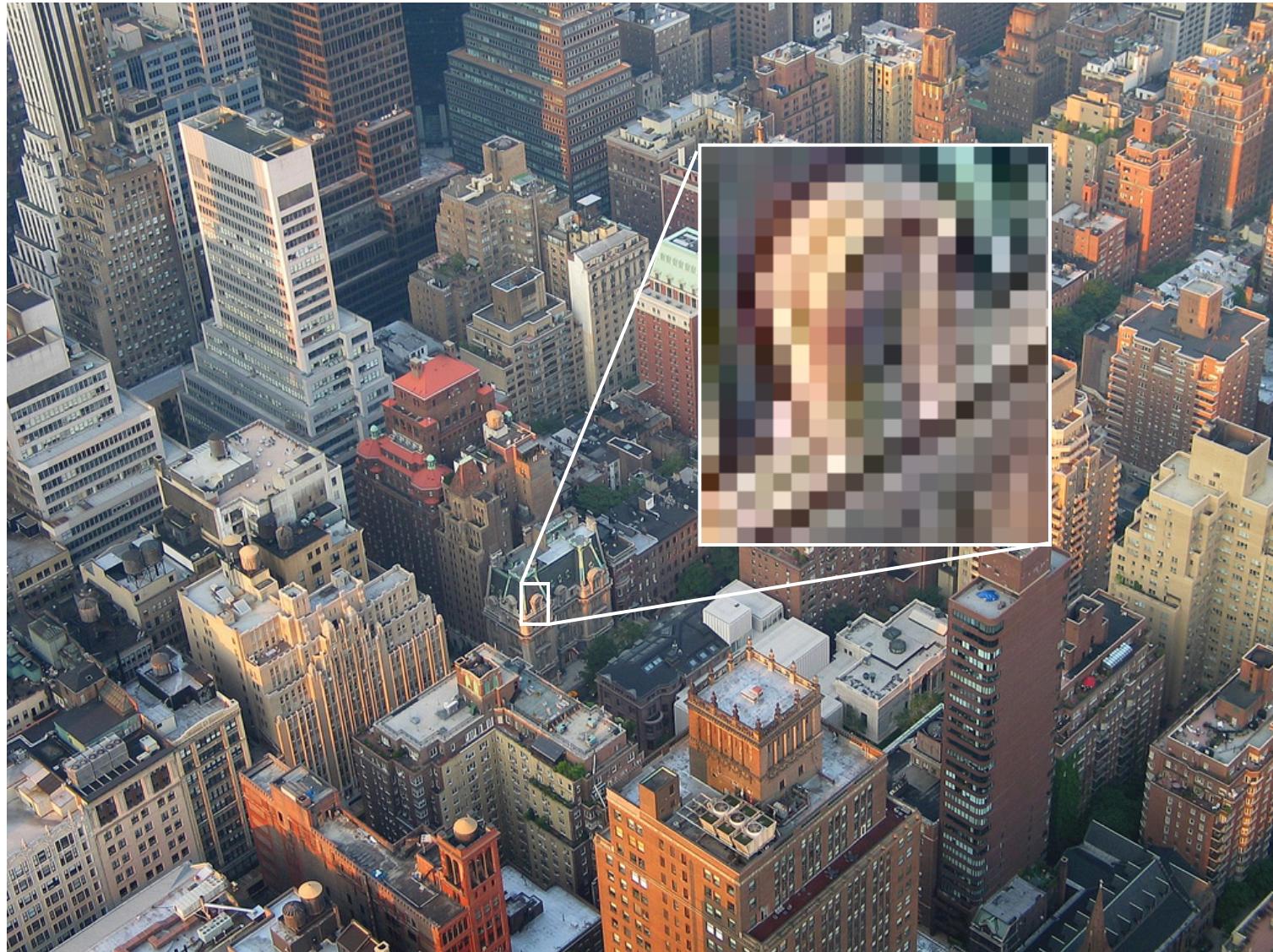
# Limitations of traditional photography

- Blur, camera shake, noise, damage



# Limitations of traditional photography

- Limited resolution



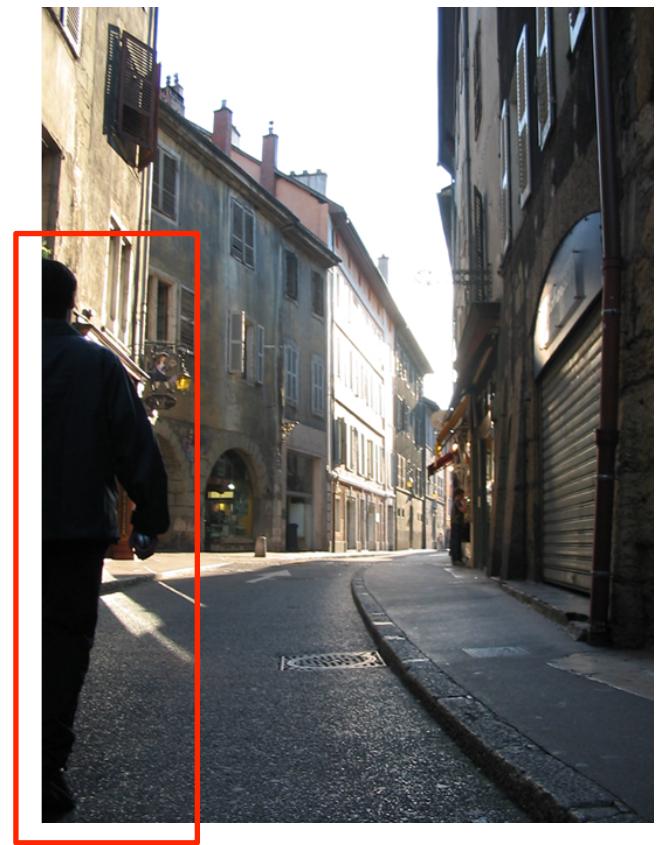
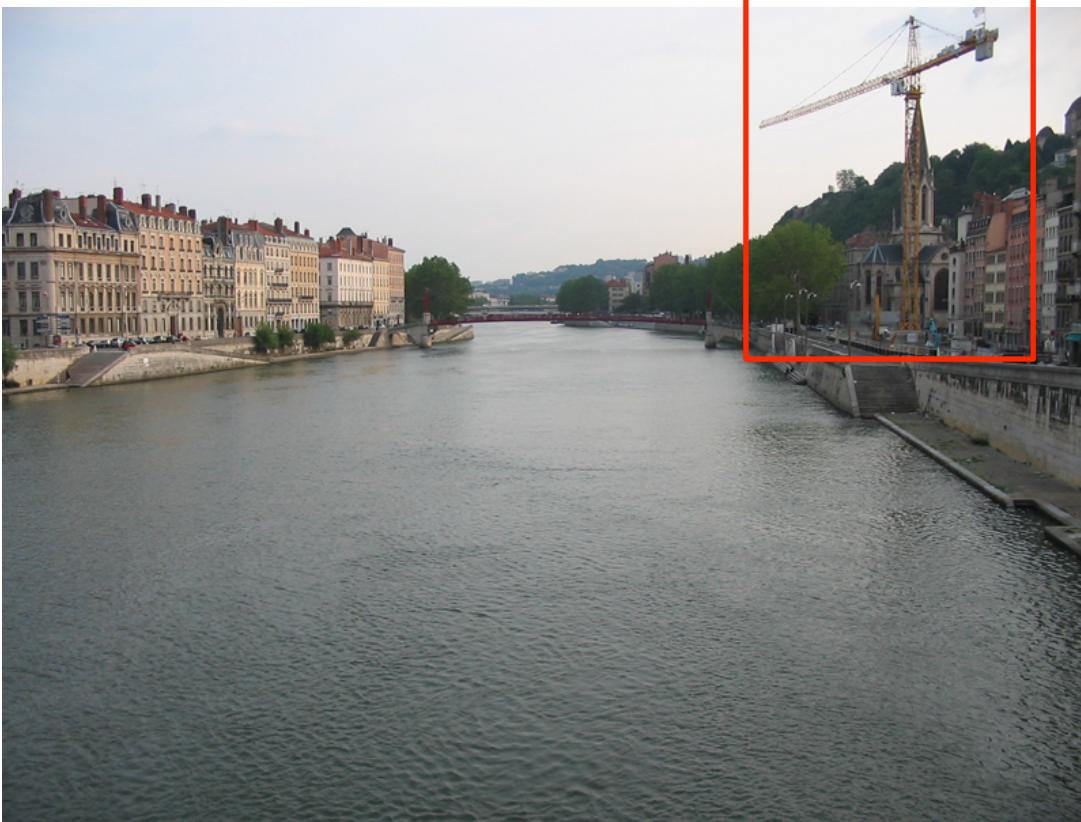
# Limitations of traditional photography

- Bad color / no color



# Limitations of traditional photography

- Unwanted objects



# Limitations of traditional photography

- Unfortunate expressions



# Limitations of traditional photography

- Limited dynamic range



# Limitations of traditional photography

- Single viewpoint, static 2D picture



# Limitations of traditional photography

- Single depth of focus



# Comp Photo and Related Fields

- Computer Graphics: Models to Images
- Comp. Photography: Images to Images
- Computer Vision: Images to Models

# Course objectives

1. You will have new abilities for visual creation.



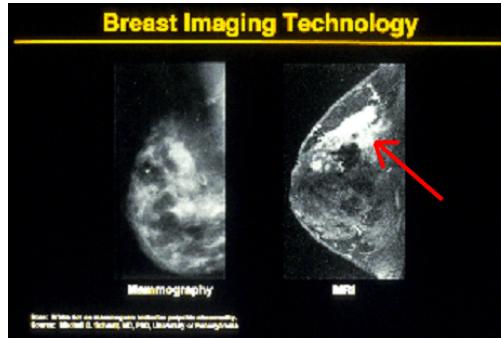
Graphic by James Hays

# Course objectives

2. You will get a foundation in computer vision.



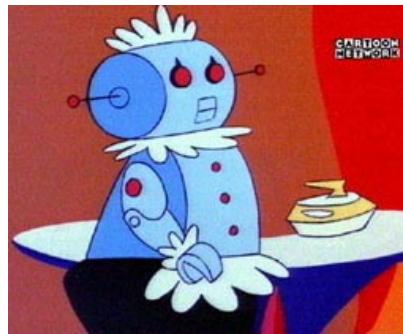
Safety



Health



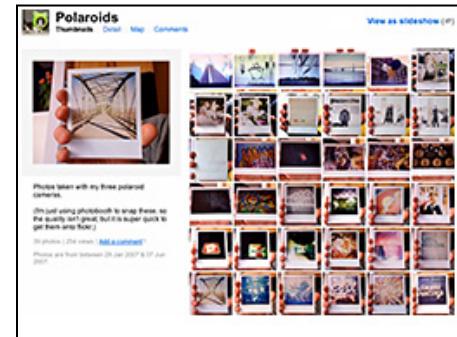
Security



Comfort



Fun



Access

# Course objectives

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



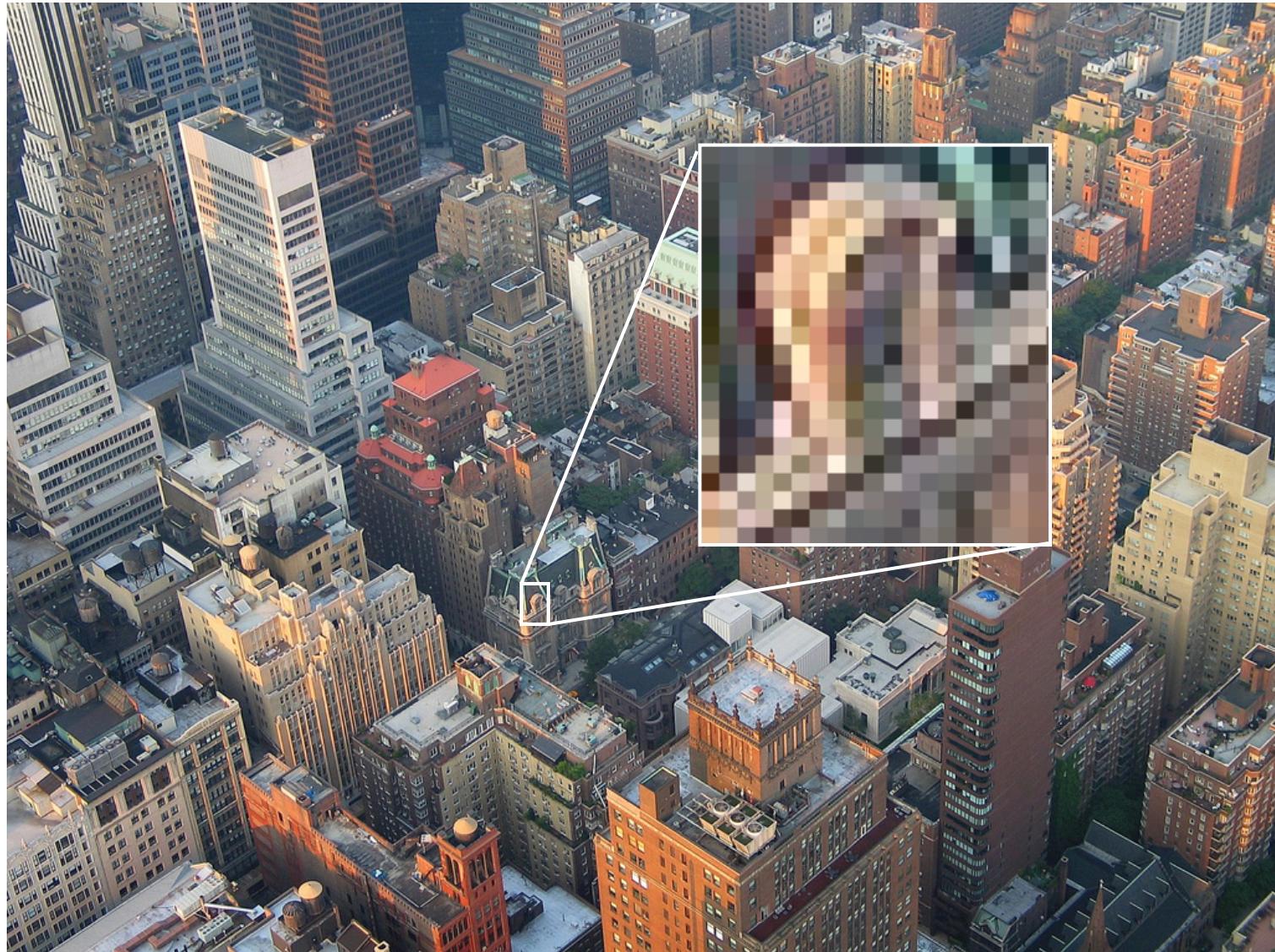
# Course objectives

4. You'll have fun doing cool stuff!

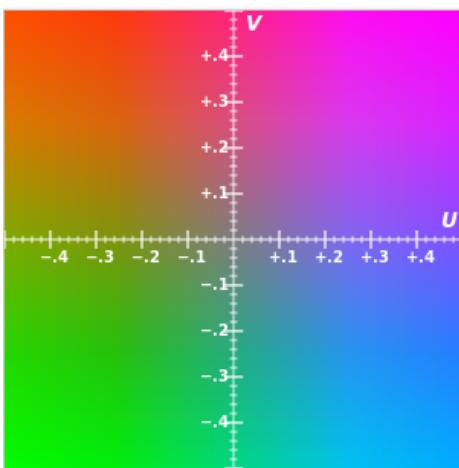
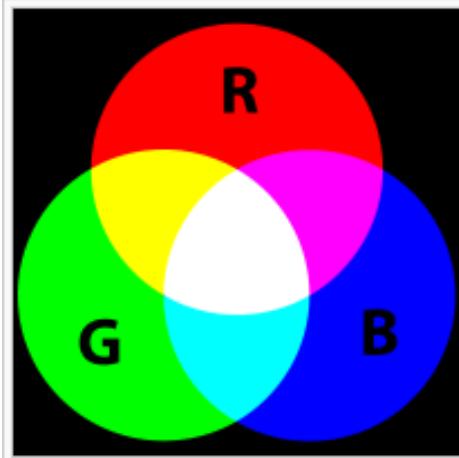
# Courses Overview

1. 计算摄影学概览
2. 图像的数字化、颜色空间、滤波与频域变换
3. 泊松图像编辑与交互式数字蒙太奇
4. 上色与重上色
5. 图像去模糊与非线性数值优化方法
6. 图像补全
7. 纹理合成与图像缩放
8. 交互式图像分割与抠像
9. 特征匹配与光流
10. 全景图拼接
11. 相机模型与运动推断结构
12. 实时摄像机跟踪
13. 单视图与多视图三维重建
14. 课程讨论与项目答辩

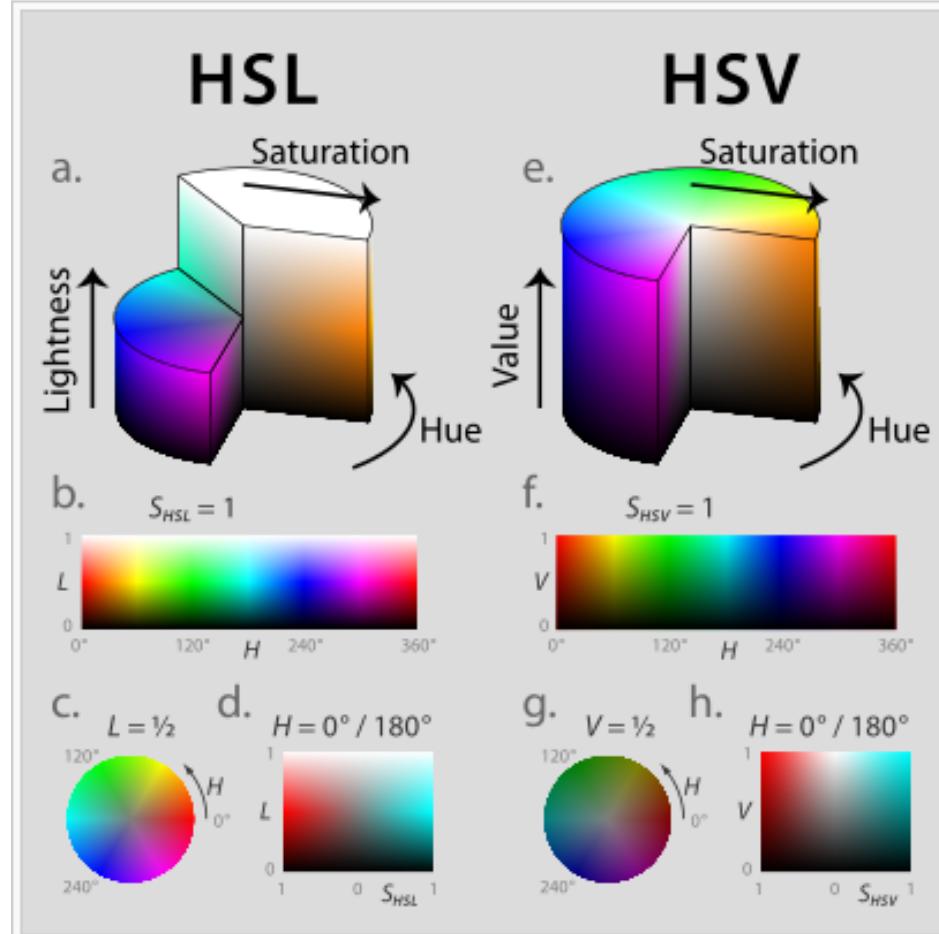
## 2. Digital Image



# 2. Color Space



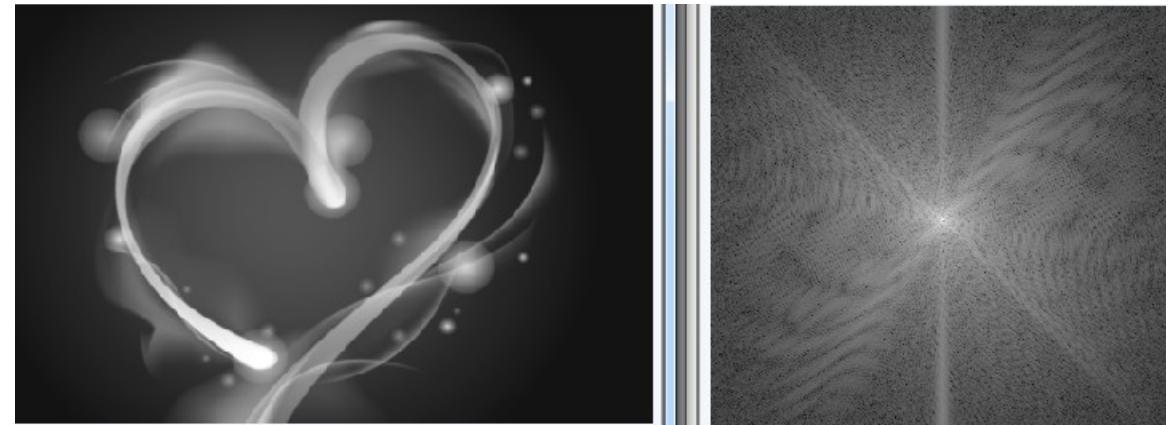
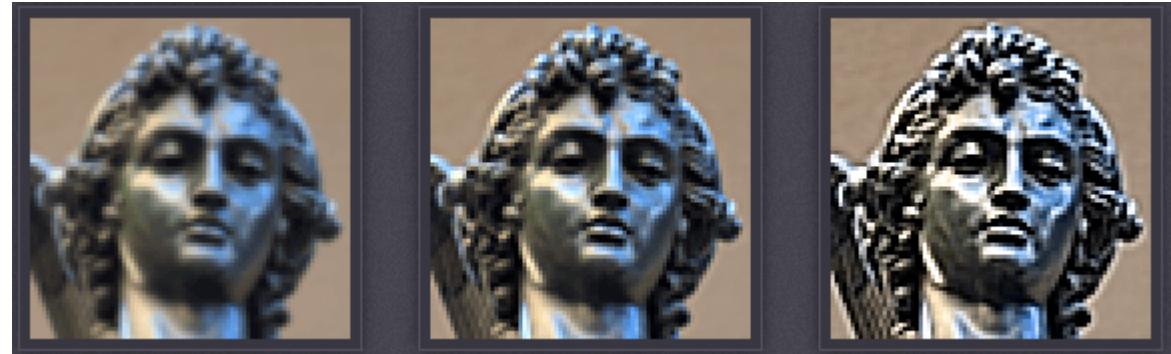
YUV



# 2. Filtering and Fourier Transform



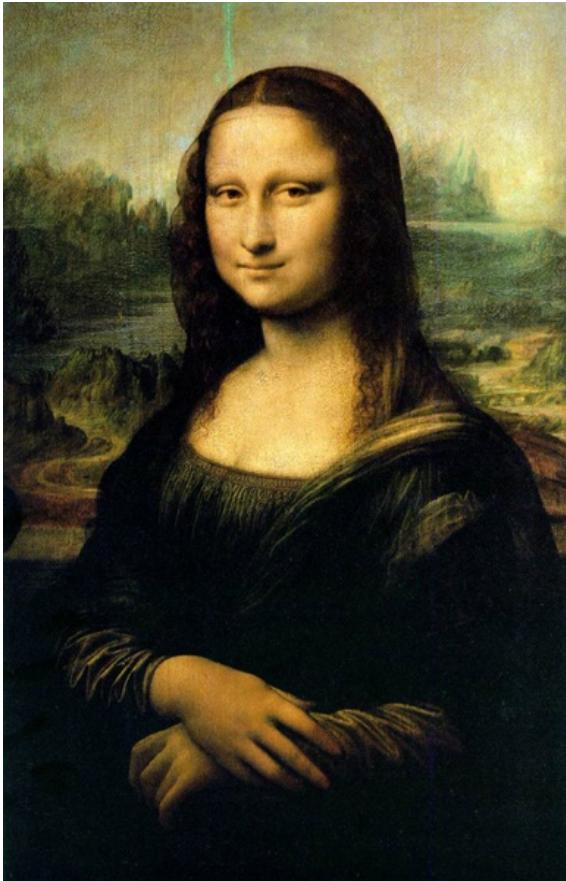
Blur



### 3. Poisson Image Editing



# 3. Poisson Image Editing



Photos from Evan Wallace

# 3. Interactive Photomontage



# 3. Interactive Photomontage

## Interactive Digital Photomontage

Aseem Agarwala, Mira Dontcheva

Maneesh Agrawala, Steven Drucker, Alex Colburn

Brian Curless, David Salesin, Michael Cohen



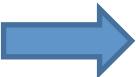
## 4. Image Colorization & Recolorization



# Crater Lake

grayscale input  
(83 frames)

# 4. Image Colorization & Recolorization



# 5. Image Deblurring

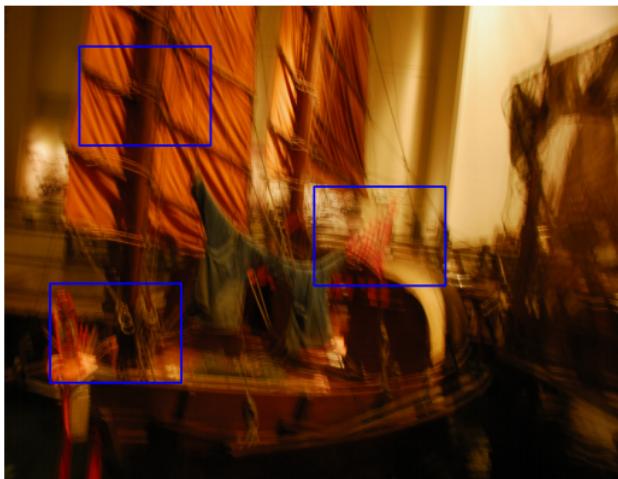


Real Image Input

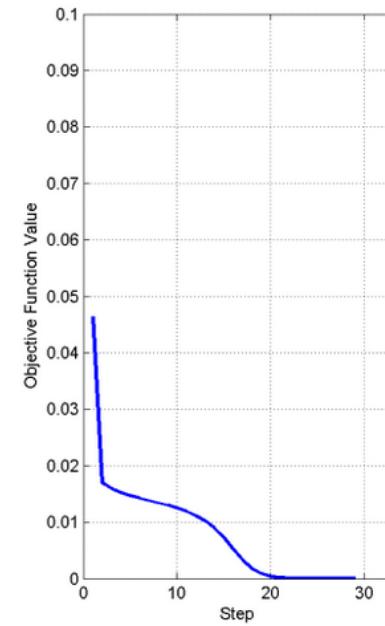
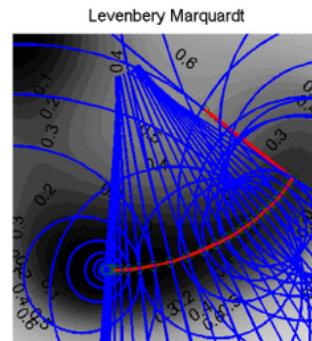
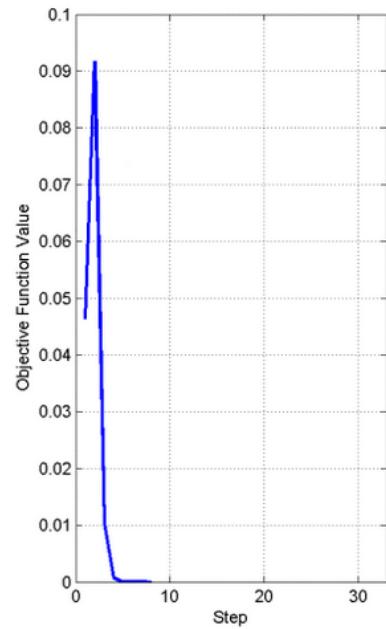
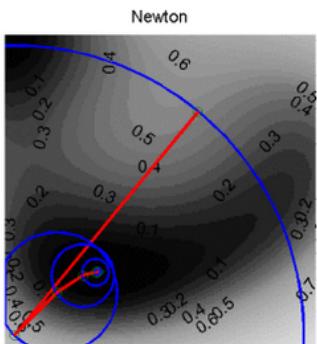


Deblurring Result

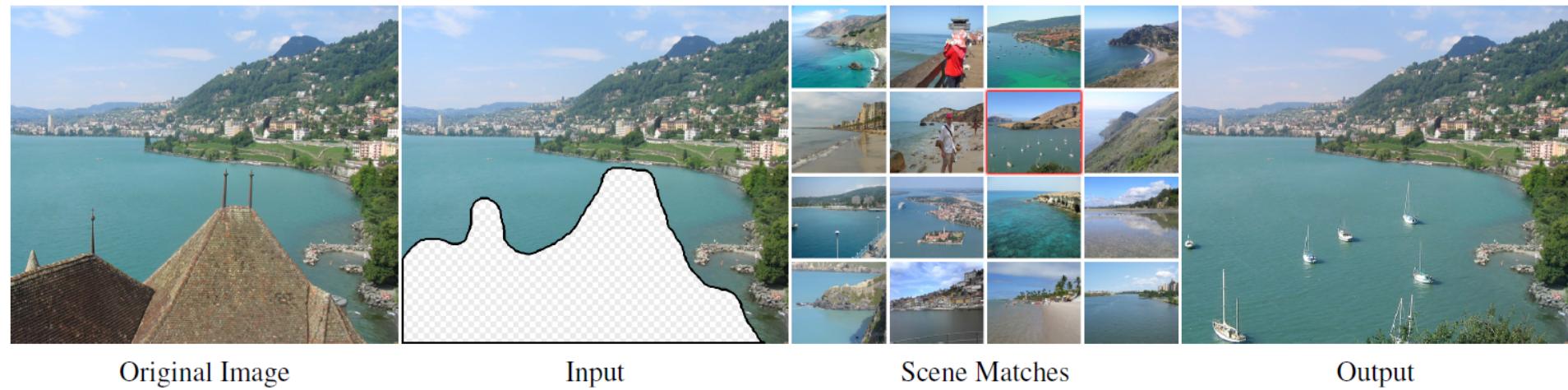
# 5. Image Deblurring



# 5. Non-Linear Optimization



# 6. Image Completion



# 6. Image Completion



**a**



**b**

# Statistics of Patch Offsets for Image Completion

## Demo

Kaiming He and Jian Sun  
Microsoft Research Asia

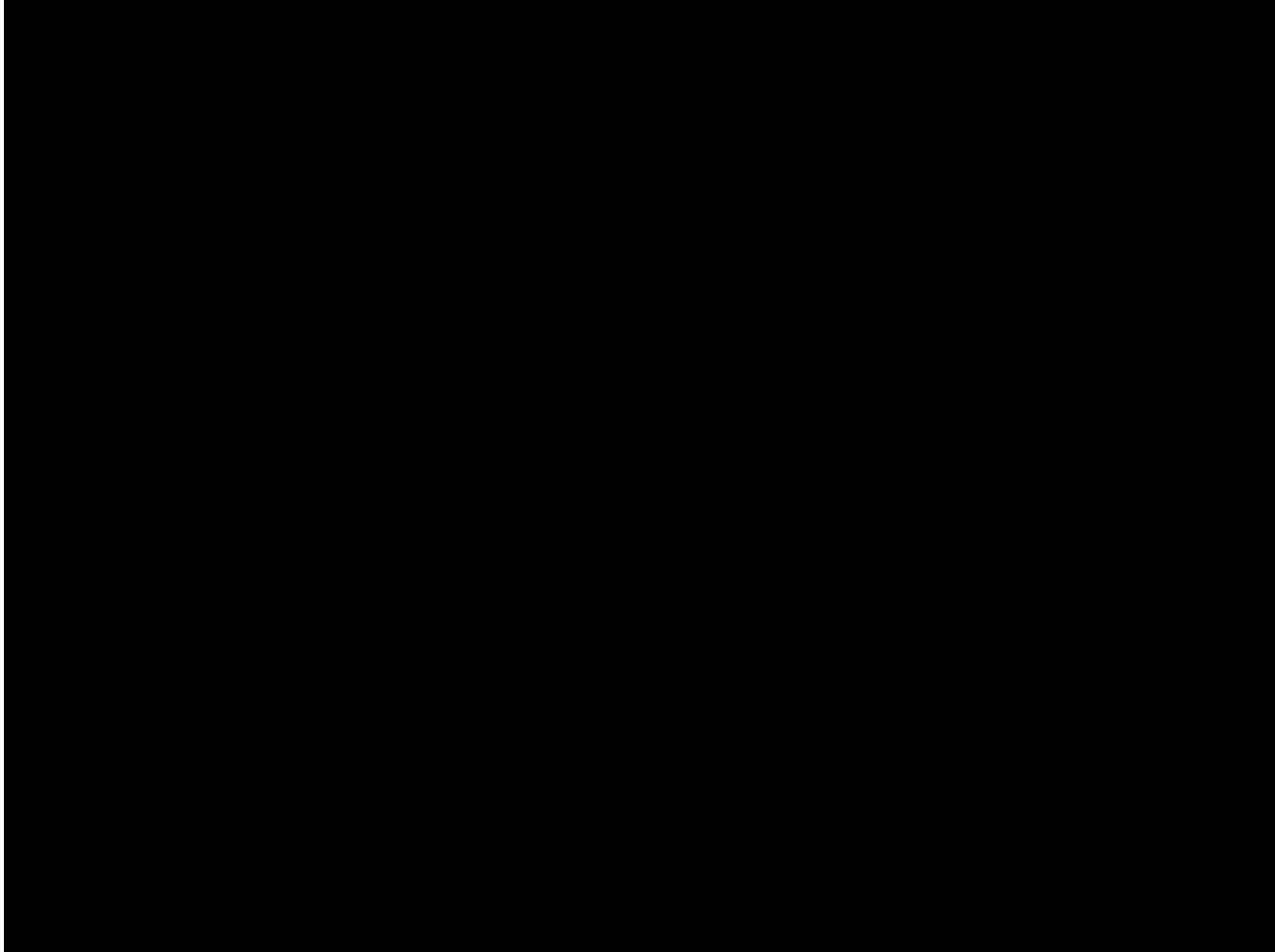
# 7. Texture Synthesis

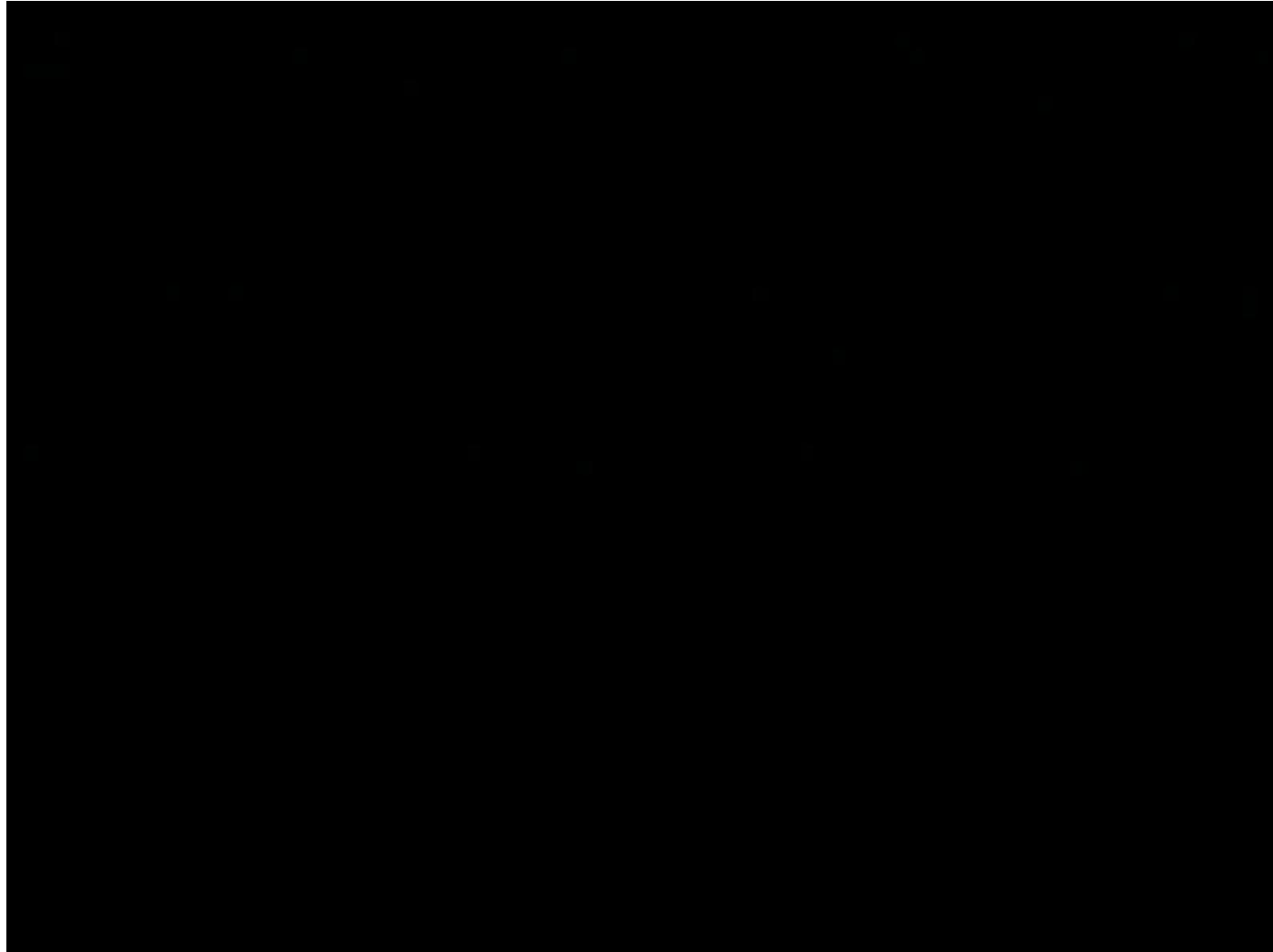


input images

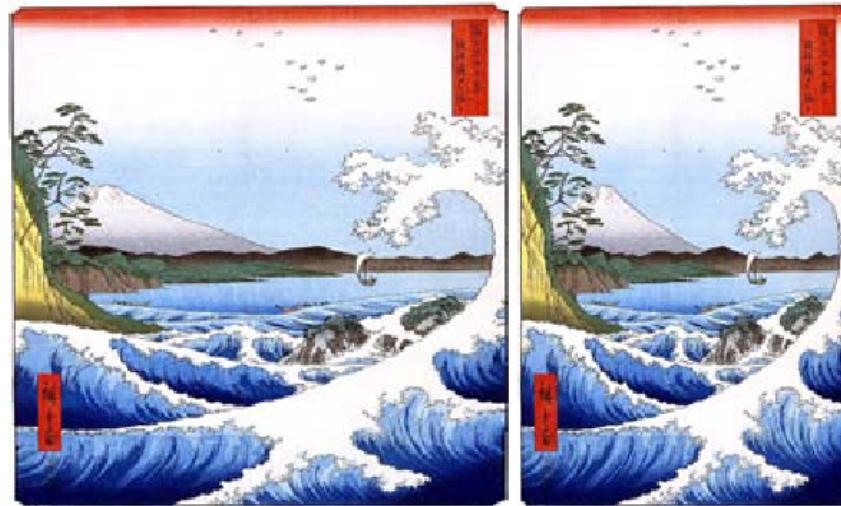


quilting results





# 7. Image Resizing

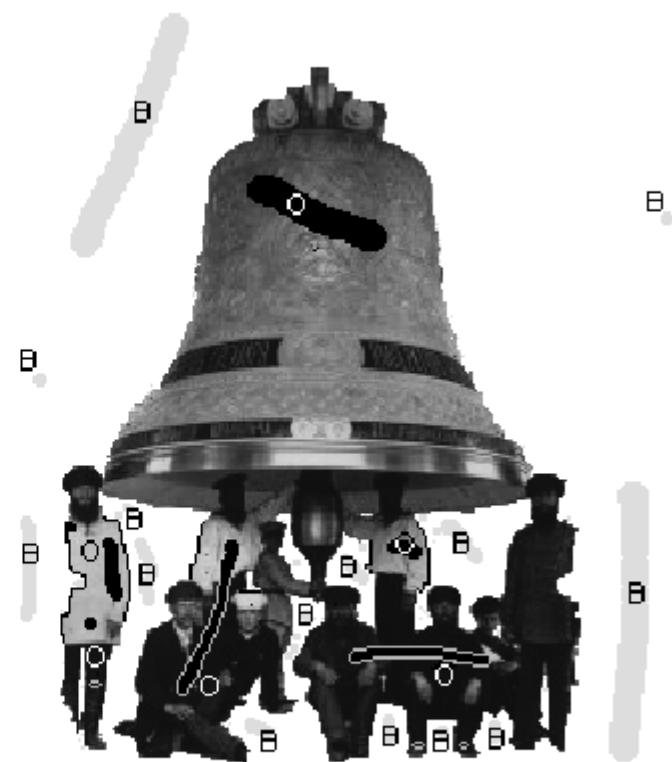


# 8. Interactive Image Segmentation

- Graph Cut



(a) Original B&W photo



(b) Segmentation results

# 8. Interactive Image Segmentation

- Grab Cut



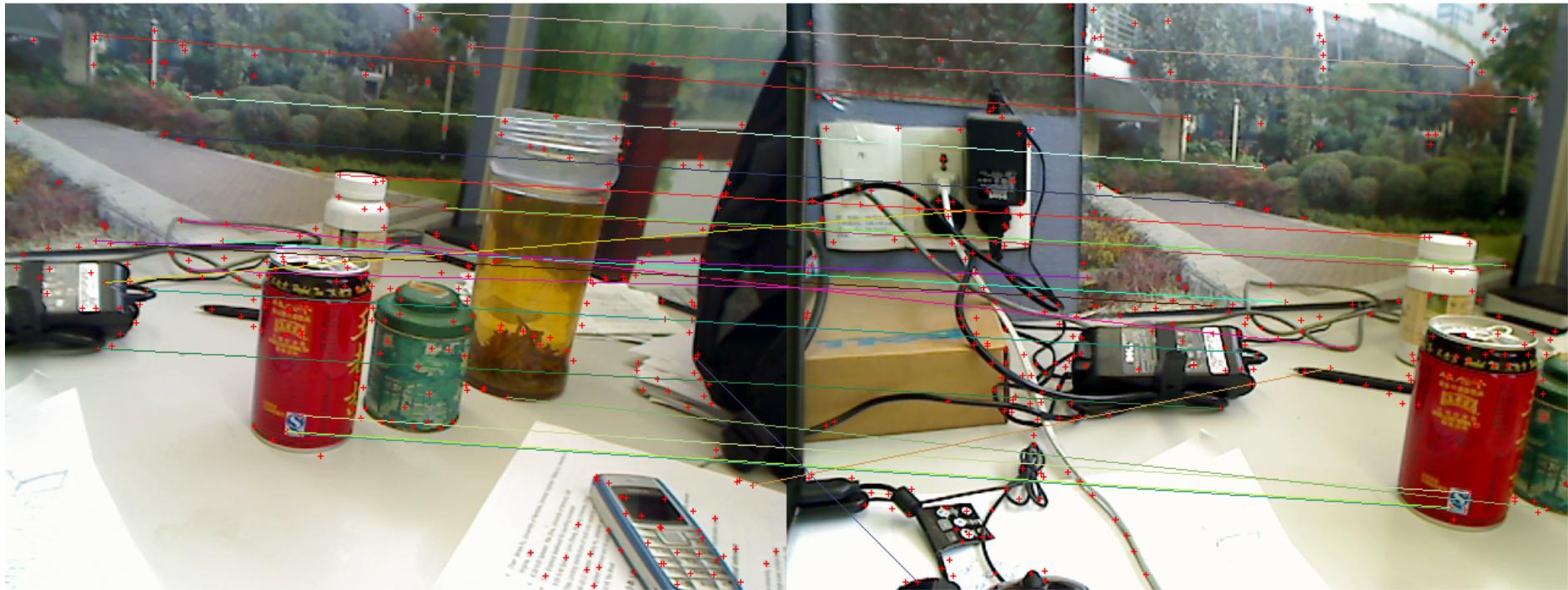
# GrabCut

## Interactive Foreground Extraction using Iterated Graph Cuts

Carsten Rother  
Vladimir Kolmogorov  
Andrew Blake

Microsoft Research Cambridge

# 9 . Feature Matching



# 9. Optical Flow

**Input Frames**



**Warped Frames**

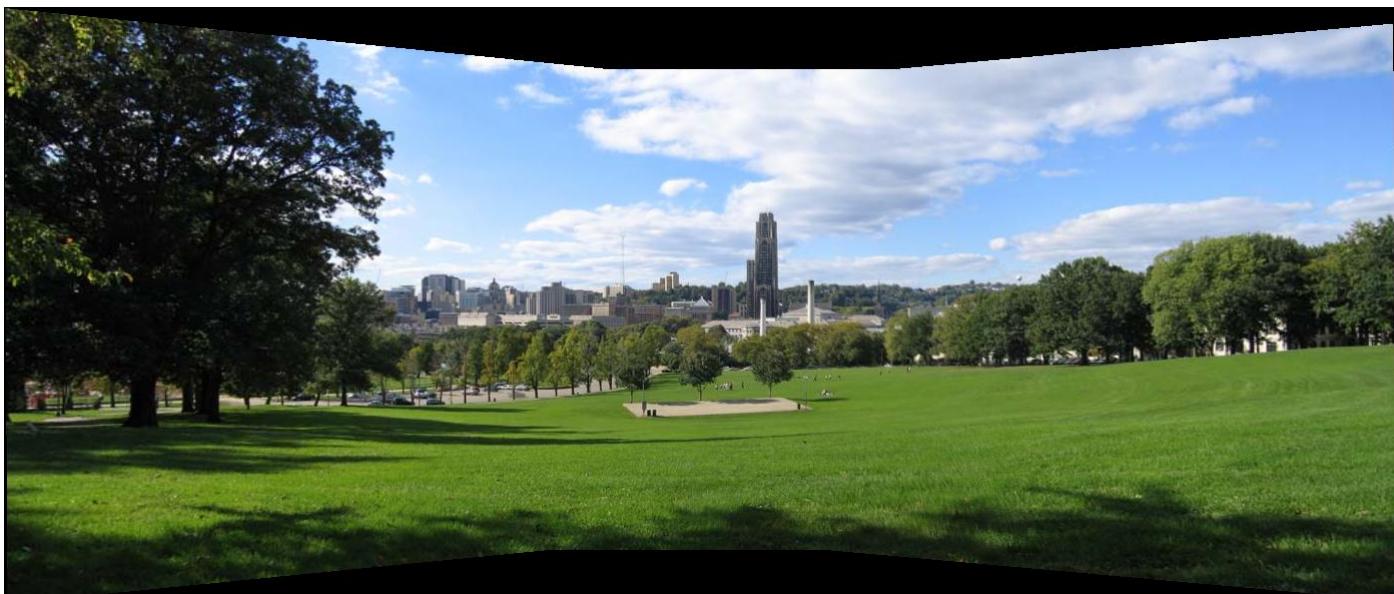


**flow Map**



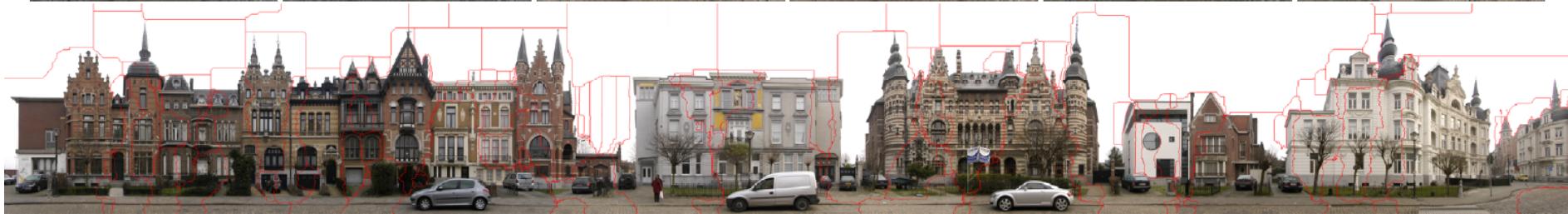
Photos from Ce Liu

# 10. Recognising Panoramas



Photos from Derek Hoiem

# 10. Multiview Panorama Stitching



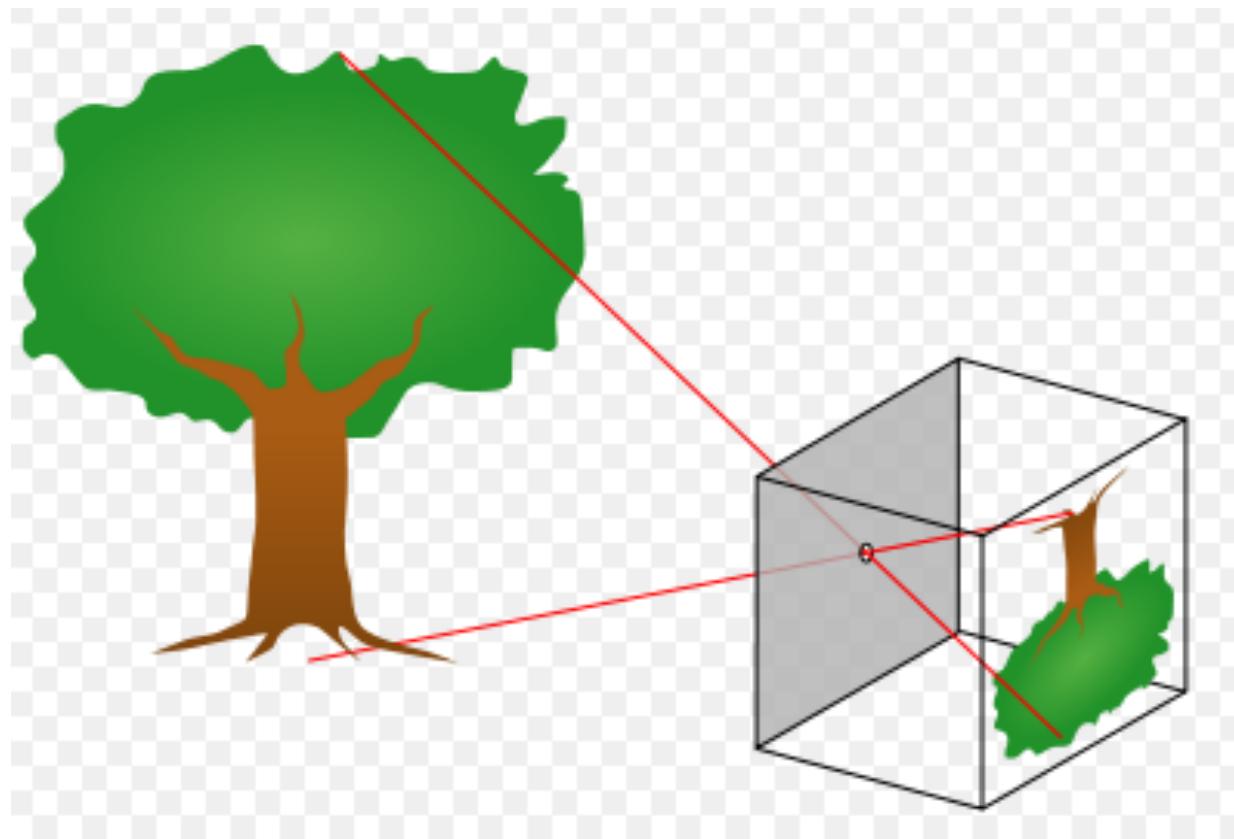
优酷

# Street Slide

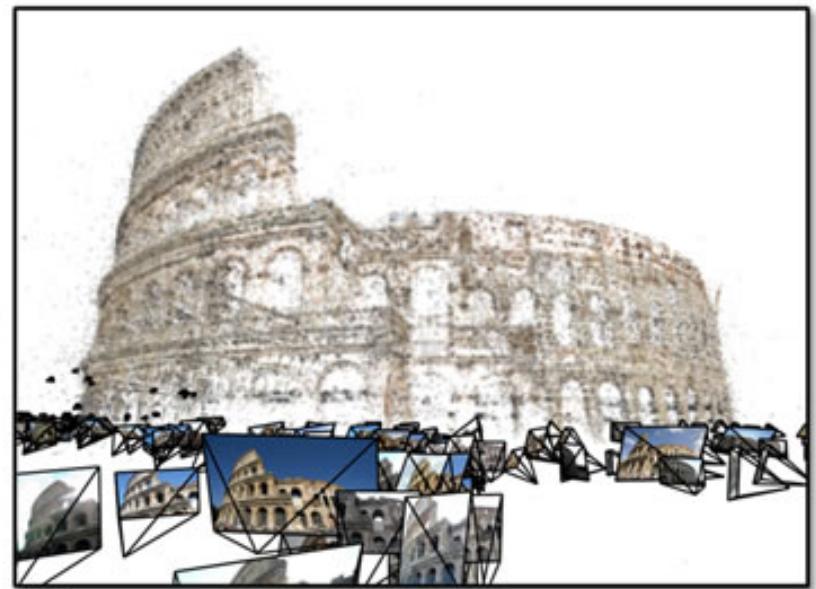
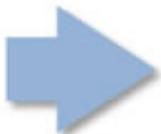
## Browsing Street Level Imagery

# 11. Camera Model

- Pinhole Camera



# 11. Structure From Motion



# Photo Tourism

## Exploring photo collections in 3D

Noah Snavely   Steven M. Seitz   Richard Szeliski  
*University of Washington*                    *Microsoft Research*

SIGGRAPH 2006

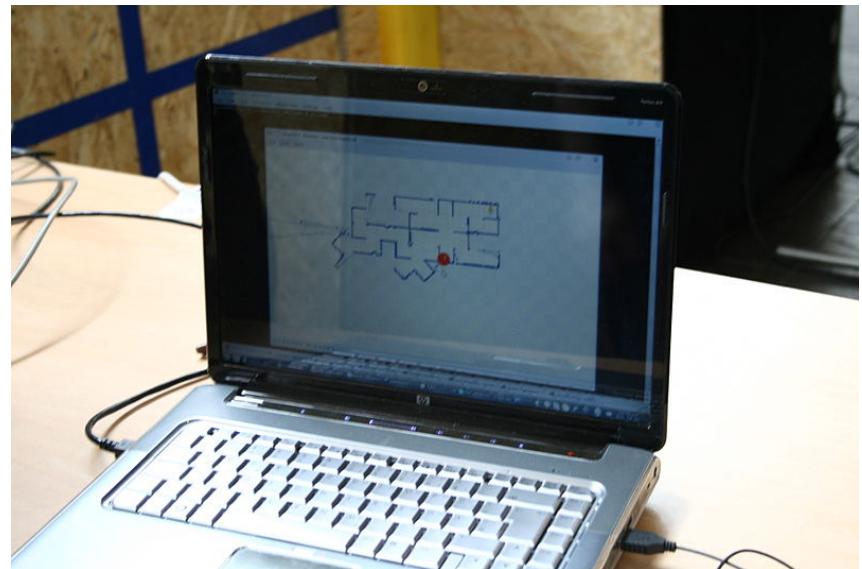
# Input Sequences

Speed: ×2



...

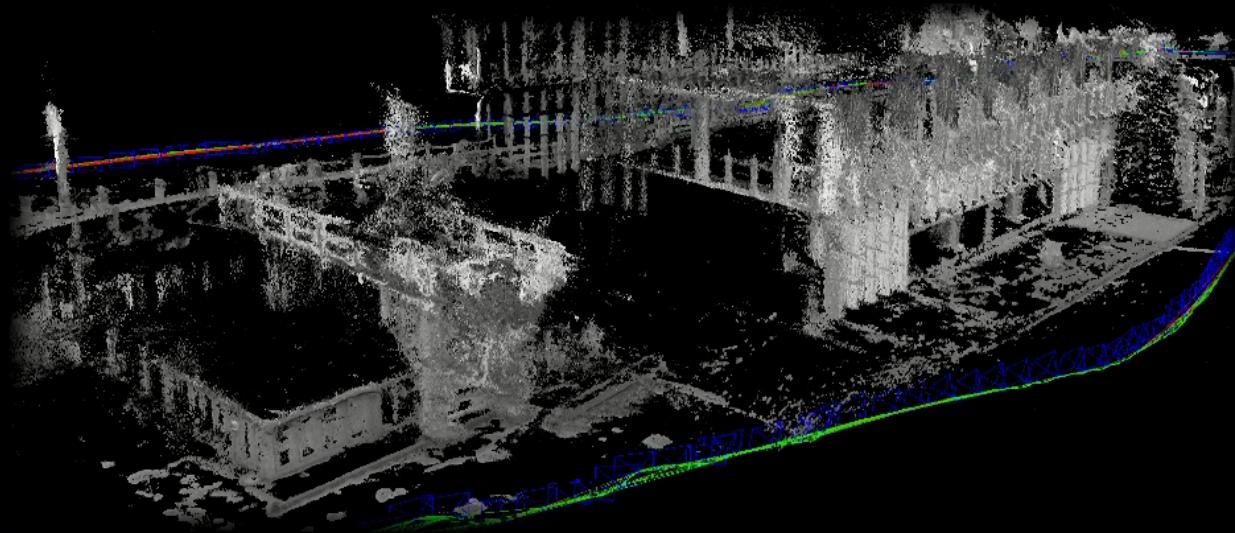
# 12. SLAM & AR



# LSD-SLAM

## **LSD-SLAM: Large-Scale Direct Monocular SLAM**

Jakob Engel, Thomas Schöps, Daniel Cremers  
**ECCV 2014, Zurich**



Computer Vision Group  
Department of Computer Science  
Technical University of Munich



# ENFT-SLAM



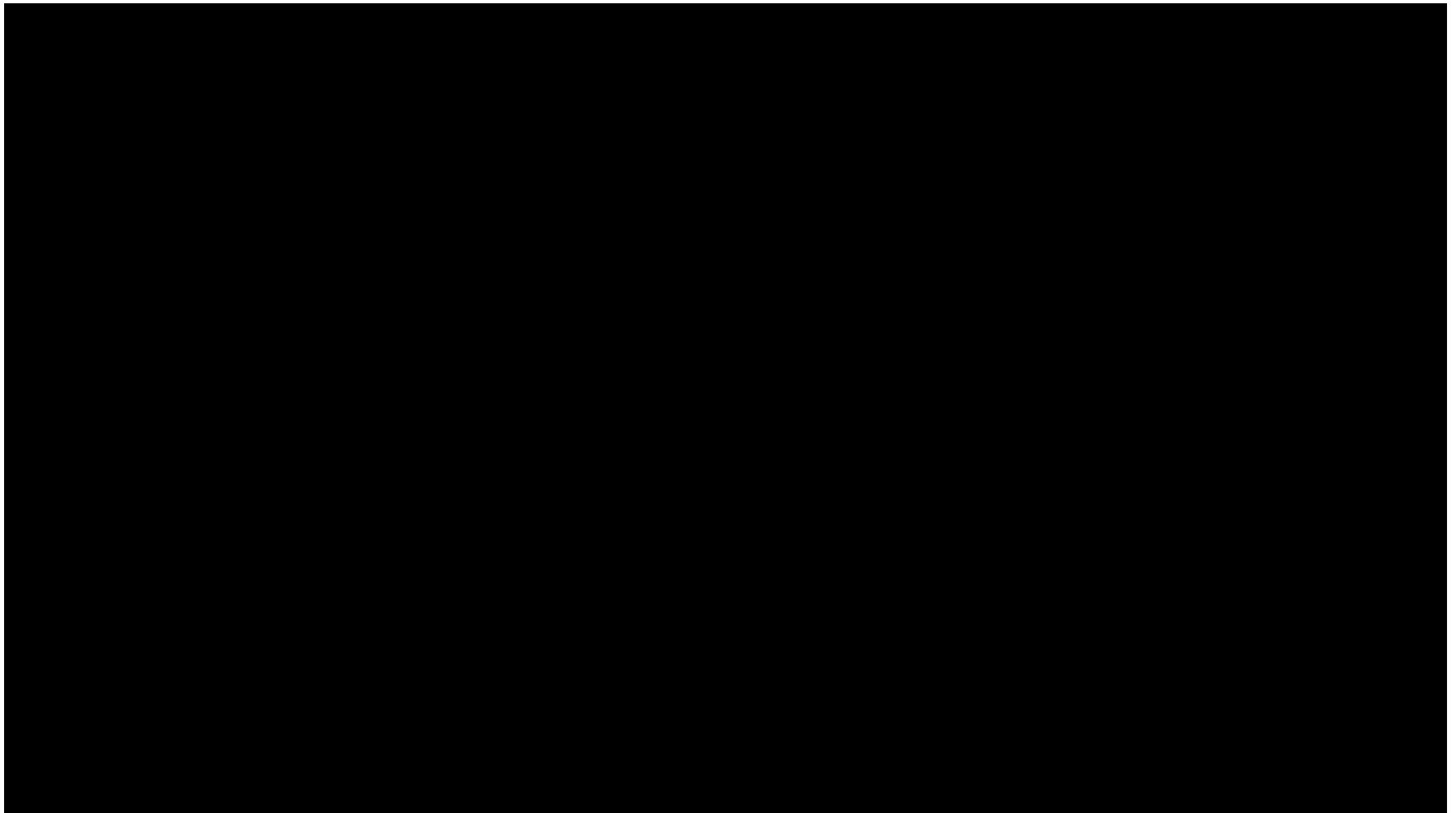
# Sony SmartAR

优酷

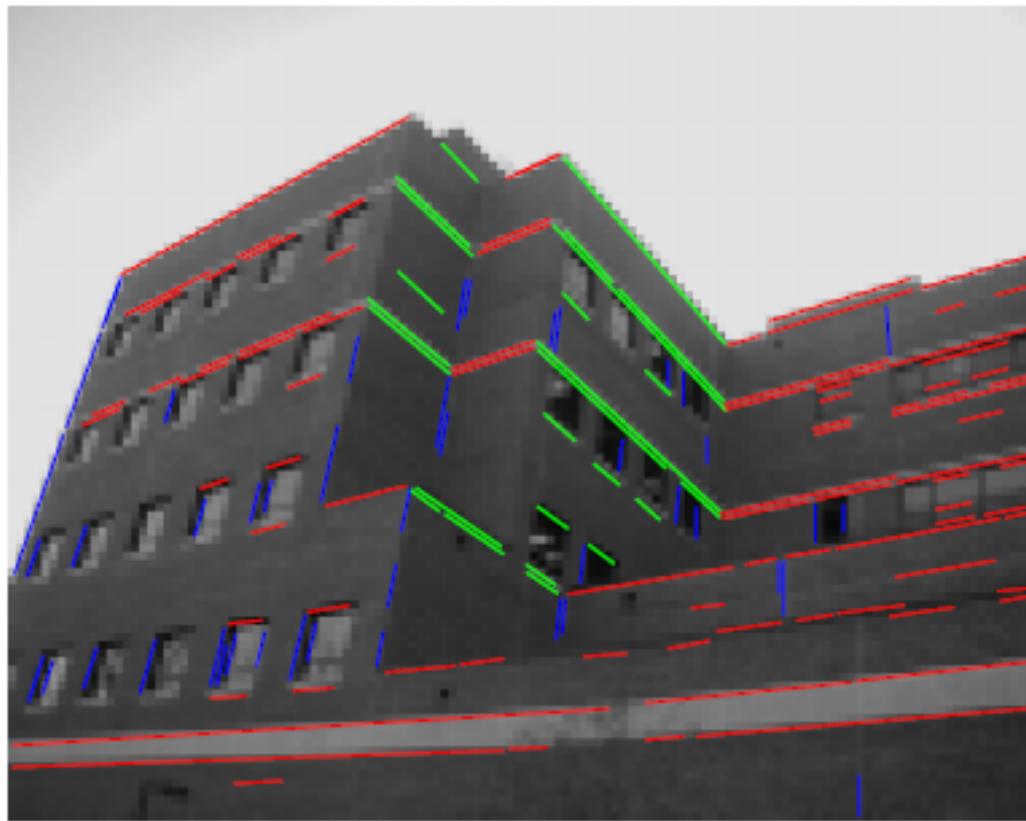
# SLAM for AR Applications

AR Application





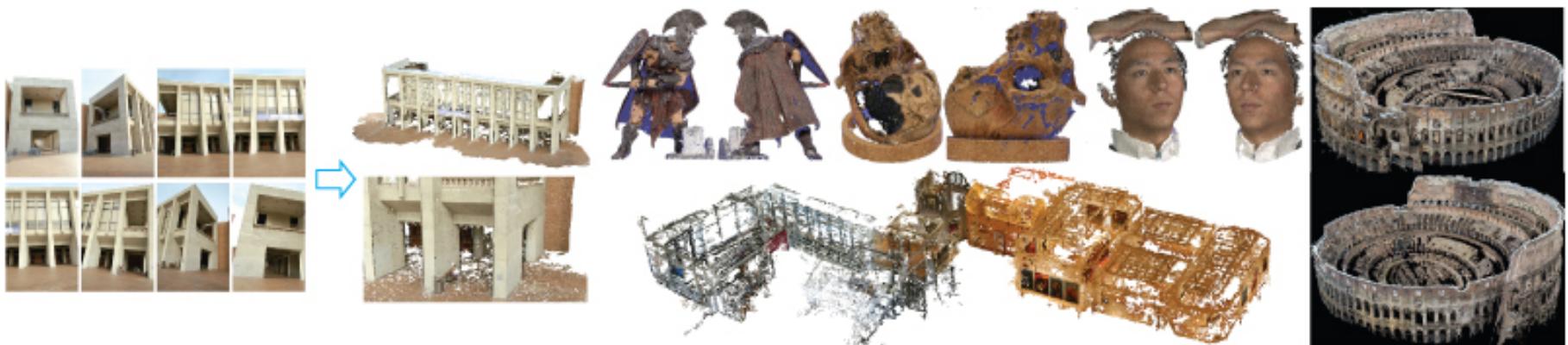
# 13. Single-View 3D Reconstruction



# **Automatic Photo Pop-up**

**D. Hoiem A.A. Efros M. Hebert  
Carnegie Mellon University**

# 13. Multi-View 3D Reconstruction

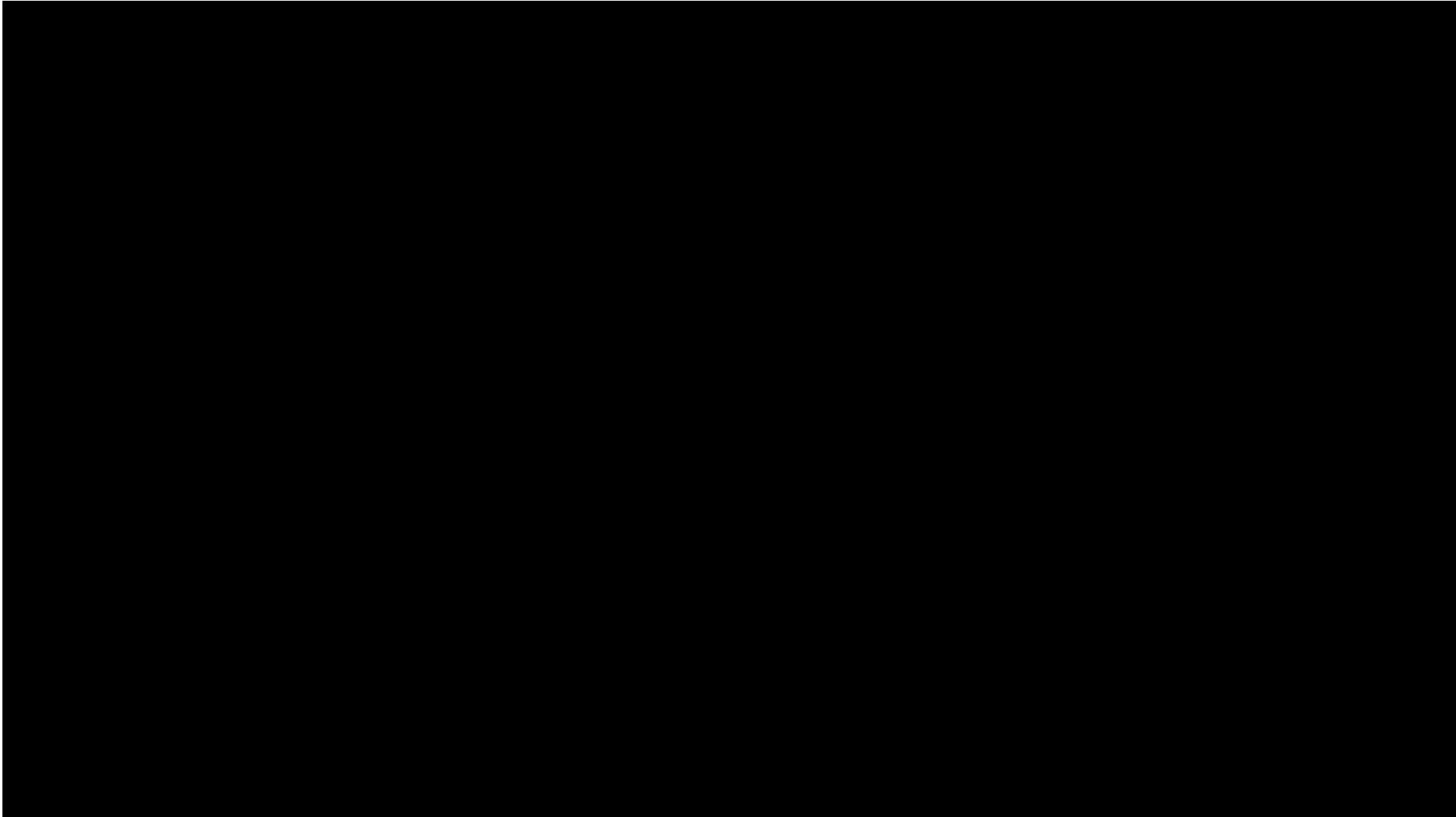


**Acute3D**  
**Technology preview**  
**Aerial and street-level imagery fusion**



generated by Smart3Dcapture™

# Microsoft HoloLens



# 课程作业

- 课后编程题
  - 有5个课后编程题
  - 考核一些基本知识的掌握程度
  - 可以在上机课里完成
- 软件工具
  - Microsoft Visual Studio, C/C++编程
  - Matlab
  - OpenCV

# 项目设计与演示

- 编程项目展示
  - 从项目列表中按兴趣自选一个项目
  - 会提供程序框架和测试数据，按要求实现模块和测试结果
  - 独立或分组合作完成（最多3人）
  - 提交完整demo和项目报告
- 课堂项目答辩
  - 每个人报告10分钟，提问5分钟
- 软件开发工具
  - Microsoft Visual Studio, C/C++编程
  - OpenCV

# 提供设备



KINECT™



Structure sensor



佳能100D



GoPro运动相机



Sony HDV

# 考试方式及要求

- 评分分为3个部分
  - 课程作业: 40%
  - 项目设计与演示: 40%
  - 项目课堂答辩: 20%
- 注意事项
  - 可以相互之间讨论，但不能共享代码
  - 要自己实现，不能借鉴他人
  - 如果遇到问题，可以找我讨论

# 课件与答疑

- 课程教学网站
  - [http://www.cad.zju.edu.cn/home/gfzhang/  
course/computational-photography/](http://www.cad.zju.edu.cn/home/gfzhang/course/computational-photography/)
- 答疑
  - 助教:
    - 李津羽 (ljy.swimming@qq.com)
    - 赵长飞 (386414602@qq.com)
  - 时间地点:
    - 每周一下午2:00-3:40 (上机课) 曹西503

Questions?