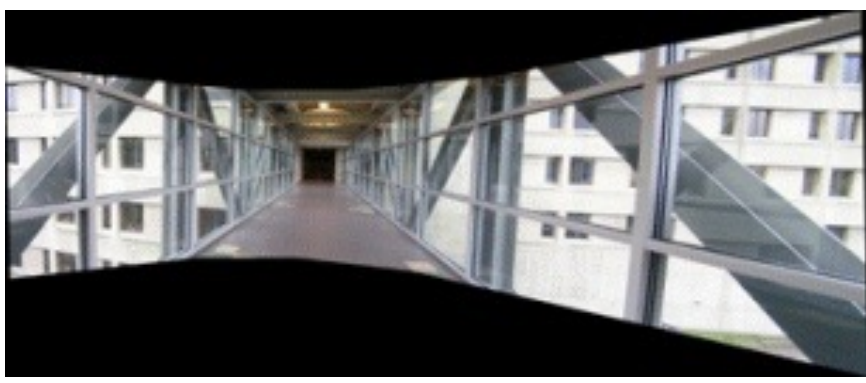




# 计算摄影学

章国锋、周晓巍



# 课程简介和目标

- 课程简介
  - 计算摄影学是一个新兴的研究领域，旨在通过可计算的图像获取、处理和操纵技术，将软硬件有机结合起来克服传统数码相机局限性，实现对图像能力的增强或扩展。
- 课程目标
  - 了解计算摄影的基本概念原理以及各种运用于图像和视频的计算技术，并介绍计算摄影学的最新研究方向和研究成果，可以开阔学生的研究视野，提高学生的创新能力，激发学生对科研工作的兴趣。
- 课程内容：基础和前沿研究结合，借鉴/借用了一些国外大学相关课程和课件内容（James Hays, Alexei Efros, ...）。

# 拍摄的苦恼

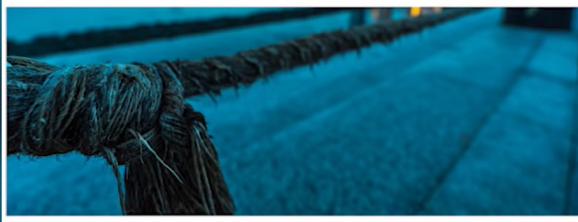
- 如何拍出完美的照片？





# 景深融合

HEY!  
DRONES

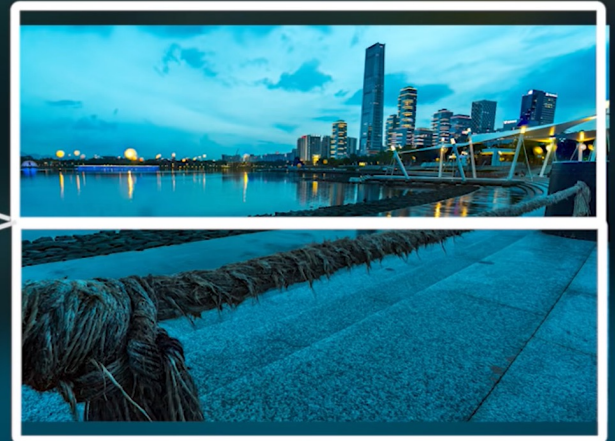


近景

合成

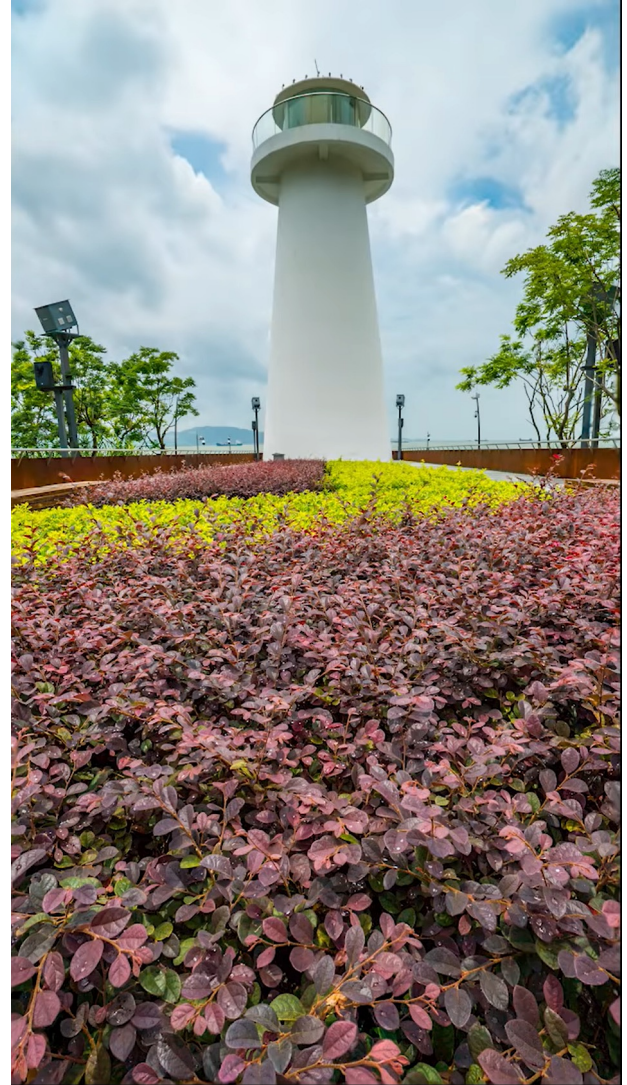


远景

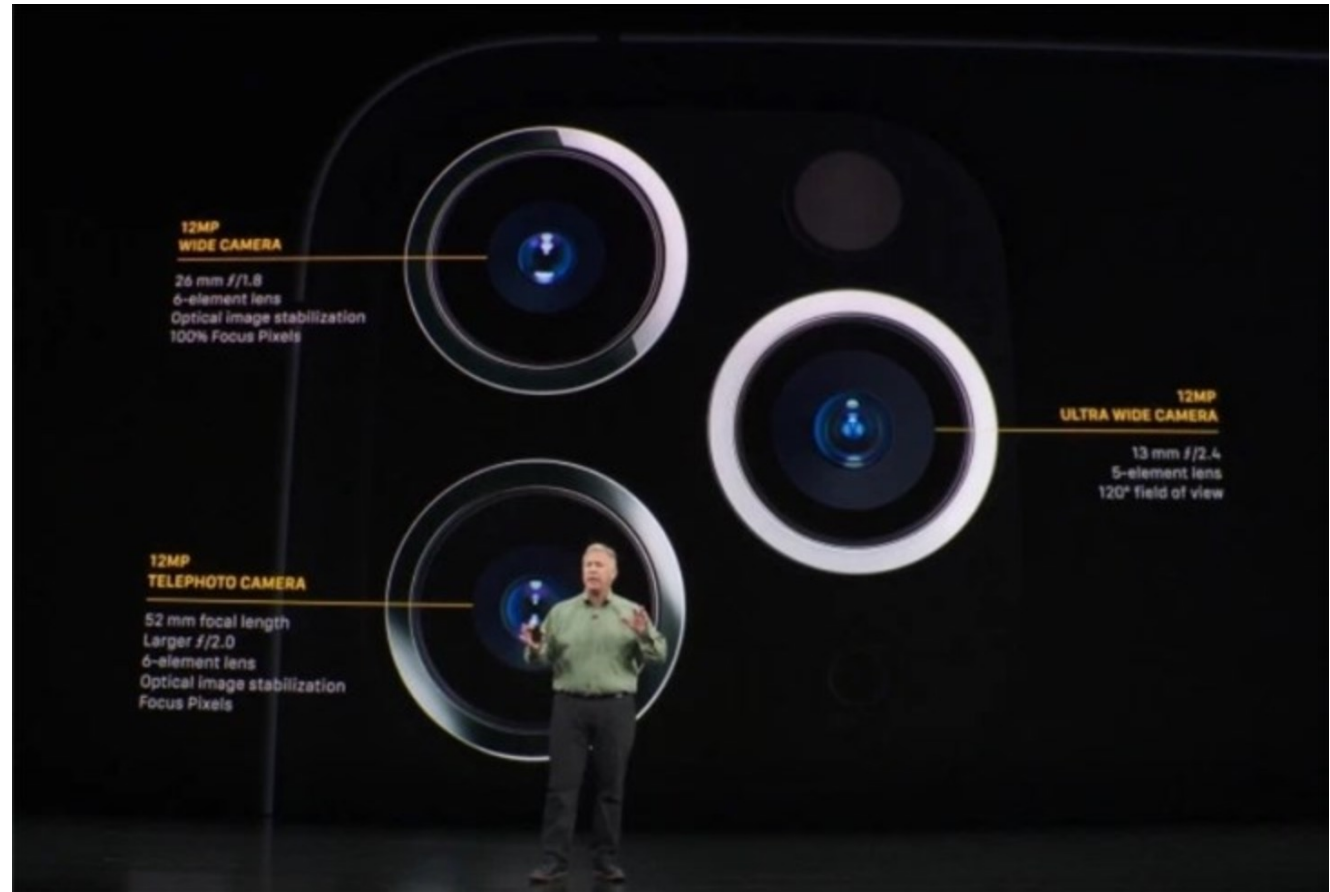




# 景深融合



# 多摄像头合成





# 多摄像头合成





# Deep Fusion

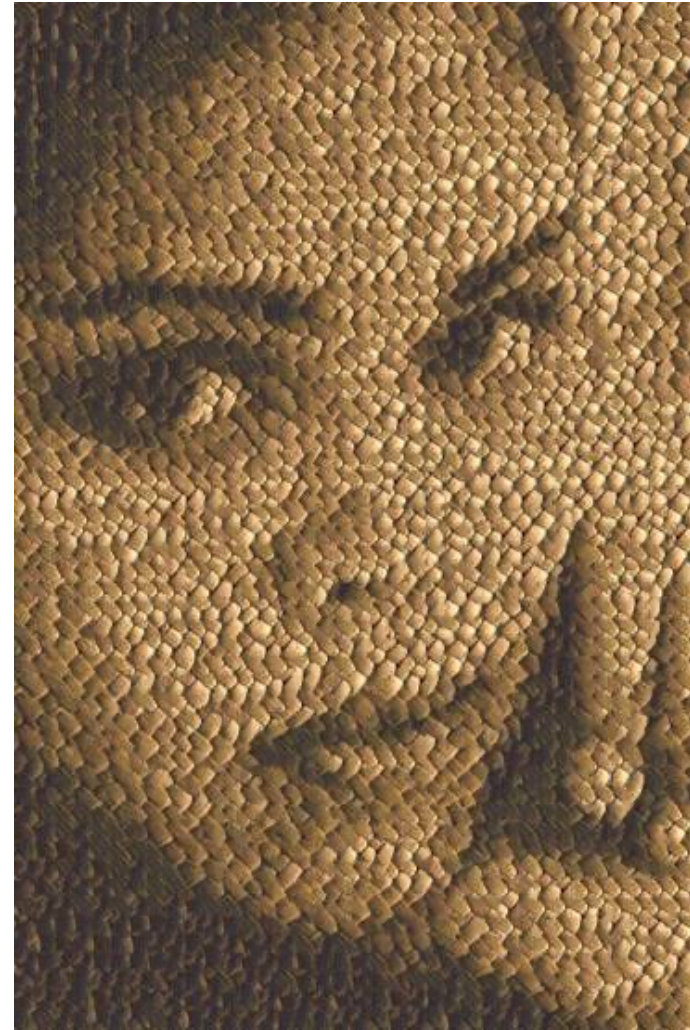
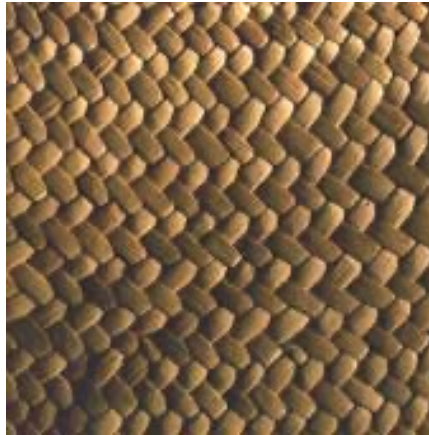


# Deep Fusion





# Creating Stylized Images





# Creating unlikely juxtapositions



# Creating unlikely juxtapositions



Jeff Wall, *Flooded Grave*



Scott Mutter, *Escalator*



# 美颜美体





# 全景拼接



# 本次课的主要内容

- 摄影历史
- 什么是计算摄影学？
- 课程目标
- 课程大纲
- 作业和大程

# 可视媒体历史简要回顾



# 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)



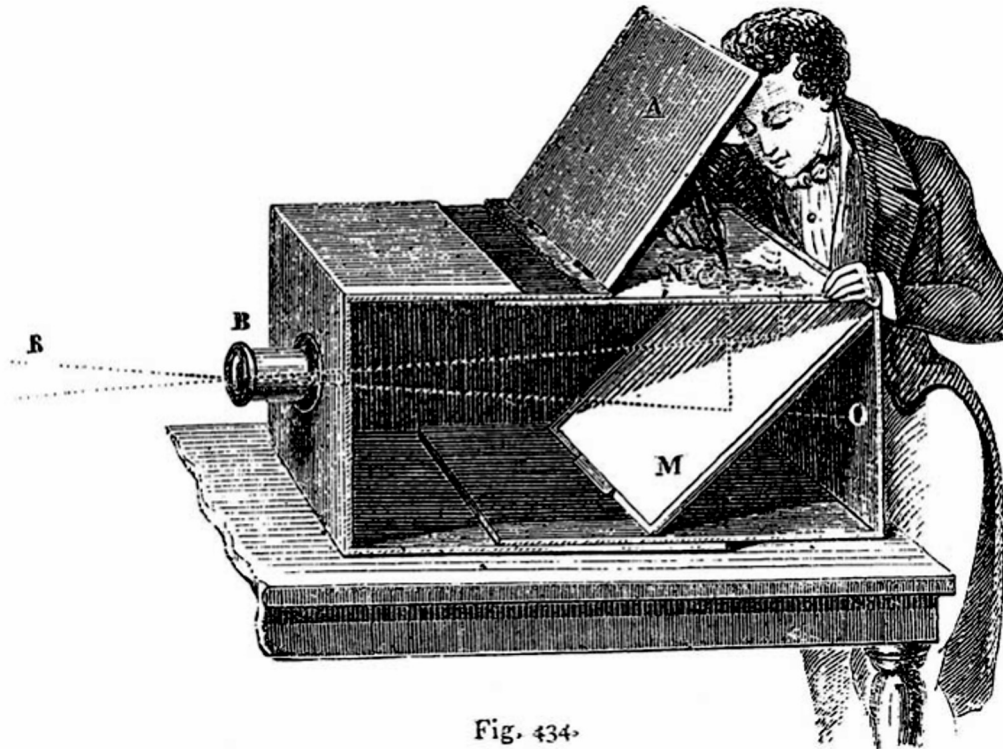


# Depicting Our World: Renaissance



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

# Depicting Our World: Toward Perfection



Lens Based Camera Obscura, 1568

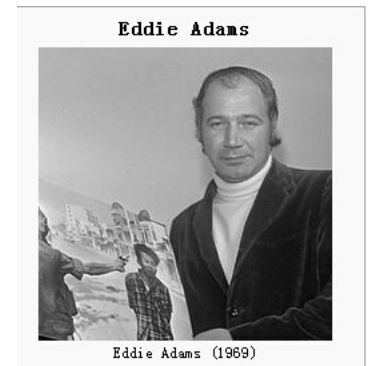
# Depicting Our World: Perfection!



*Still Life*, Louis Daguerre, 1837



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



# 什么是计算摄影学? ——从硬件的视角



# 从硬件的视角

- **数字摄影**
  - 只需用数字技术替代传统传感器和记录
  - 仅涉及简单的图像处理
- **计算摄影学**
  - 相机设计考虑了计算
  - 更精细的图像处理和计算

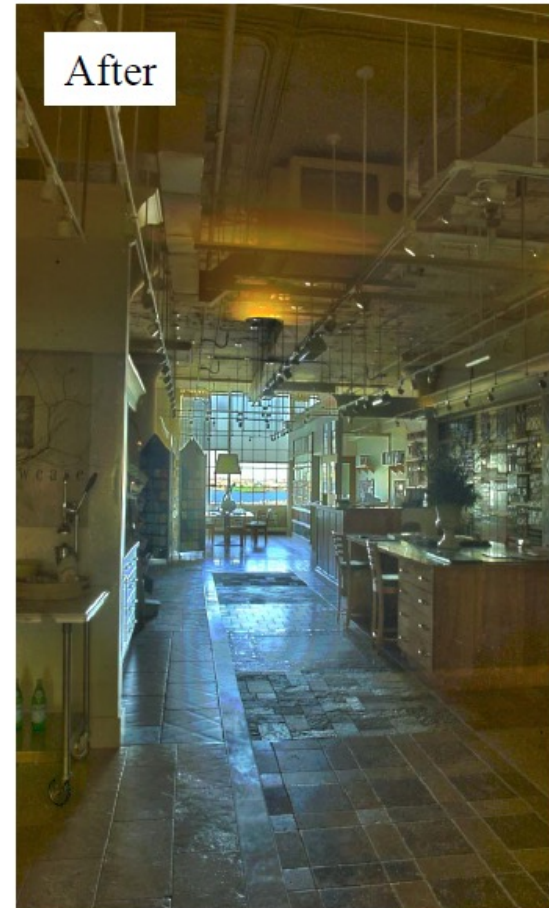
# Examples

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



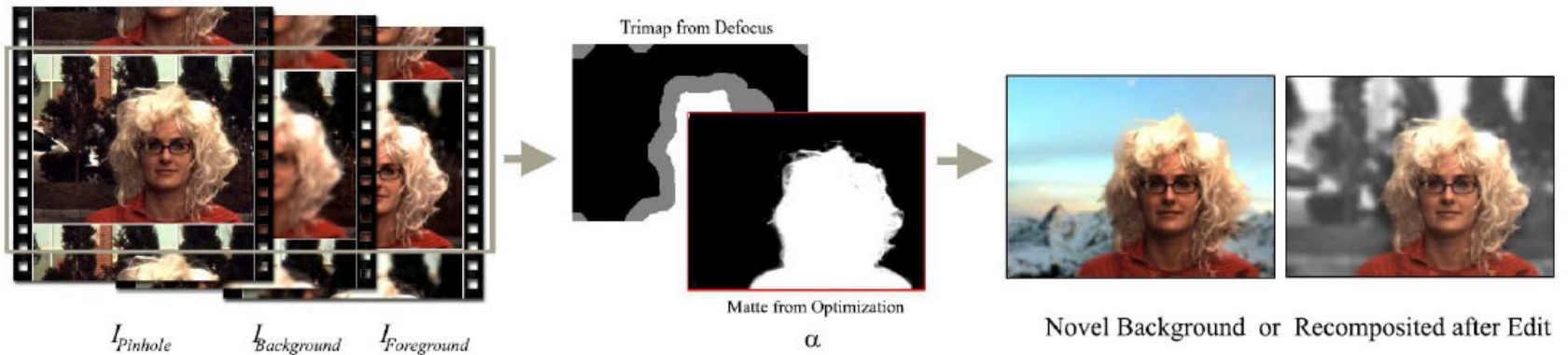
# Tone mapping

**Suitable for HDR images**

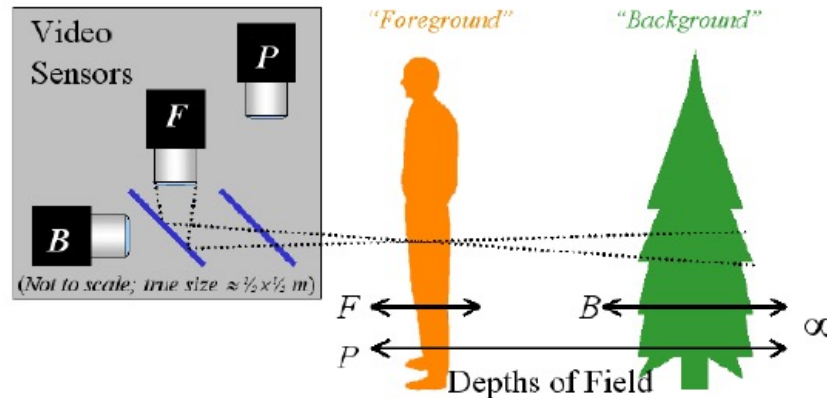


# Defocus Matting

- What can be achieved

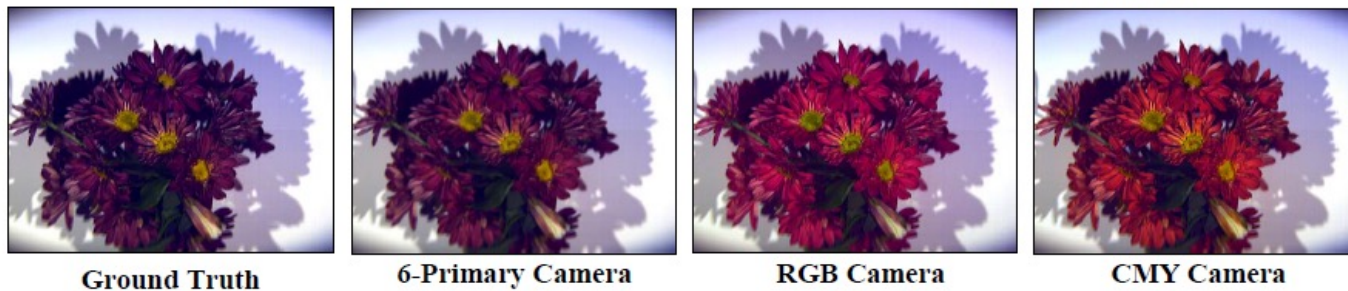
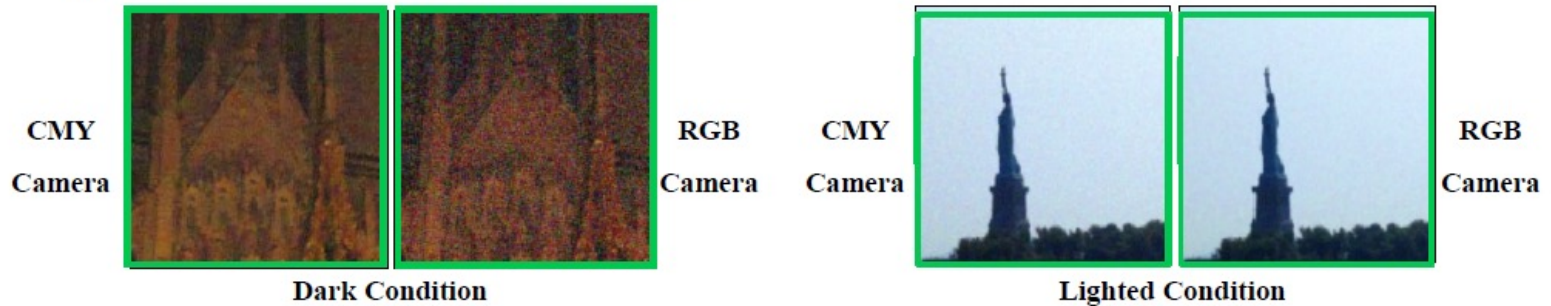


- Design: use 3 streams with different focus

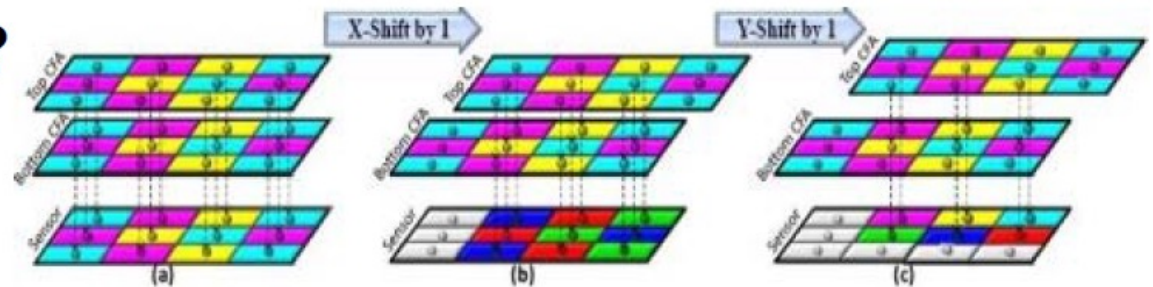


# Multi-Modal Cameras

- What can be achieved



- How it works?



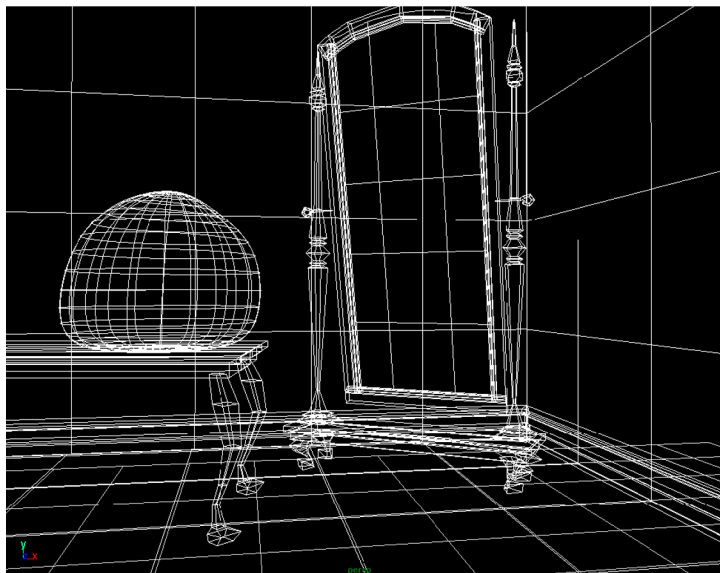


# 什么是计算摄影学? ——从软件的视角

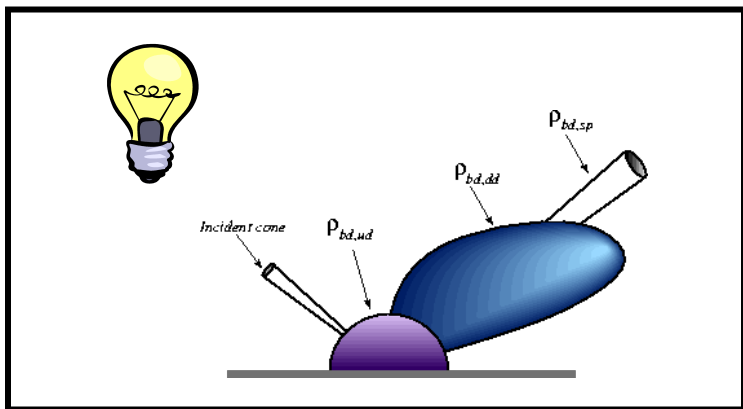
# 从软件的视角看

- 定义一：使用摄影图像来生成图形内容。

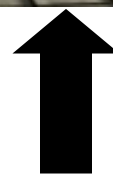
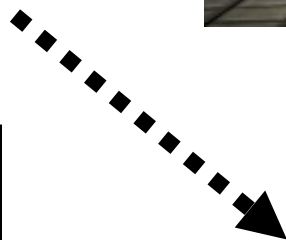
# 传统计算机图形学



三维几何



物理



投影



# 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

哪些对于计算机图形  
来说很难去建模？



# 1. People



From "Final Fantasy"

On the Tube, London



## 2. Faces / Hair



From "Final Fantasy"



Photo by Joaquin Rosales Gomez



# 3. Urban Scenes



Virtual LA (SGI)



Photo of LA



# 4. Nature



River Cherwell,  
Oxford



# 生成真实的图像

## 计算机图形学



- + 巨大的创意可能性
- + 容易操纵物体和视角
- 缺点：需要丰富的专业知识和花费很大的人力才能做到非常真实的效果

## 计算摄影学

真实性  
操纵  
获取的容易度

## 摄影



- + 拍摄下来就是真实的
- + 容易获取
- 缺点：极难对物体和视角进行操纵

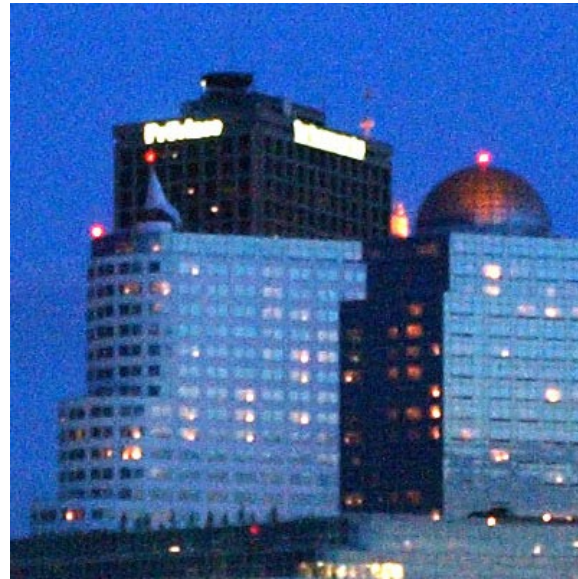
# 从软件的角度

- 定义一：使用摄影图像来生成图形内容。
- 定义二：使用计算技术来克服传统摄影的局限性。



# Limitations of traditional photography

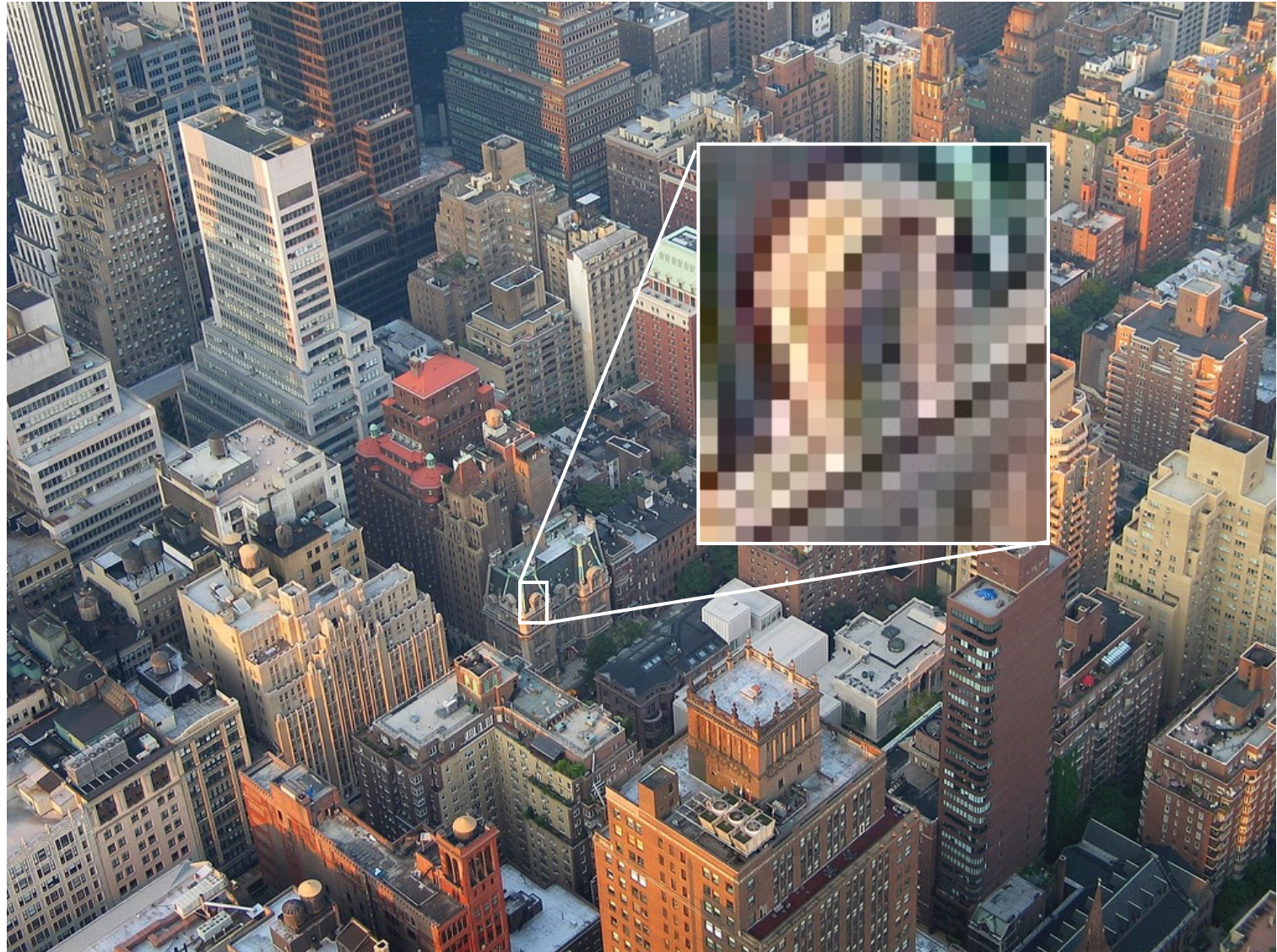
- Blur, camera shake, noise, damage





# Limitations of traditional photography

- Limited resolution





# Limitations of traditional photography

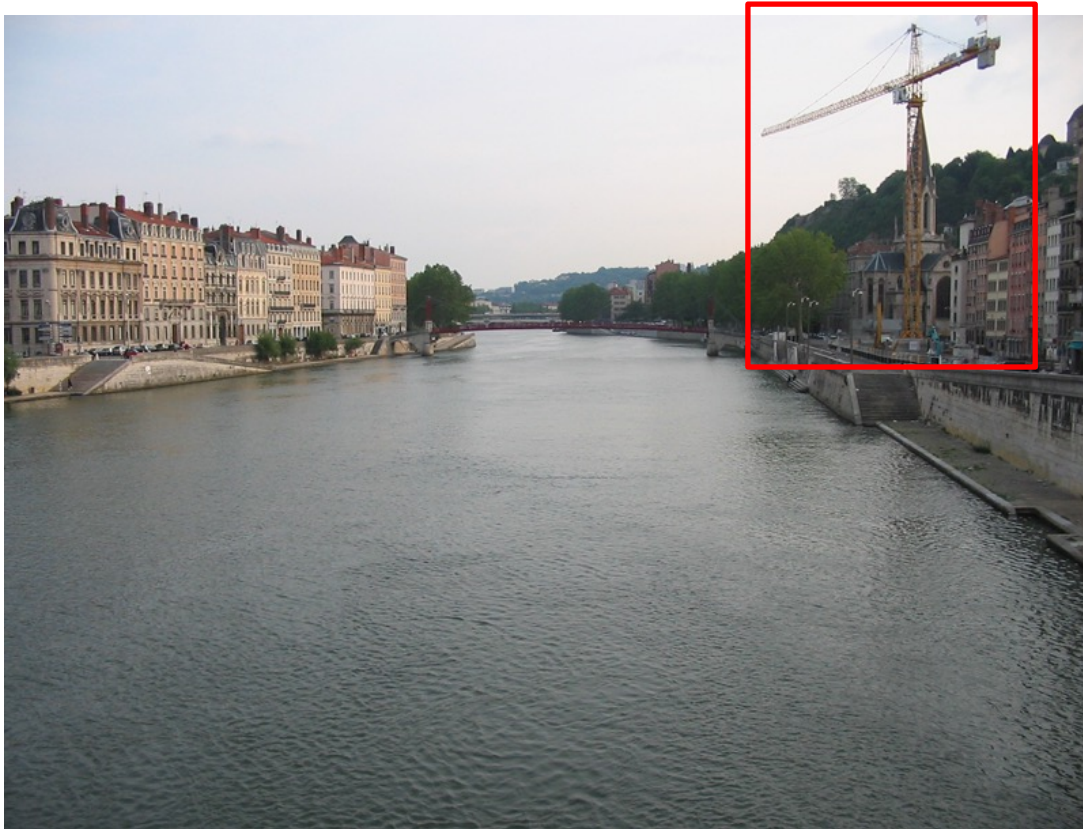
- Bad color / no color





# 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



# 计算摄影学和相关领域

- 计算机图形学：模型到图像
- 计算摄影学：图像到图像
- 计算机视觉：图像到模型



# Course objectives

1. You will have new abilities for visual creation.

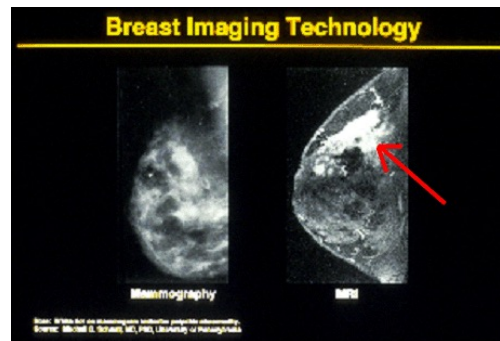


# Course objectives

2. You will get a foundation in computer vision.



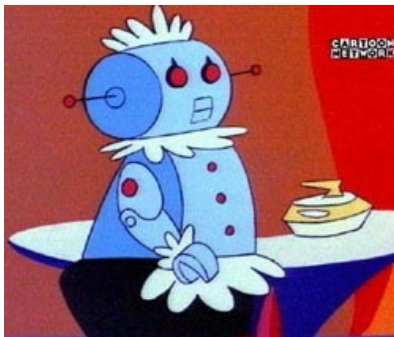
Safety



Health



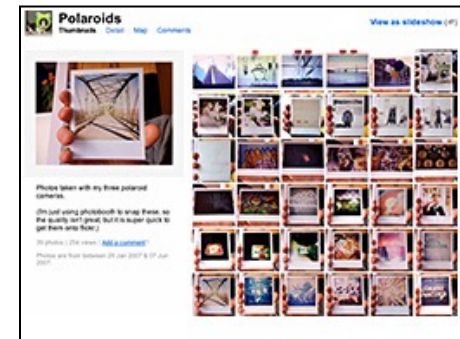
Security



Comfort



Fun



Access

# Course objectives

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



Is that a  
queen or a  
bishop?



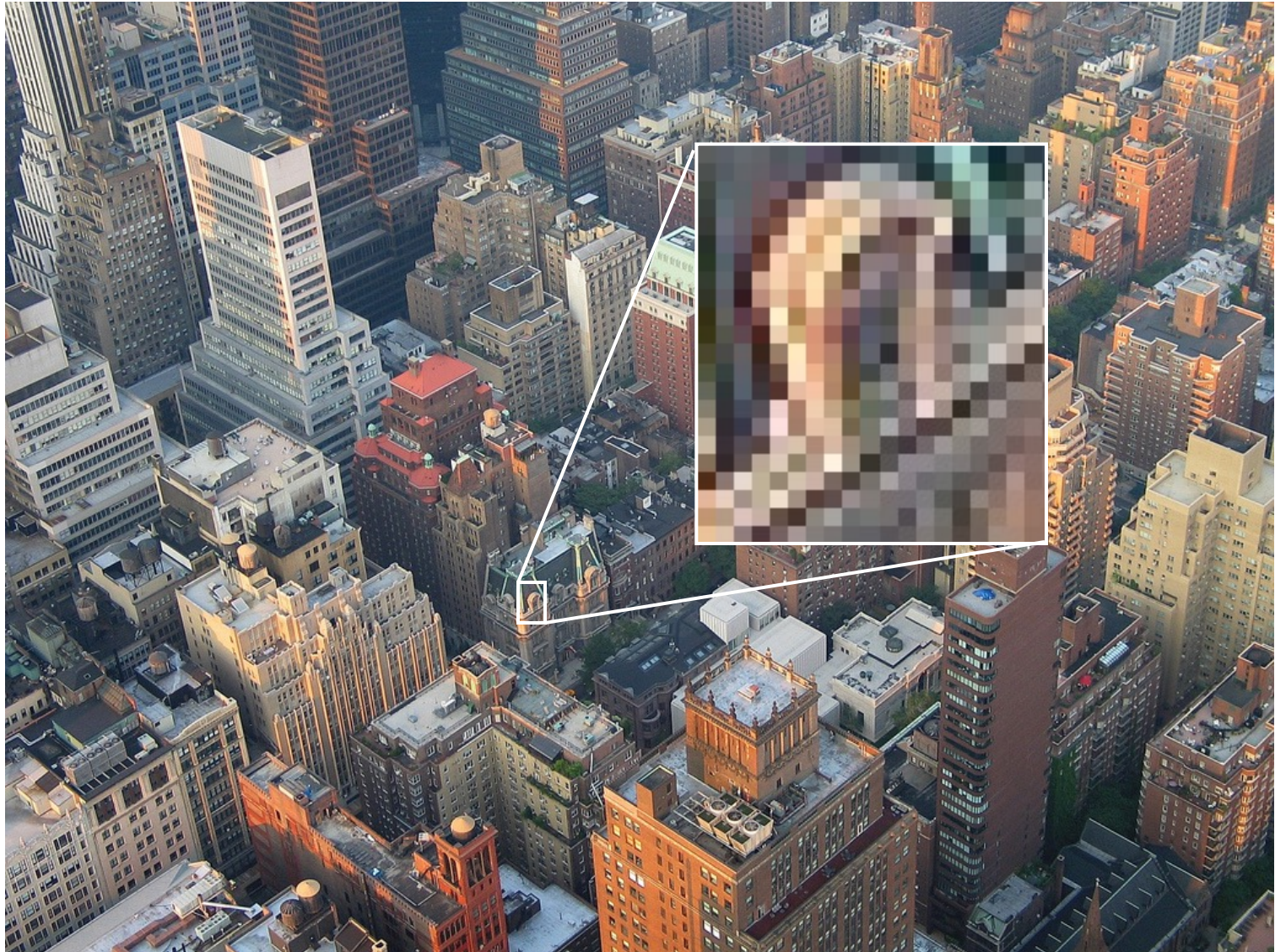
# Course objectives

4. You'll have fun doing cool stuff!

# Courses Overview

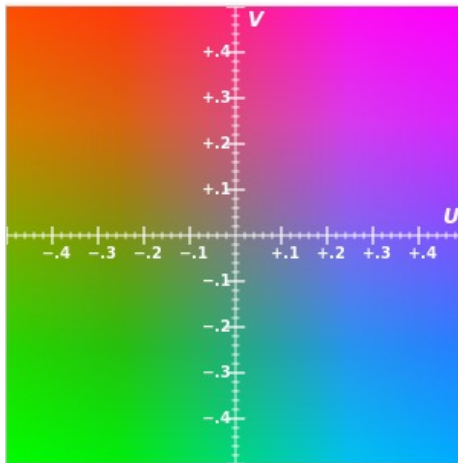
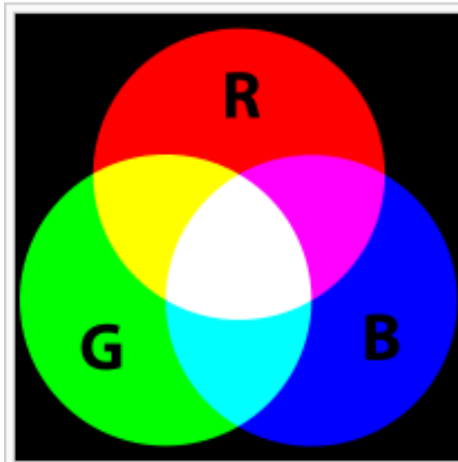
1. 计算摄影学概览
2. 图像的数字化、颜色空间、滤波与频域变换
3. 泊松图像编辑与交互式数字蒙太奇
4. 非线性数值优化
5. 深度学习
6. 特征匹配与光流
7. 全景图拼接
8. 相机模型与运动恢复结构
9. 实时摄像机跟踪
10. 单视图与多视图三维重建
11. 交互式图像分割与抠像
12. 图像缩放与补全
13. 图像上色与HDR图像合成
14. 图像去模糊
15. 课程讨论与项目答辩
16. 课程讨论与项目答辩

## 2. Digital Image

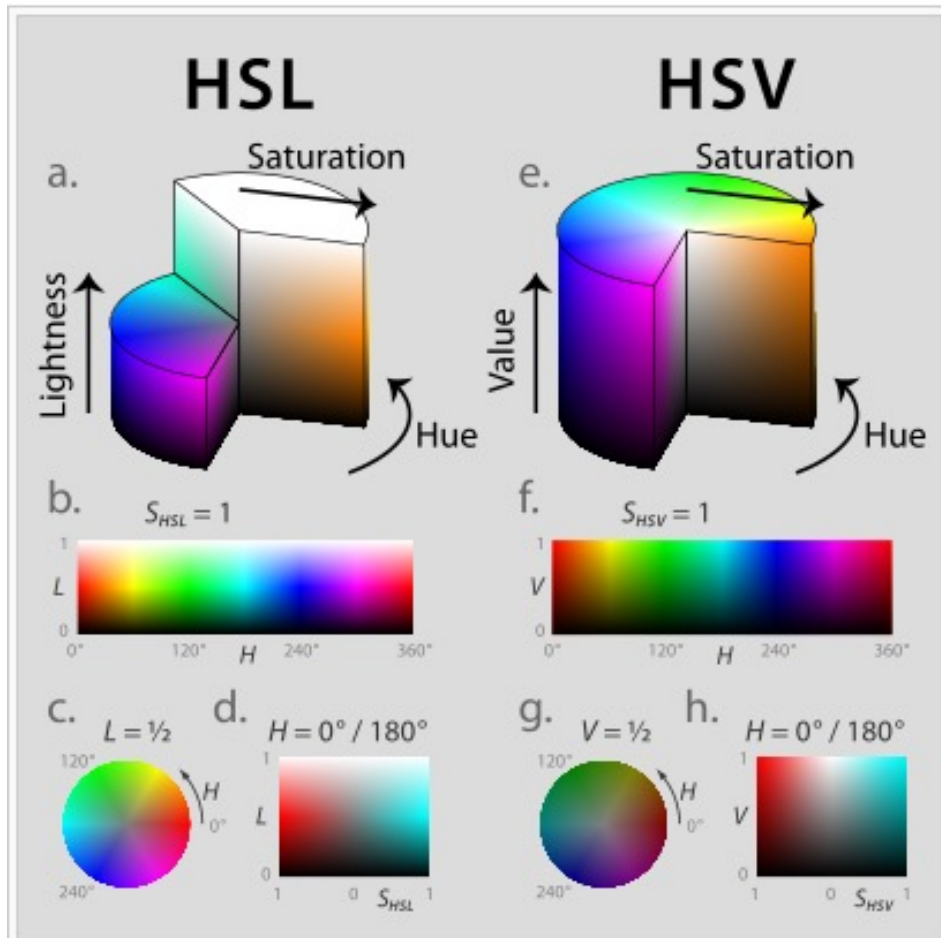




# 2. Color Space



YUV



# 2. Filtering and Fourier Transform



Original

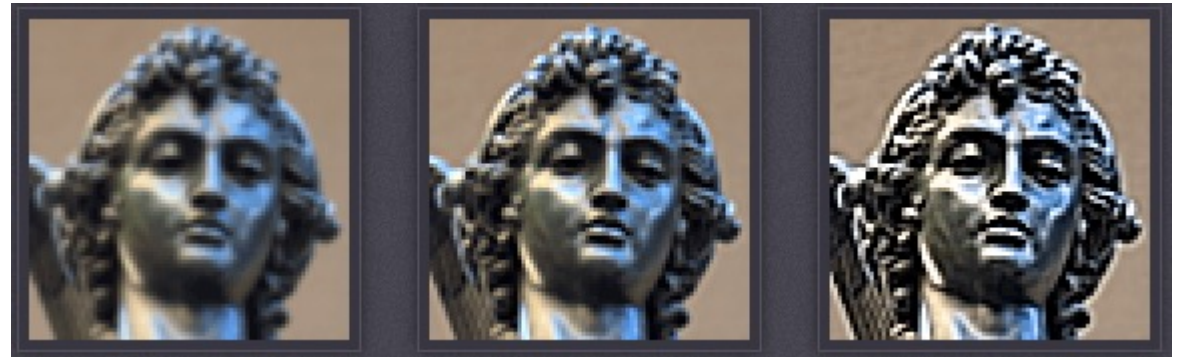


• Three pixel radius

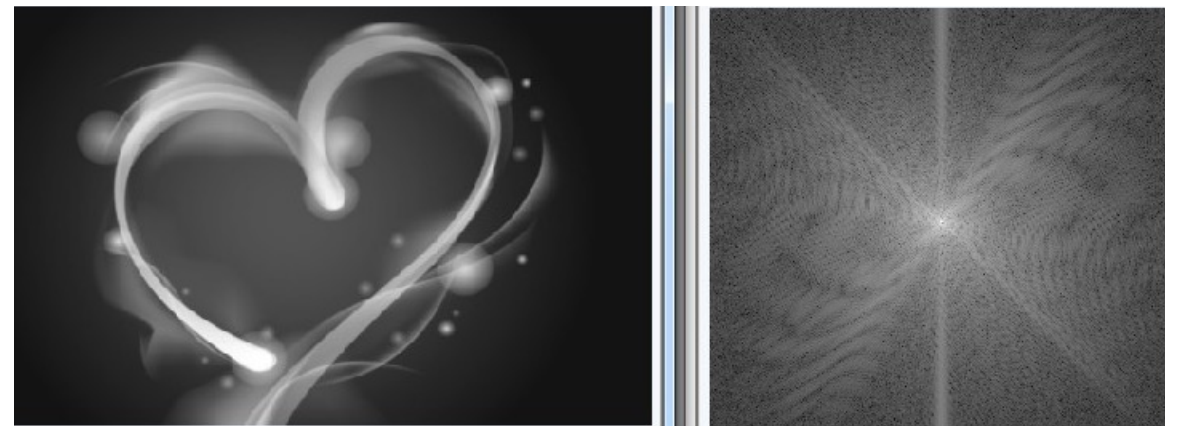


● Ten pixel radius

Blur



Sharpening



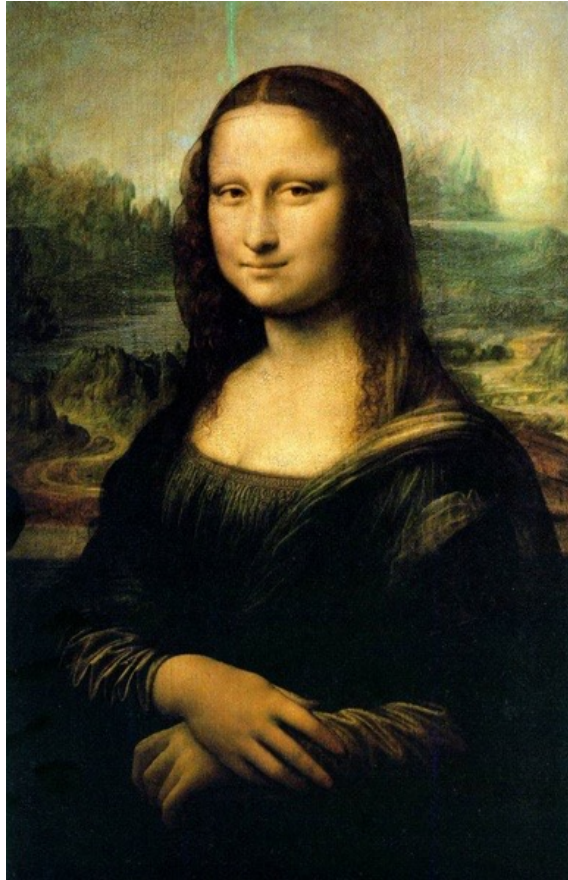
Fourier Transformation

# 3. Poisson Image Editing





# 3. Poisson Image Editing



# 3. Interactive Photomontage



# 3. Interactive Photomontage

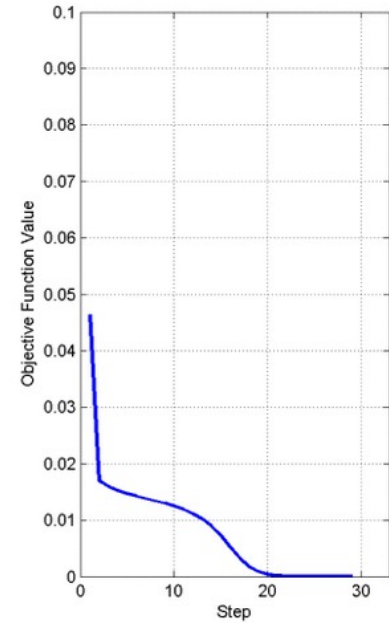
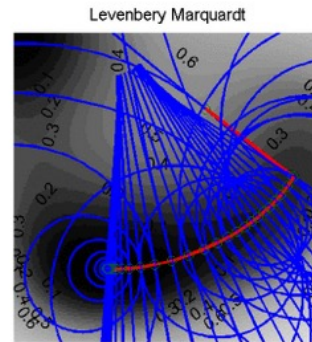
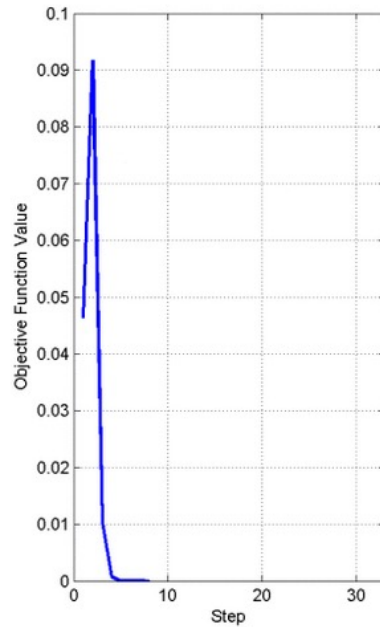
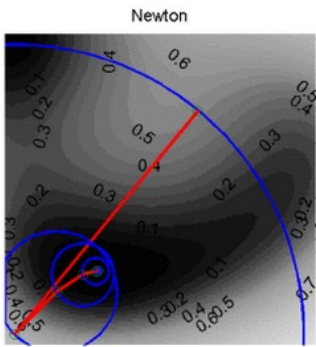
## Interactive Digital Photomontage

Aseem Agarwala, Mira Dontcheva  
Maneesh Agrawala, Steven Drucker, Alex Colburn  
Brian Curless, David Salesin, Michael Cohen





# 4. Non-Linear Optimization



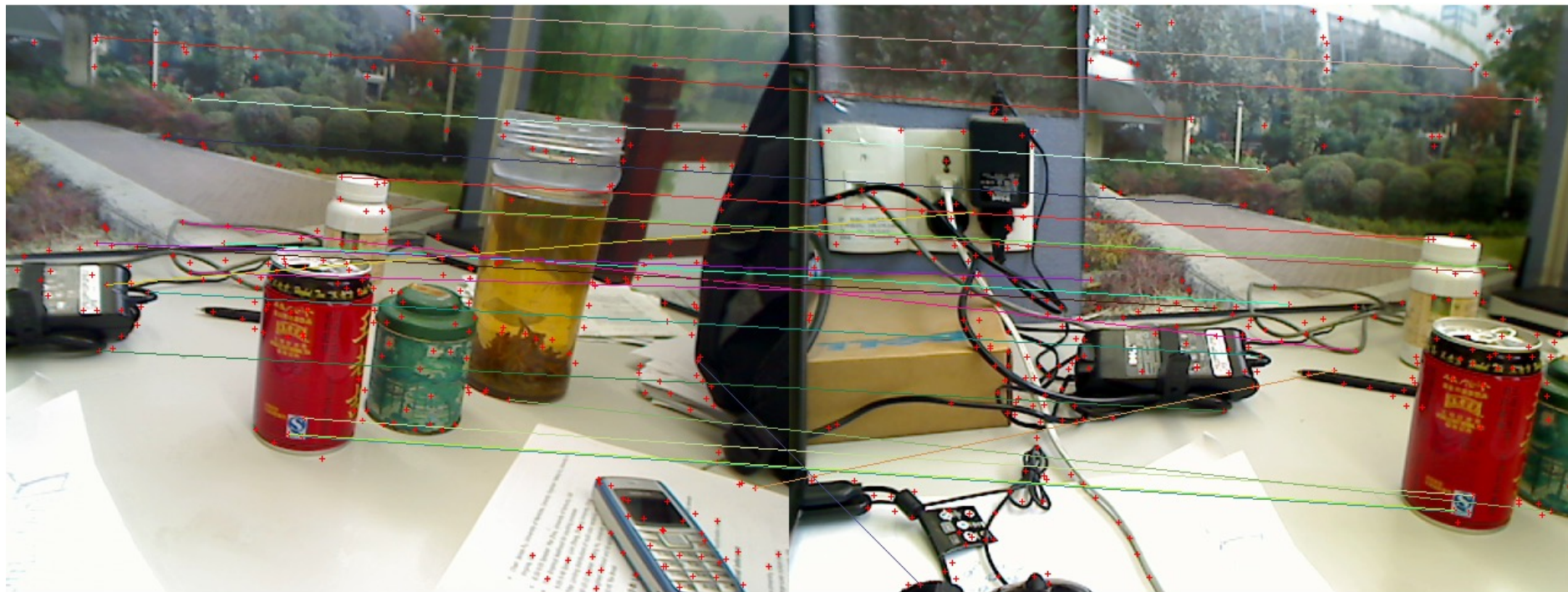
# 5. Deep Learning



(assume given set of discrete labels)  
{dog, cat, truck, plane, ...}

→ cat

# 6 . Feature Matching





# 6. Optical Flow

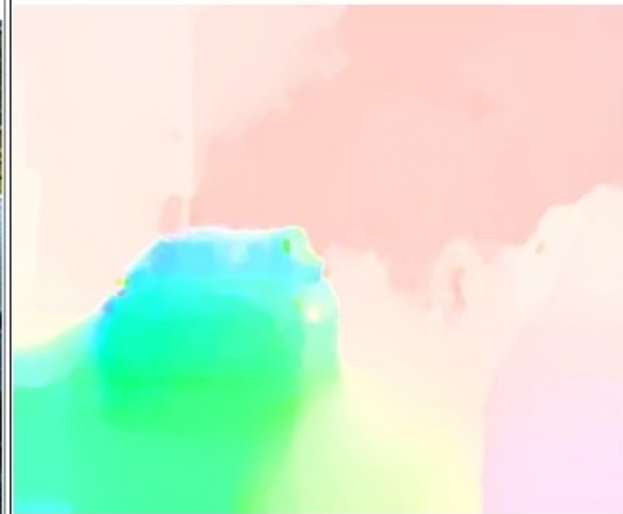
**Input Frames**



**Warped Frames**



**flow Map**



# 7. Recognising Panoramas





# 7. Multiview Panorama Stitching





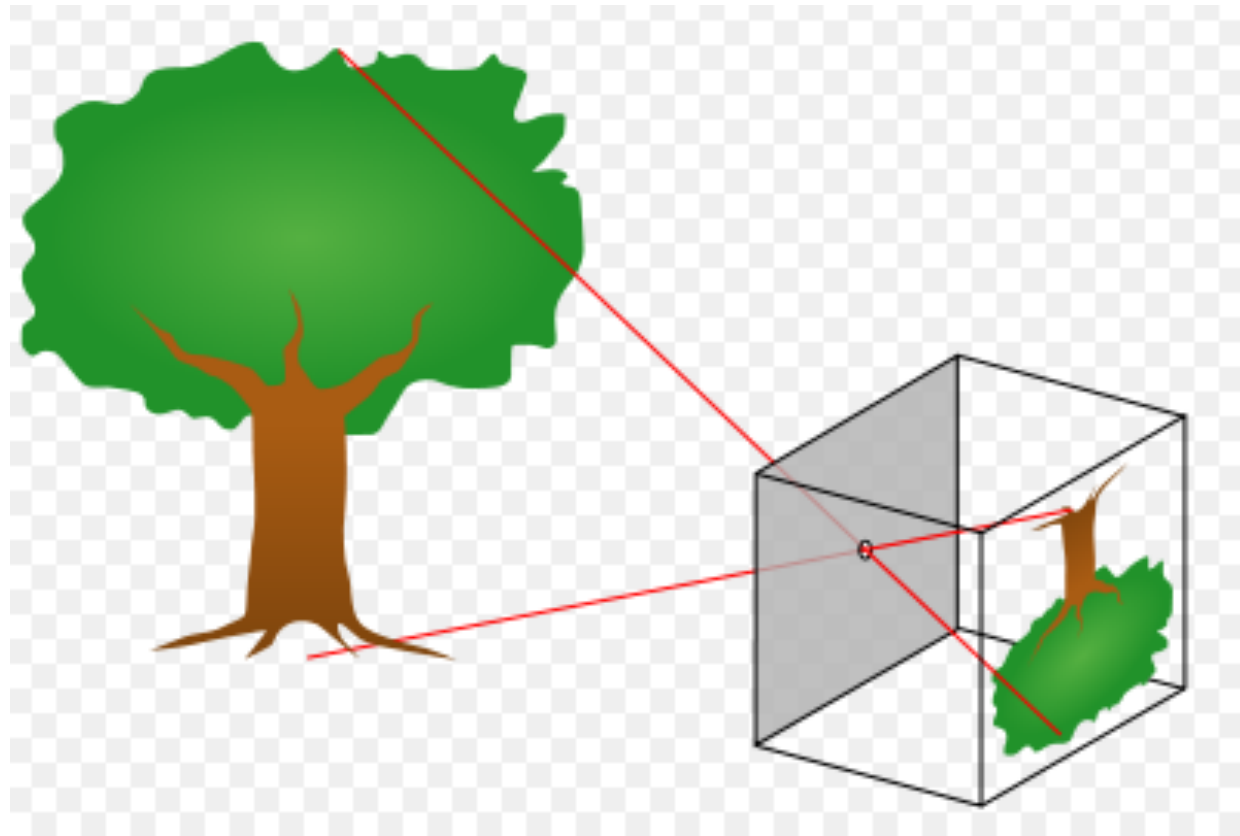
优酷

# Street Slide

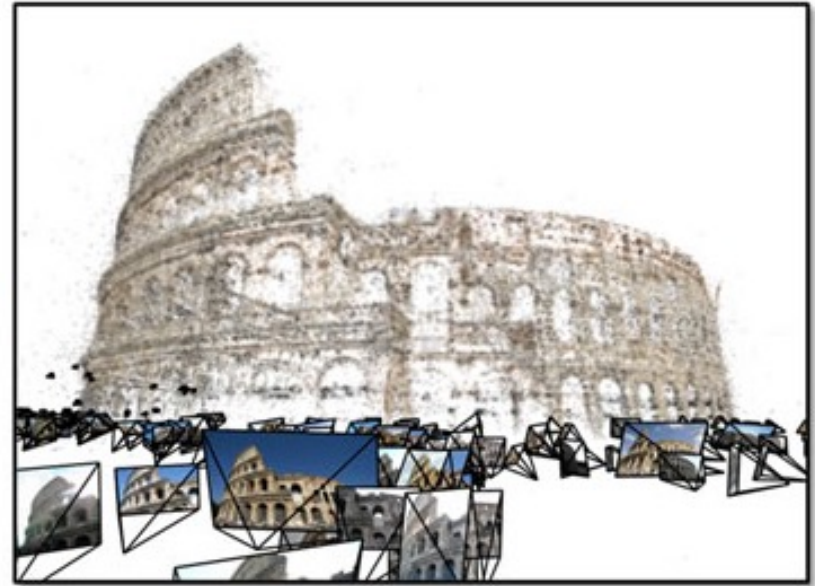
Browsing Street Level Imagery

# 8. Camera Model

- Pinhole Camera



# 8. Structure from Motion





# Photo Tourism

## Exploring photo collections in 3D

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

SIGGRAPH 2006

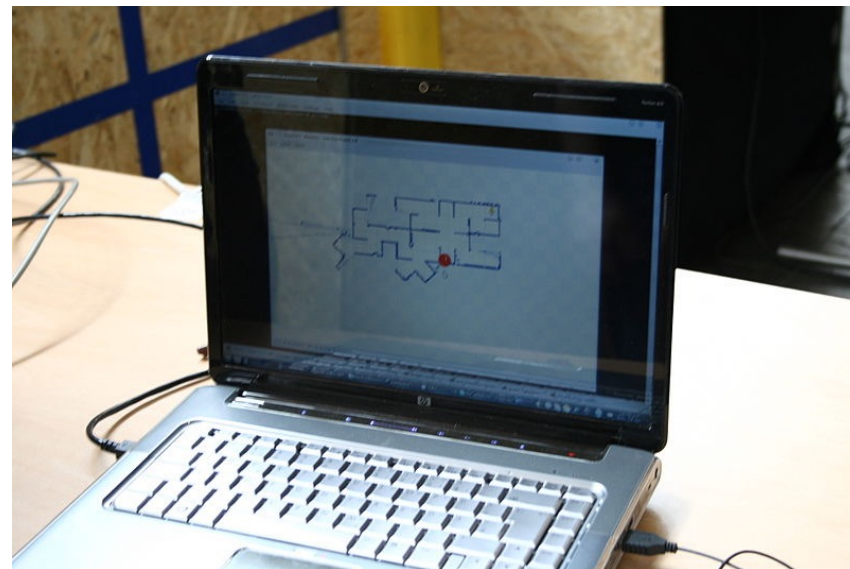
# Input Sequences

Speed: x2



...

# 9. 实时摄像机跟踪





# ORB-SLAM2



**Universidad**  
Zaragoza



Instituto Universitario de Investigación  
en Ingeniería de Aragón  
**Universidad** Zaragoza

ORB-SLAM2: an Open-Source SLAM System  
for Monocular, Stereo and RGB-D Cameras

Raúl Mur-Artal and Juan D. Tardós

[raulmur@unizar.es](mailto:raulmur@unizar.es)

[tardos@unizar.es](mailto:tardos@unizar.es)

# ORB-SLAM3



**Universidad**  
Zaragoza



Instituto Universitario de Investigación  
**en Ingeniería de Aragón**  
Universidad Zaragoza

## **ORB-SLAM3: An Accurate Open-Source Library for Visual, Visual-Inertial and Multi-Map SLAM**

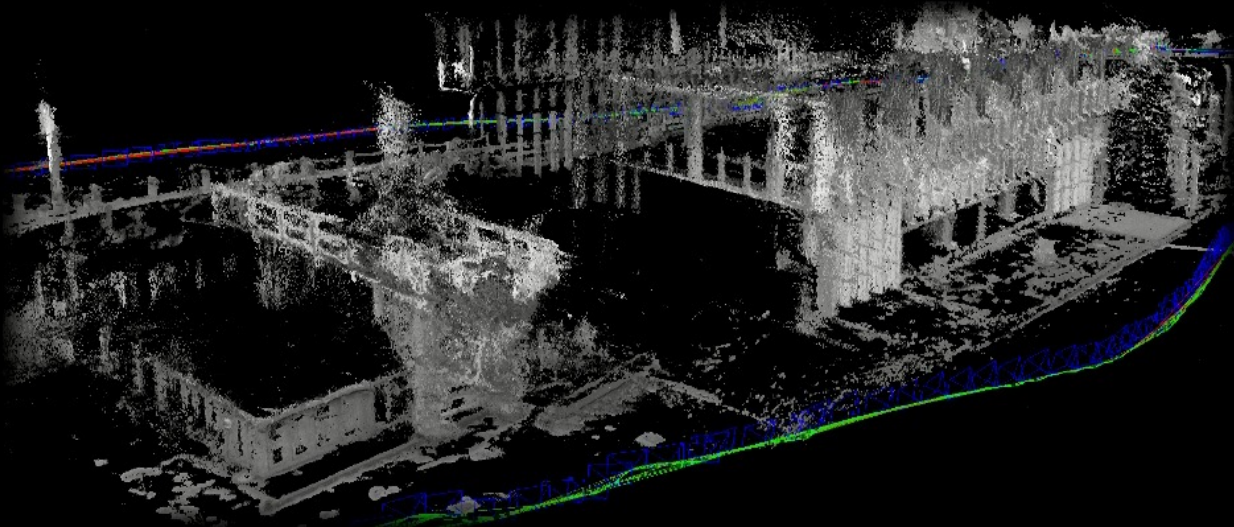
Carlos Campos\*, Richard Elvira\*, Juan J. Gómez Rodríguez,  
José M. M. Montiel and Juan D. Tardós

Dataset: TUM VI Benchmark  
Sequence: Outdoors6  
Setup: Monocular-Inertial

# 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



Droid-SLAM

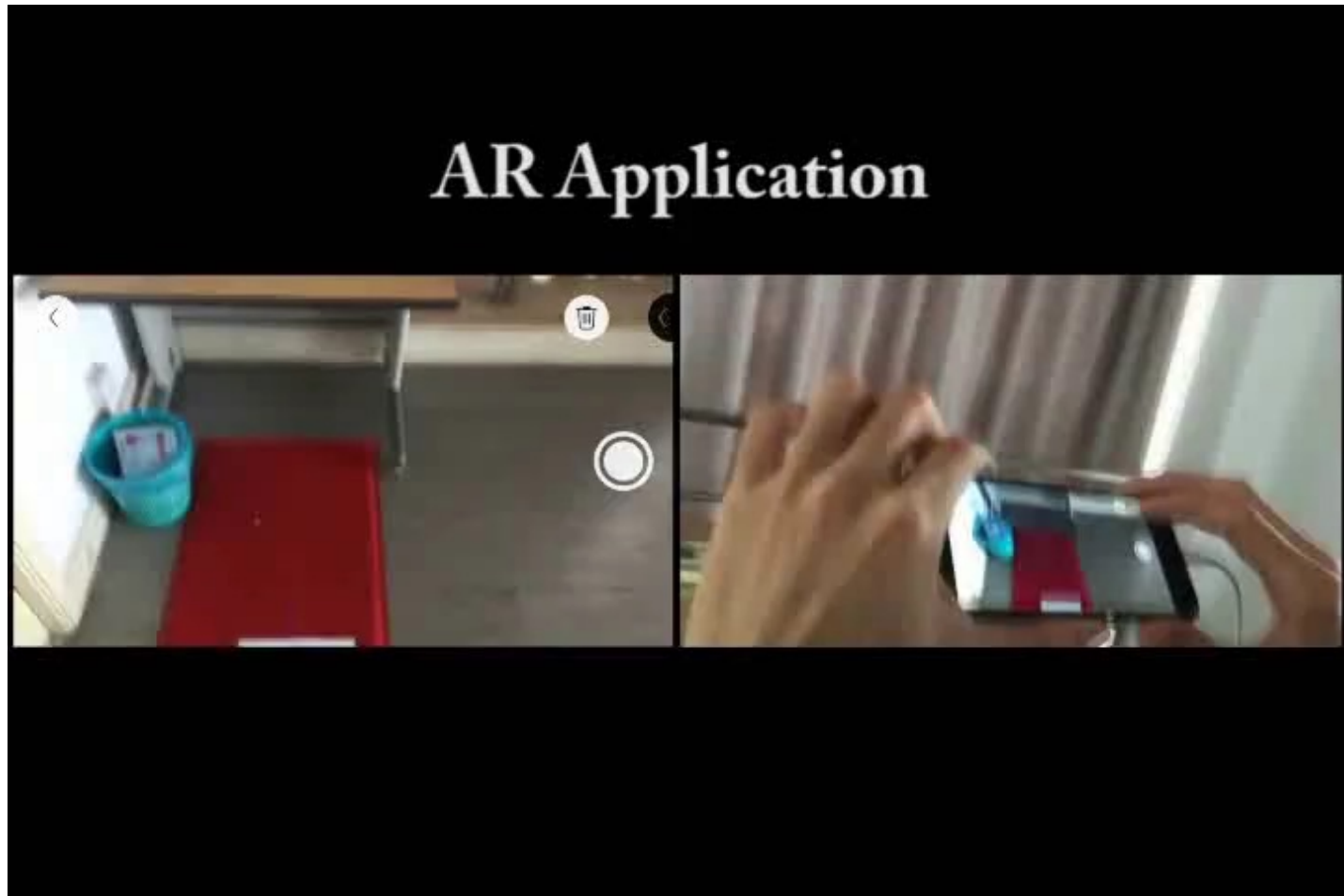
# DROID-SLAM

Deep Visual SLAM for Monocular,  
Stereo, and RGB-D Cameras

Zachary Teed and Jia Deng  
Princeton University



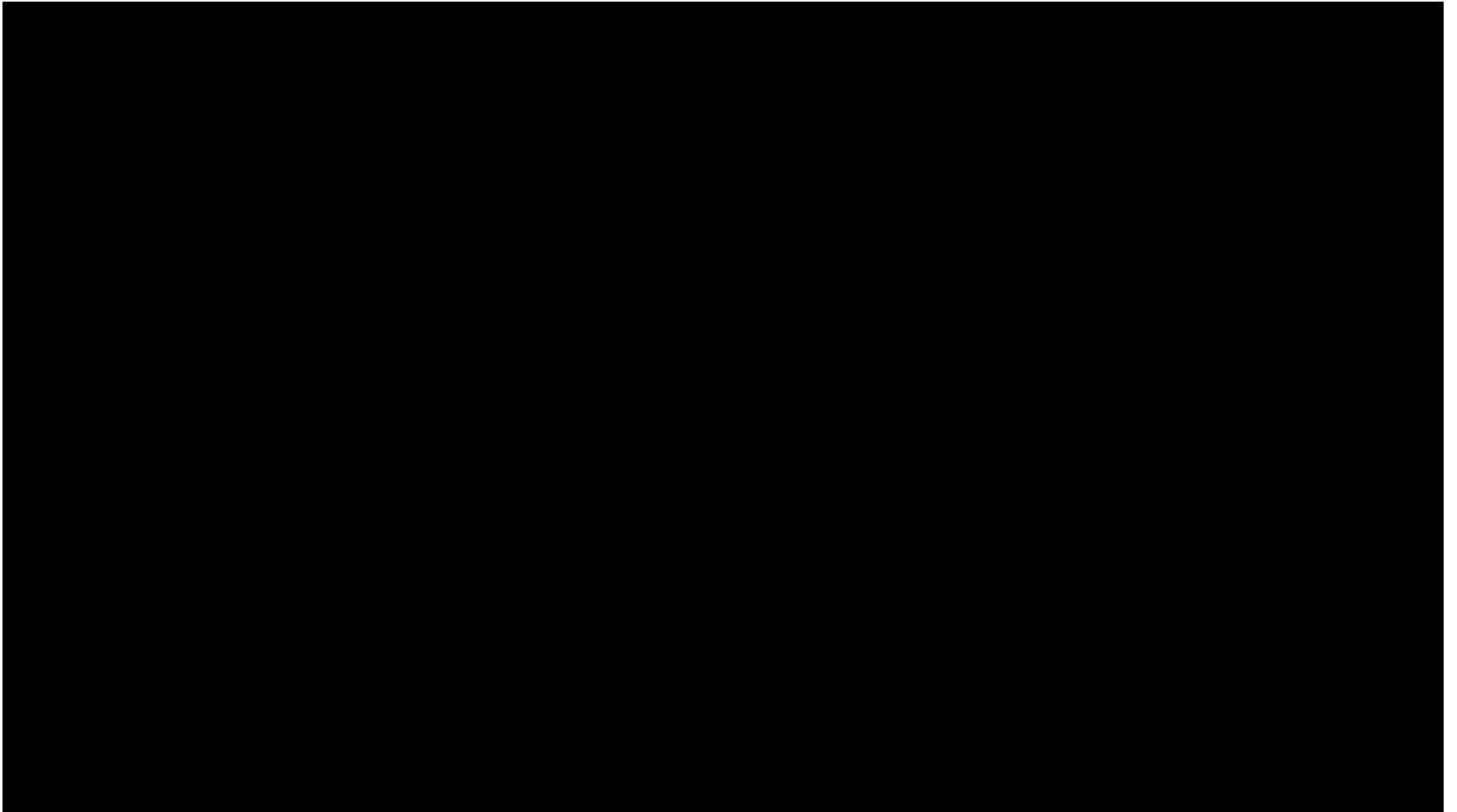
# SLAM for AR Applications



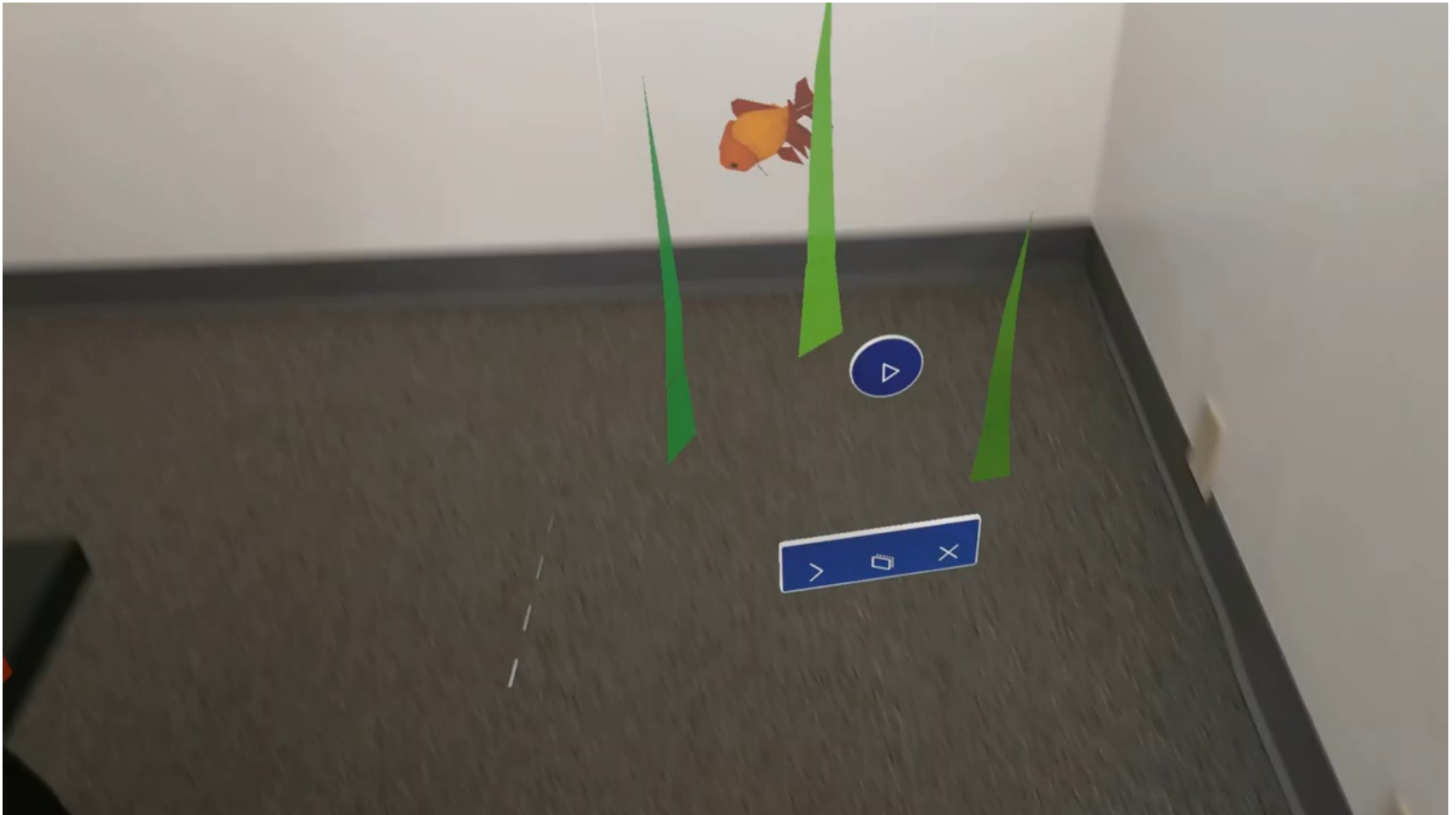




# Huawei Cyberverse



# Microsoft HoloLens2

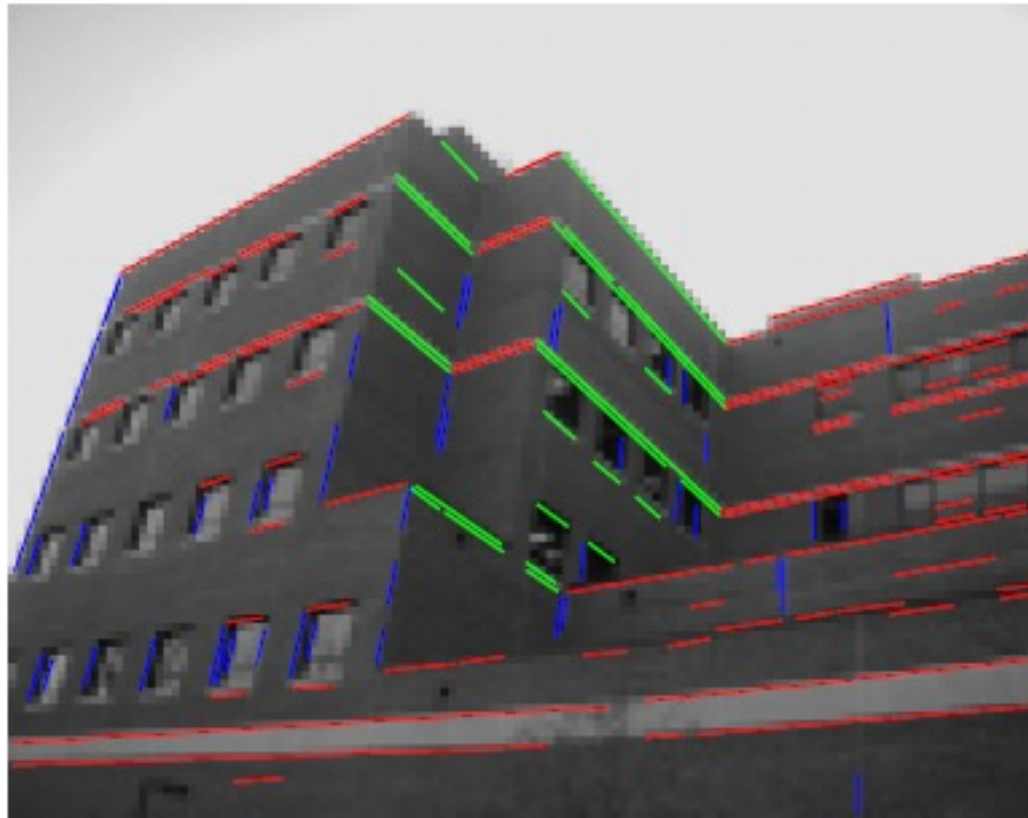




# 微软HoloLens Mesh



# 10. Single-View 3D Reconstruction



# **Automatic Photo Pop-up**

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



# MegaDepth

MegaDepth 0.2093s (4.8 FPS)



Input: 512x384

[github.com/lixx2938/MegaDepth](https://github.com/lixx2938/MegaDepth)

# SDF-SRN

## **SDF-SRN**: Learning Signed Distance 3D Object Reconstruction from Static Images

Chen-Hsuan Lin

Chaoyang Wang

Simon Lucey

Carnegie Mellon University

**NeurIPS 2020**

# Pix2NeRF



## Pix2NeRF: Unsupervised Conditional $\pi$ -GAN for Single Image to Neural Radiance Fields Translation

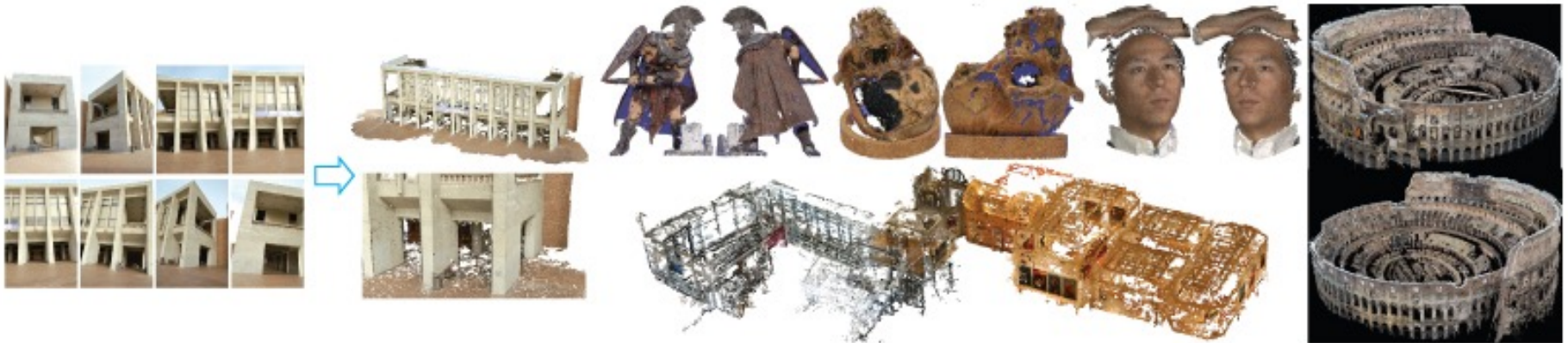
Shengqu Cai   Anton Obukhov   Dengxin Dai   Luc Van Gool

Narrator: Shengqu Cai





# 10. Multi-View 3D Reconstruction



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



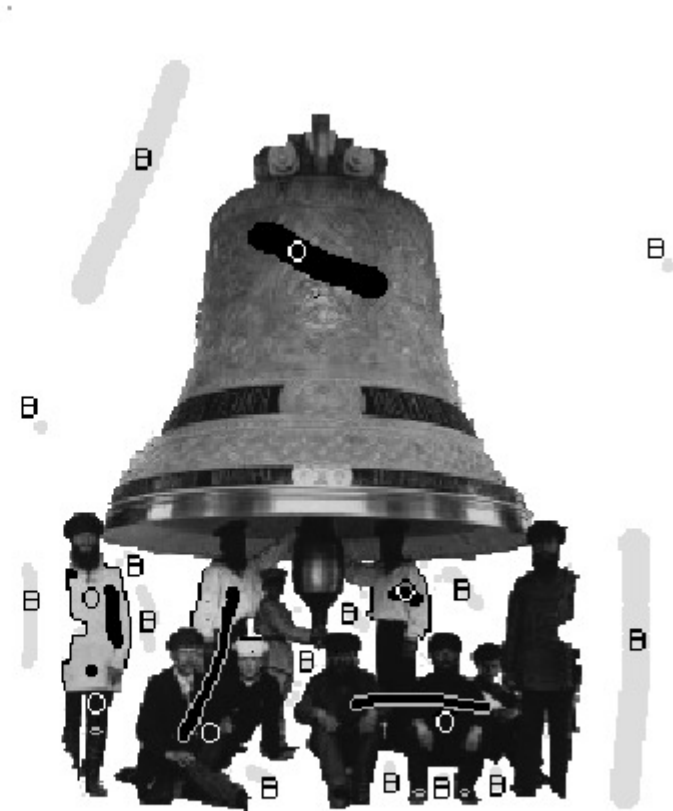


# 11. Interactive Image Segmentation

- Graph Cut



(a) Original B&W photo



(b) Segmentation results

# 11. Interactive Image Segmentation

- Grab Cut



# GrabCut

## Interactive Foreground Extraction using Iterated Graph Cuts

Carsten Rother  
Vladimir Kolmogorov  
Andrew Blake

Microsoft Research Cambridge

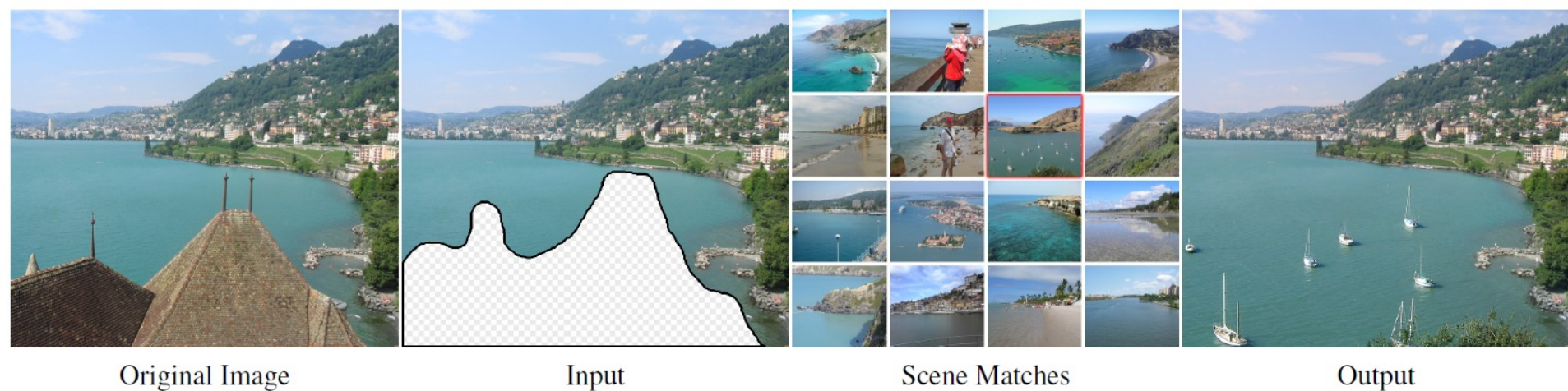


# 12. Image Resizing



Shai Avidan  
Mitsubishi Electric Research Lab  
Ariel Shamir  
The interdisciplinary Center & MERL

# 12. Image Completion



# 12. Image Completion



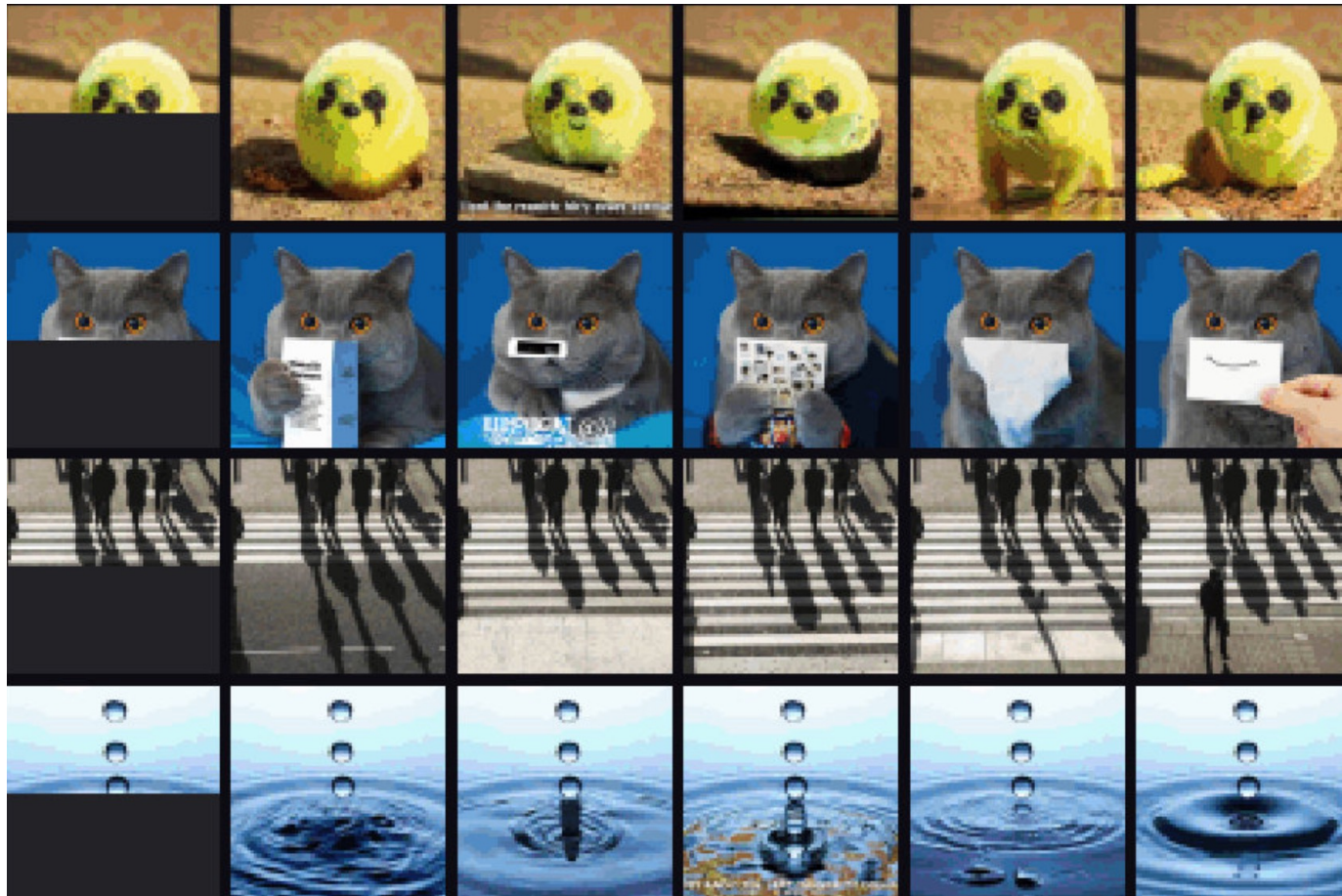
**a**



**b**



# 12. Image Completion



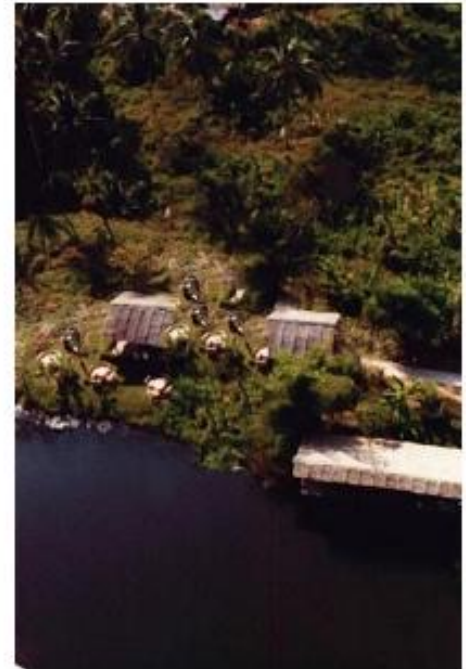
# 12. Image Completion



+



=



# Statistics of Patch Offsets for Image Completion

## Demo

Kaiming He and Jian Sun  
Microsoft Research Asia

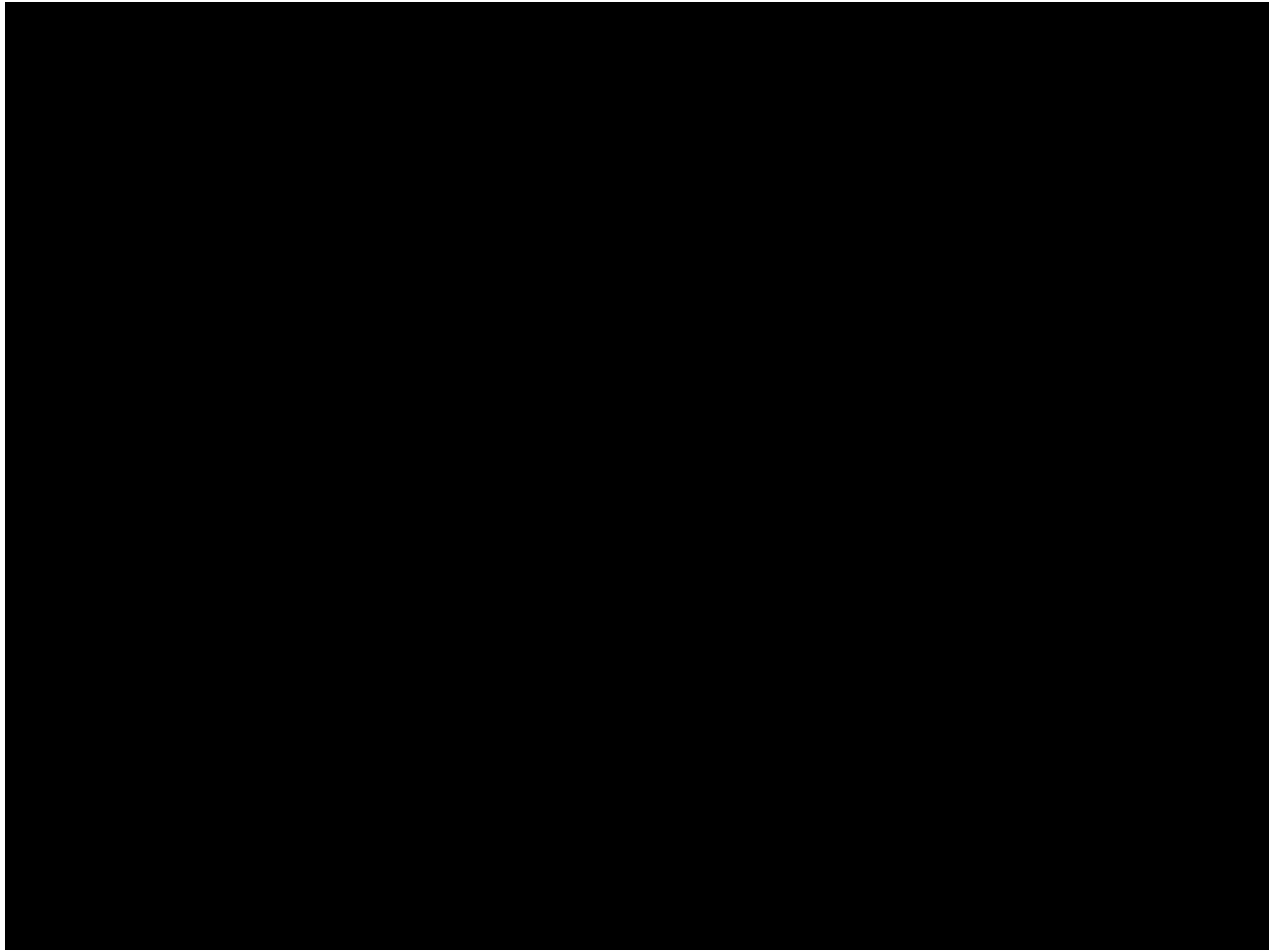


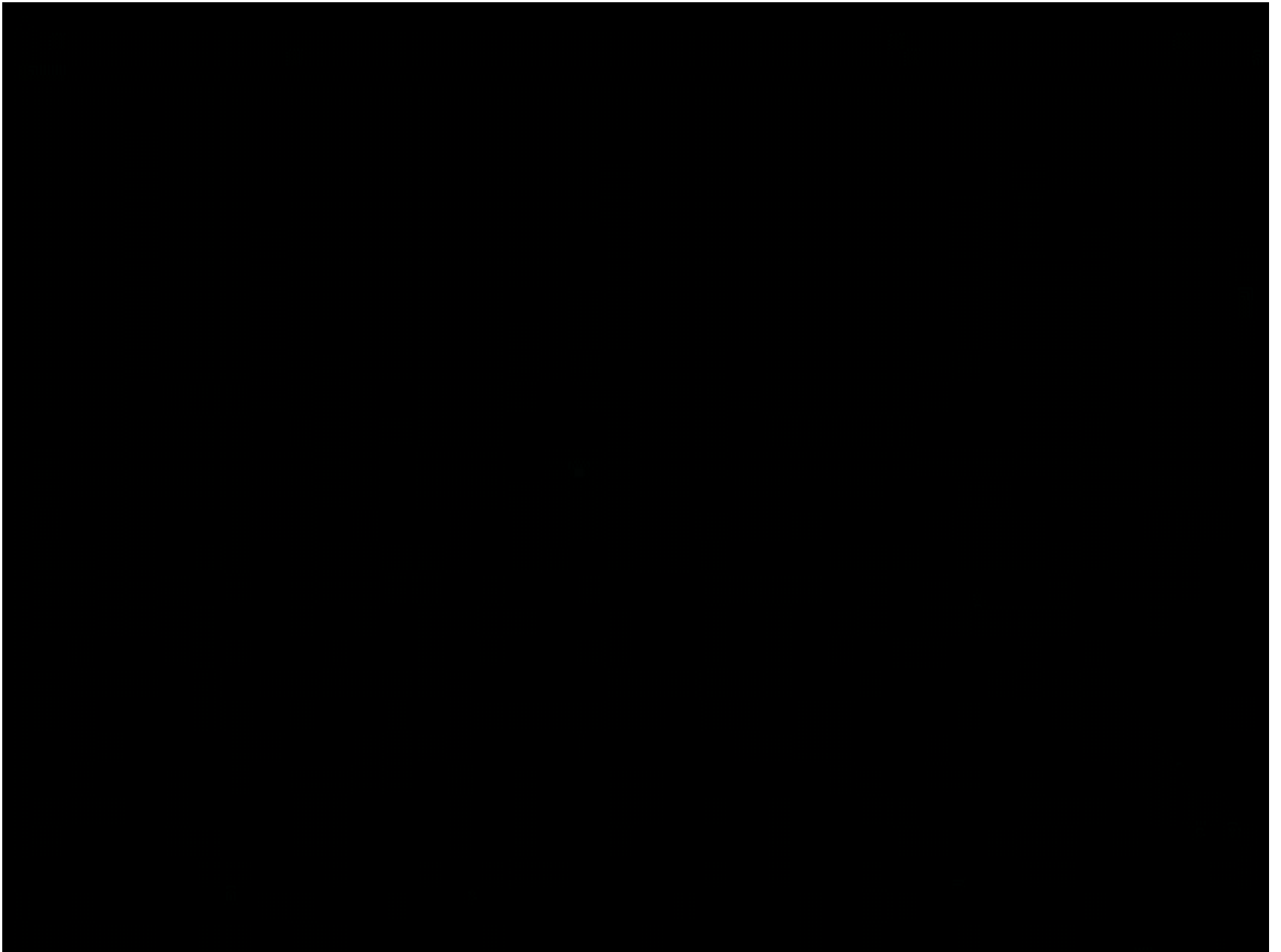
# 12. Texture Synthesis



input images

quilting results







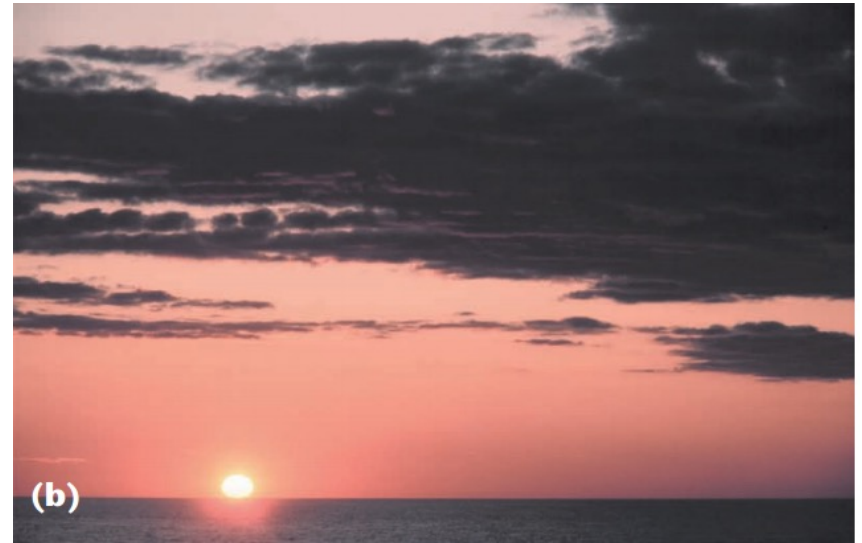
# 13. Image Colorization & Recolorization



# Crater Lake

grayscale input  
(83 frames)

# 13. Image Colorization & Recolorization





# 14. Image Deblurring

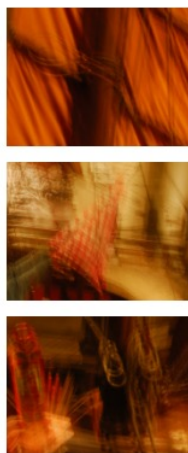
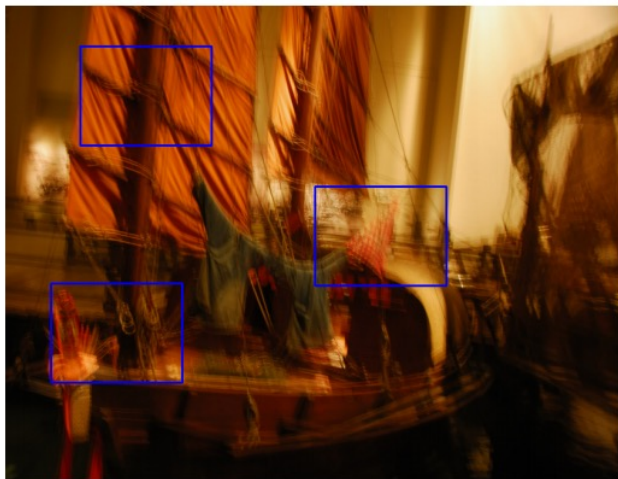


Real Image Input



Deblurring Result

# 14. Image Deblurring



# 课程作业

- 课后编程题
  - 有5个必做编程题，1个选做编程题（按完成质量酌情加分）
  - 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，建议1-2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



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：50%
  - 项目设计与演示：40%
  - 项目课堂答辩：10%
- 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，可以找老师或助教讨论

# 课件与答疑

- 课程教学网站
  - <http://www.cad.zju.edu.cn/home/gfzhang/course/computational-photography/>
- 答疑
  - 助教：
    - 翟宏佳 (zhj1999@zju.edu.cn)
    - 陈硕 (chenshuo.eric@zju.edu.cn)
    - 彭思达 (pengsida@zju.edu.cn)
    - 黄赣 (uanggan@zju.edu.cn)
    - 余星源 (RickyYXY@zju.edu.cn)
  - 时间地点：
    - 每周四下午9-10节（上机课）曹西503



Questions?