



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的局限性，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, ...）。

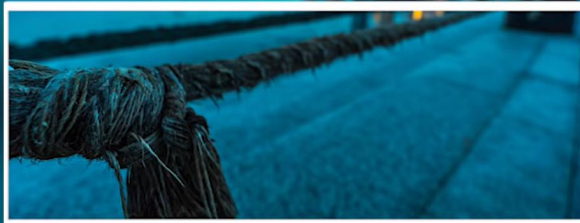
拍摄的苦恼

- 如何拍出完美的照片？

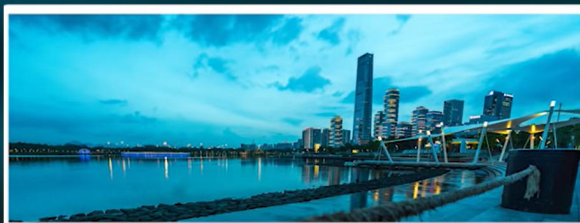


景深融合

HEY!
DRONES

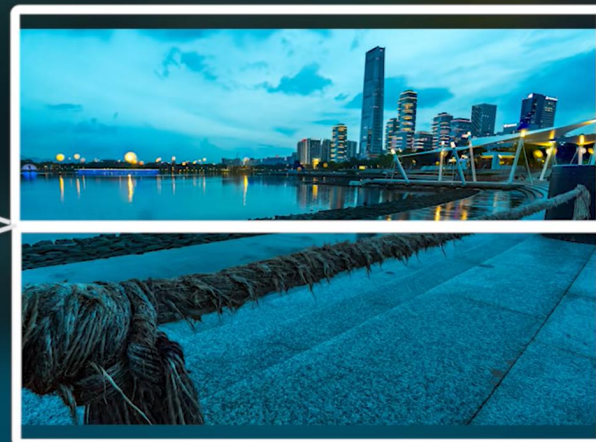


近景

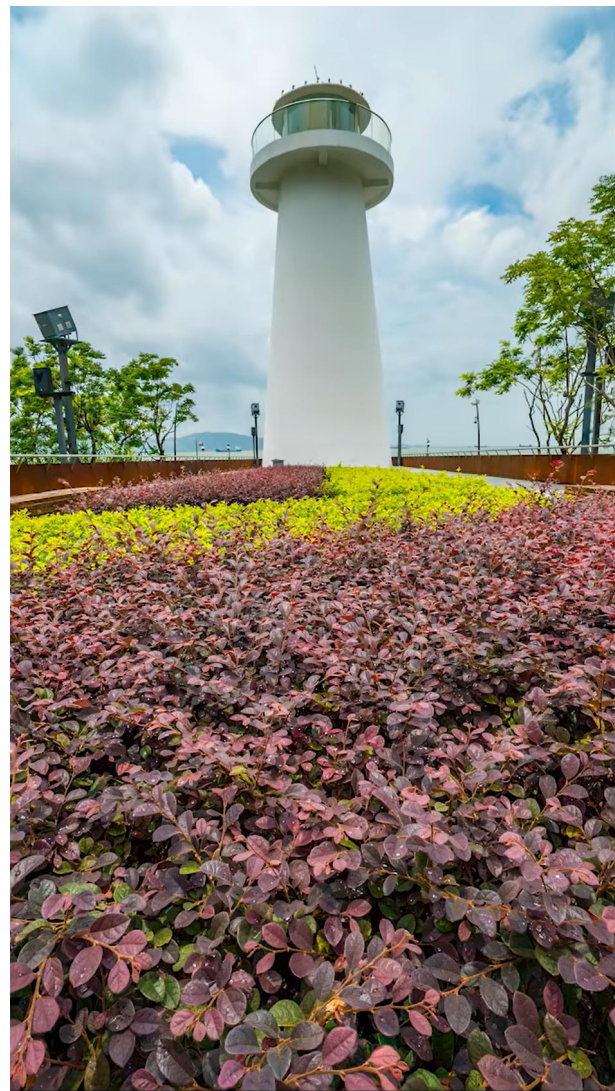


远景

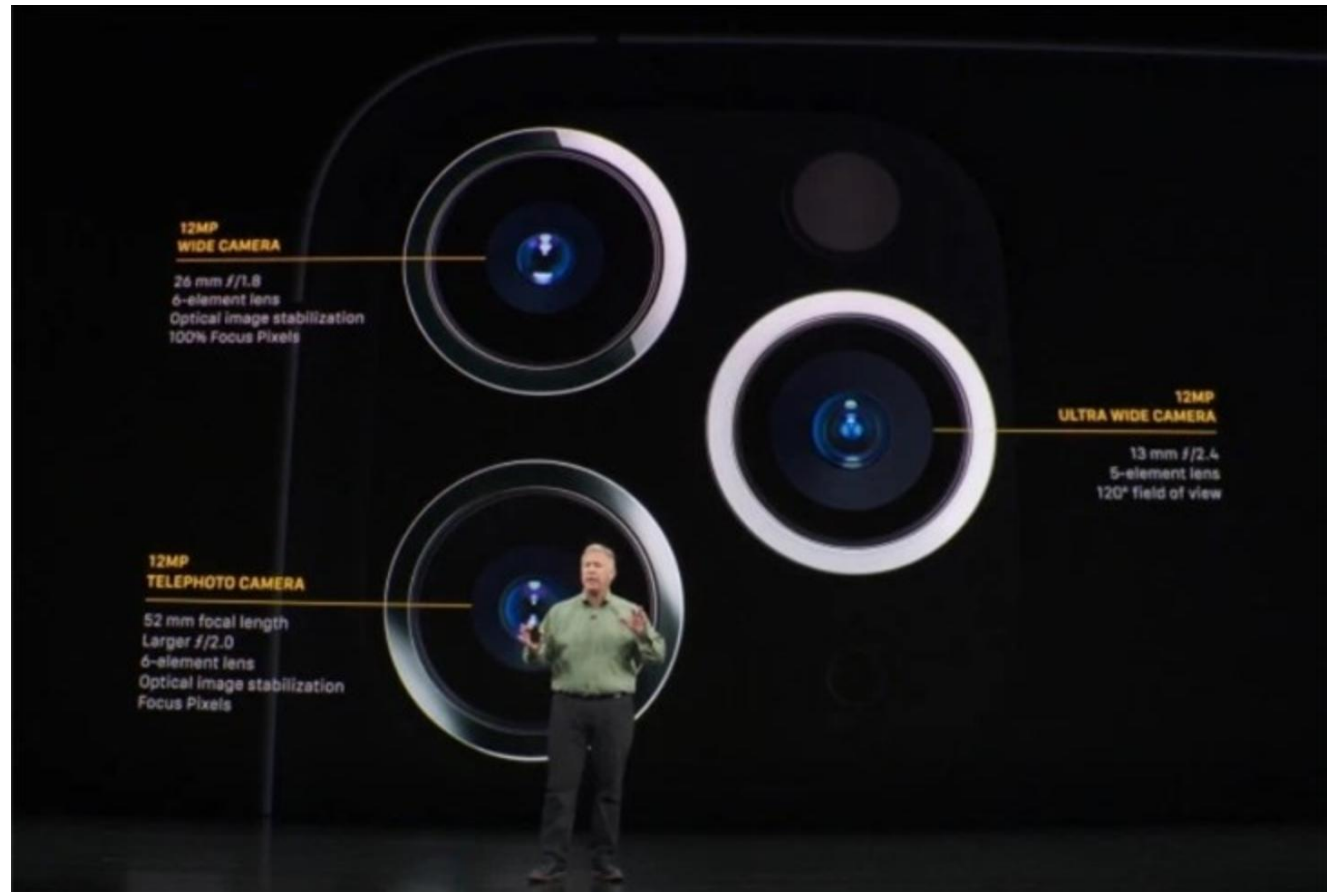
合成



景深融合



多摄像头合成



多摄像头合成



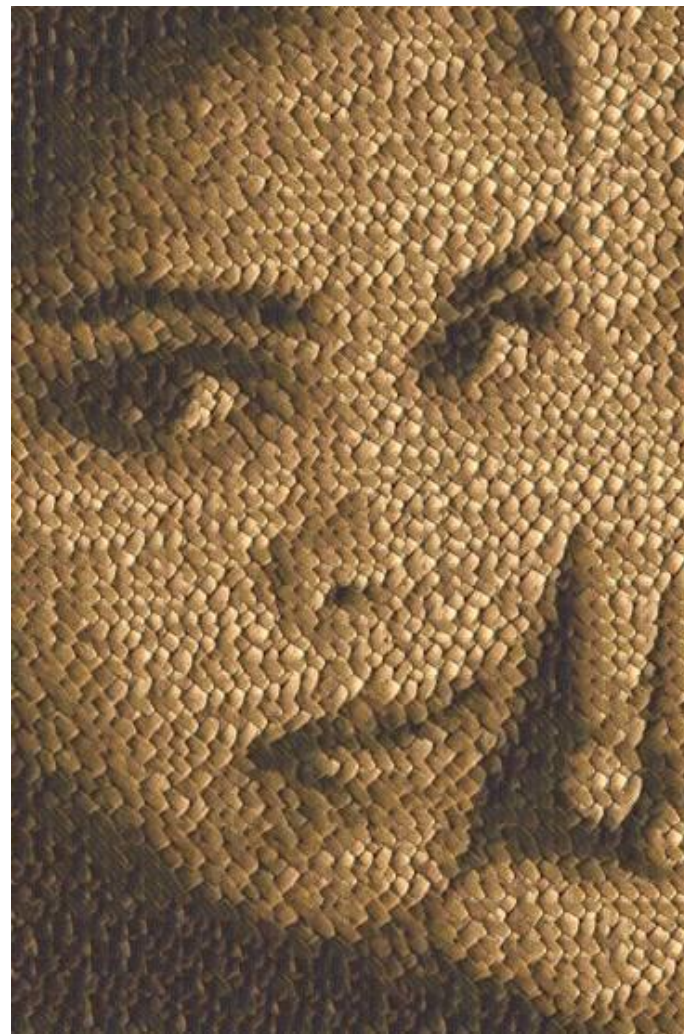
Deep Fusion



Deep Fusion



Creating Stylized Images



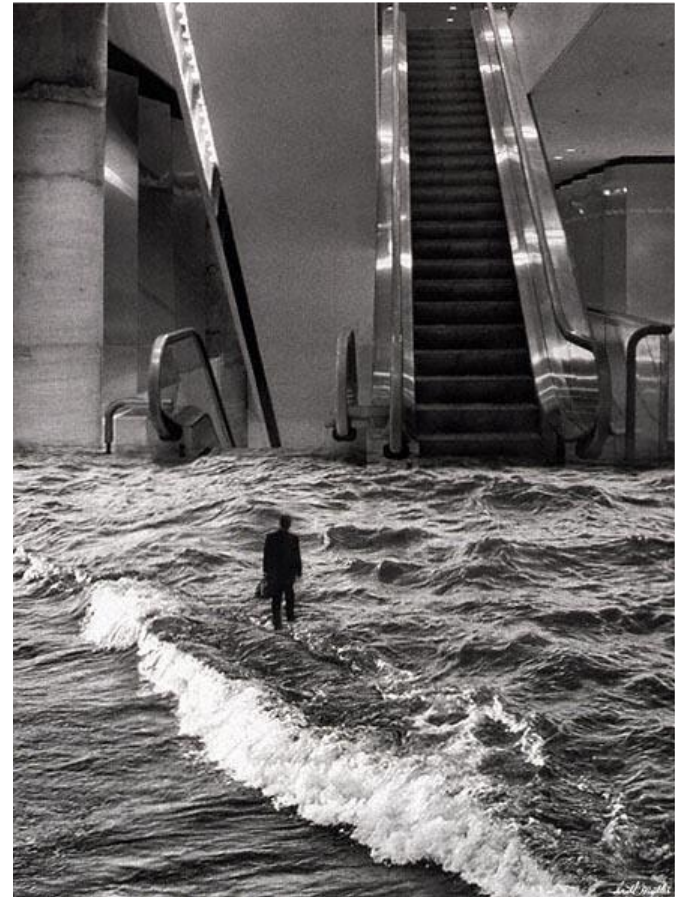
Creating unlikely juxtapositions



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)

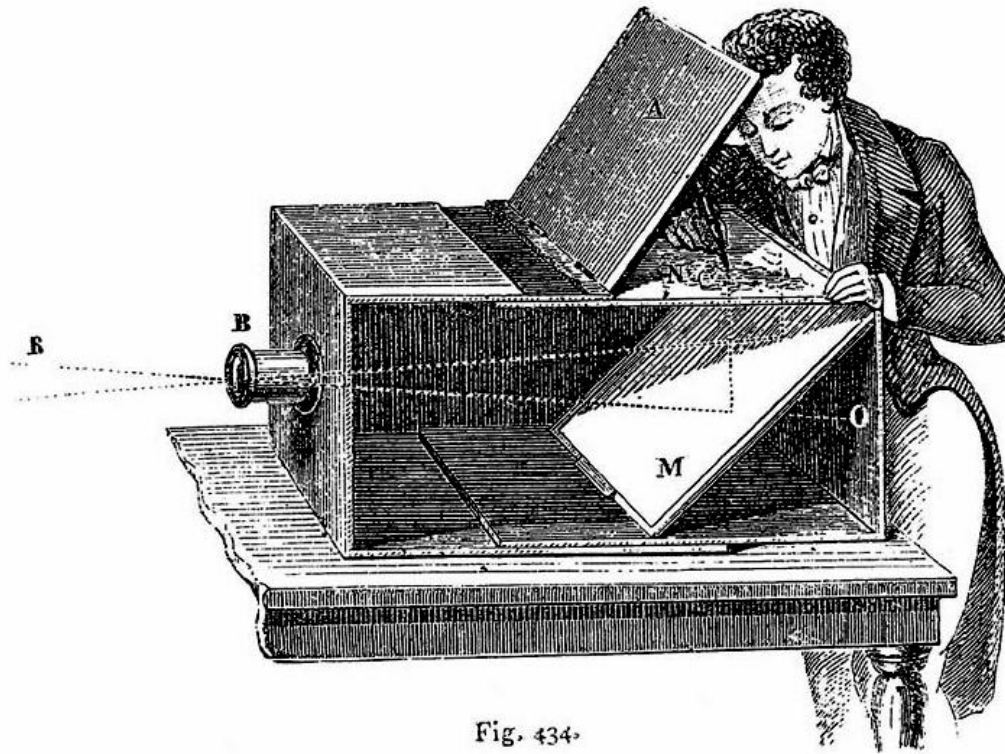


Depicting Our World: Renaissance



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

Depicting Our World: Toward Perfection



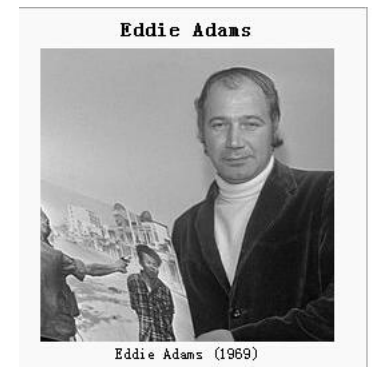
Lens Based Camera Obscura, 1568

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

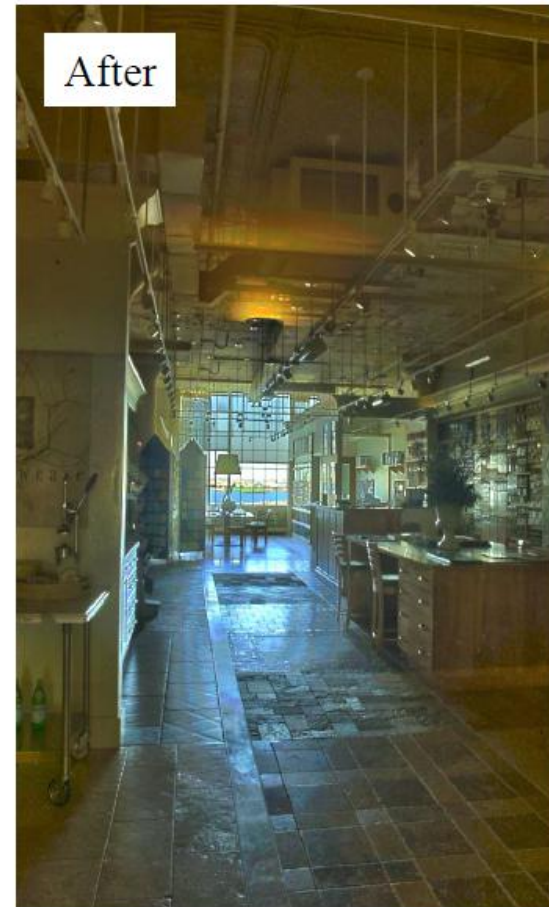
- **数字摄影**
 - 只需用数字技术替代传统传感器和记录
 - 仅涉及简单的图像处理
- **计算摄影学**
 - 相机设计考虑了计算
 - 更精细的图像处理和计算

Examples

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

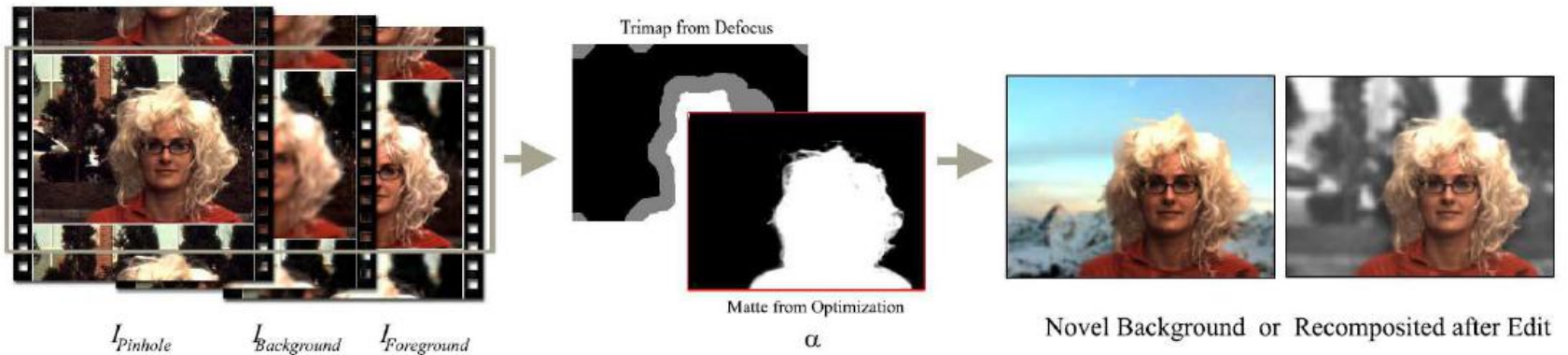
Tone mapping

Suitable for HDR images

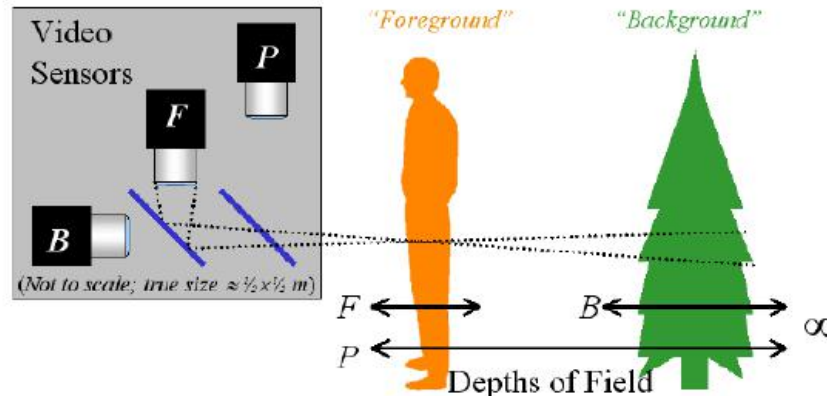


Defocus Matting

- What can be achieved

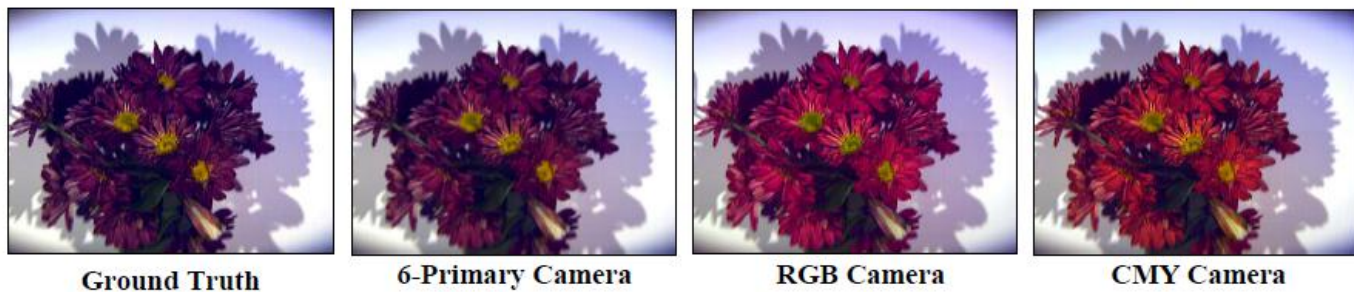
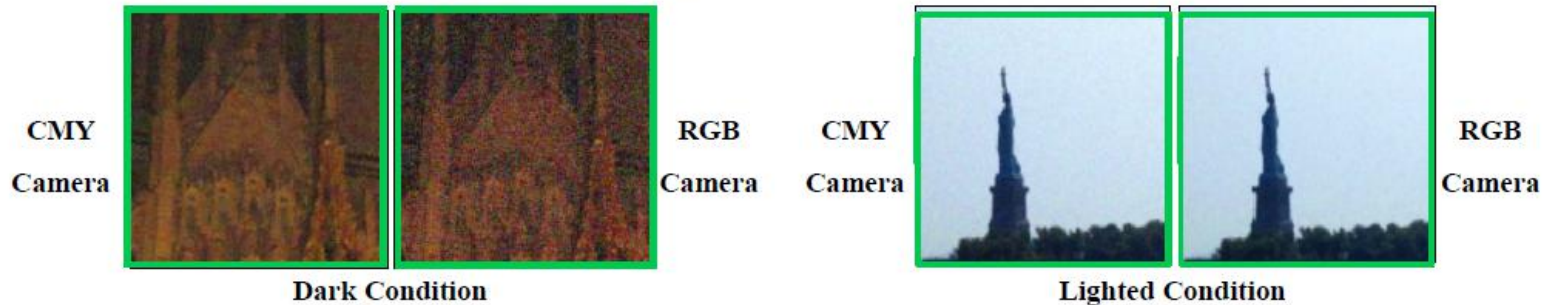


- Design: use 3 streams with different focus

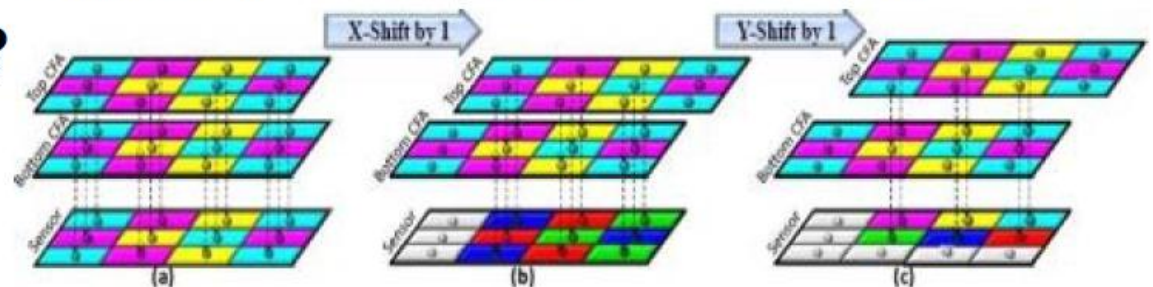


Multi-Modal Cameras

- What can be achieved



- How it works?

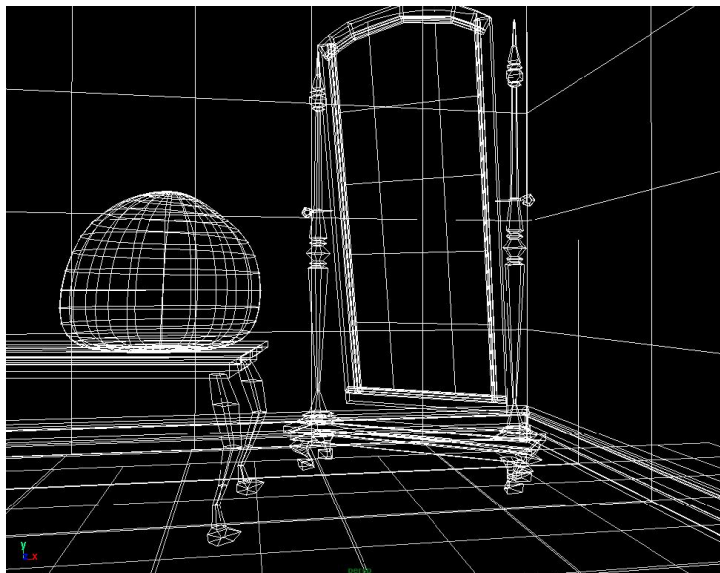


什么是计算摄影学？ ——从软件的视角

从软件的视角看

- 定义一：使用摄影图像来生成图形内容。

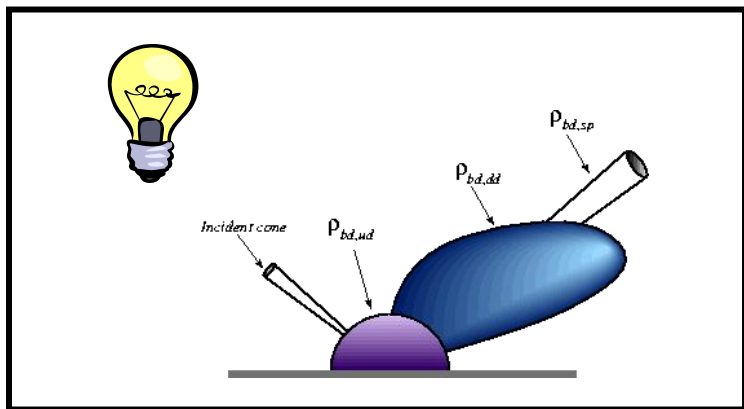
传统计算机图形学



三维几何



投影



物理

仿真

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



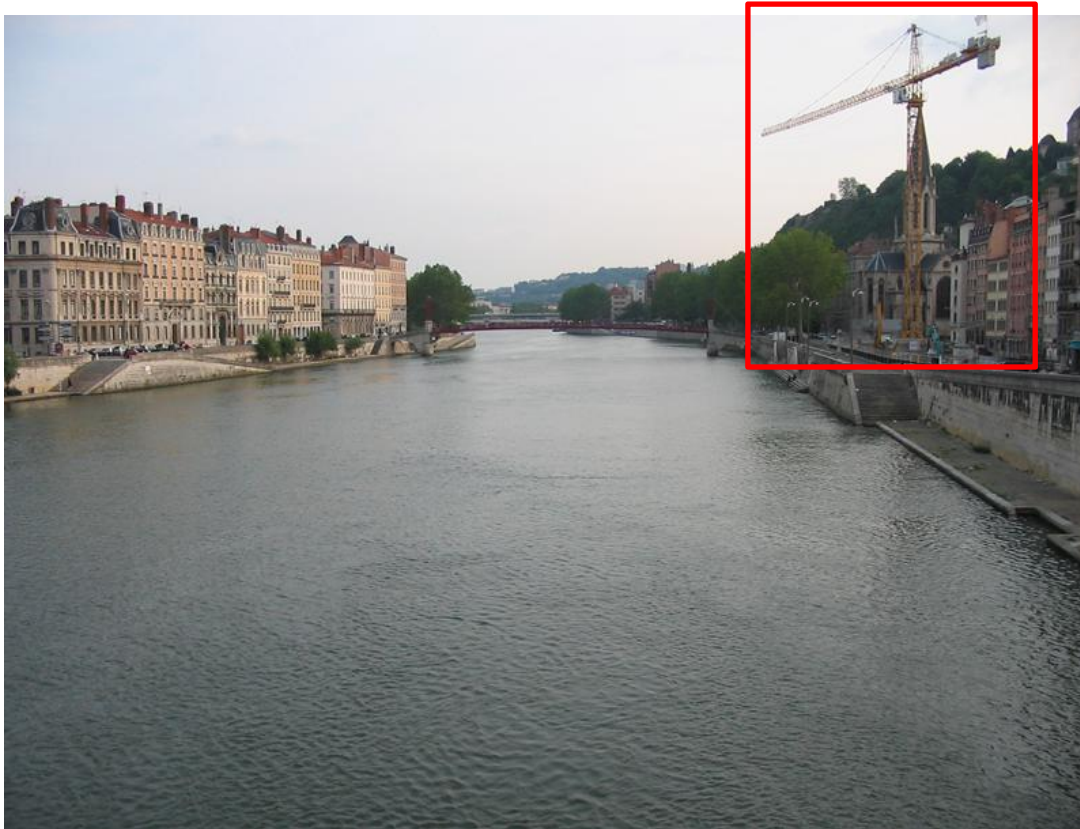
Limitations of traditional photography

- 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.

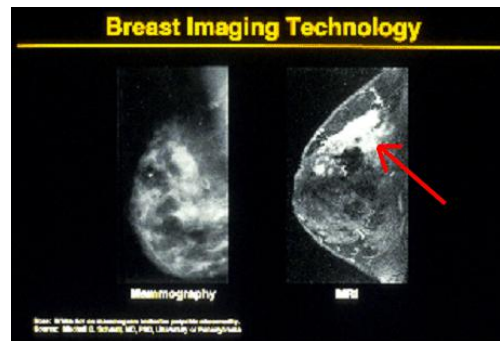


Course objectives

2. You will get a foundation in computer vision.



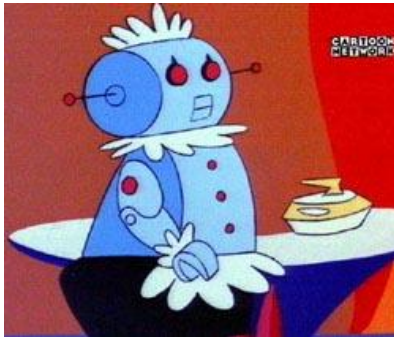
Safety



Health



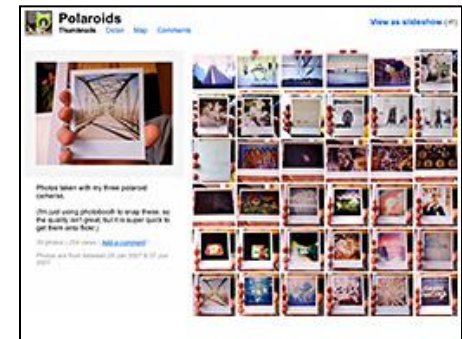
Security



Comfort



Fun



Access

Course objectives

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



Course objectives

4. You'll have fun doing cool stuff!

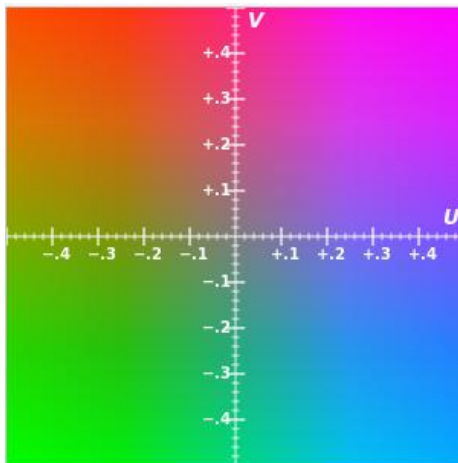
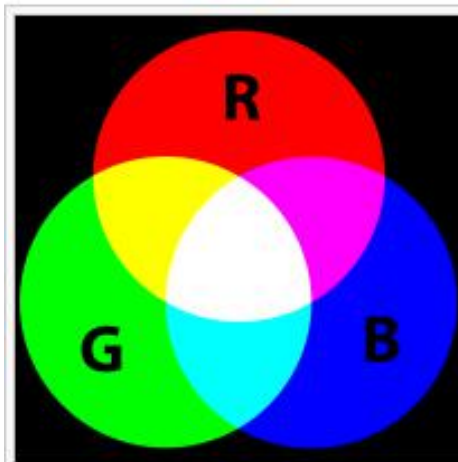
Courses Overview

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

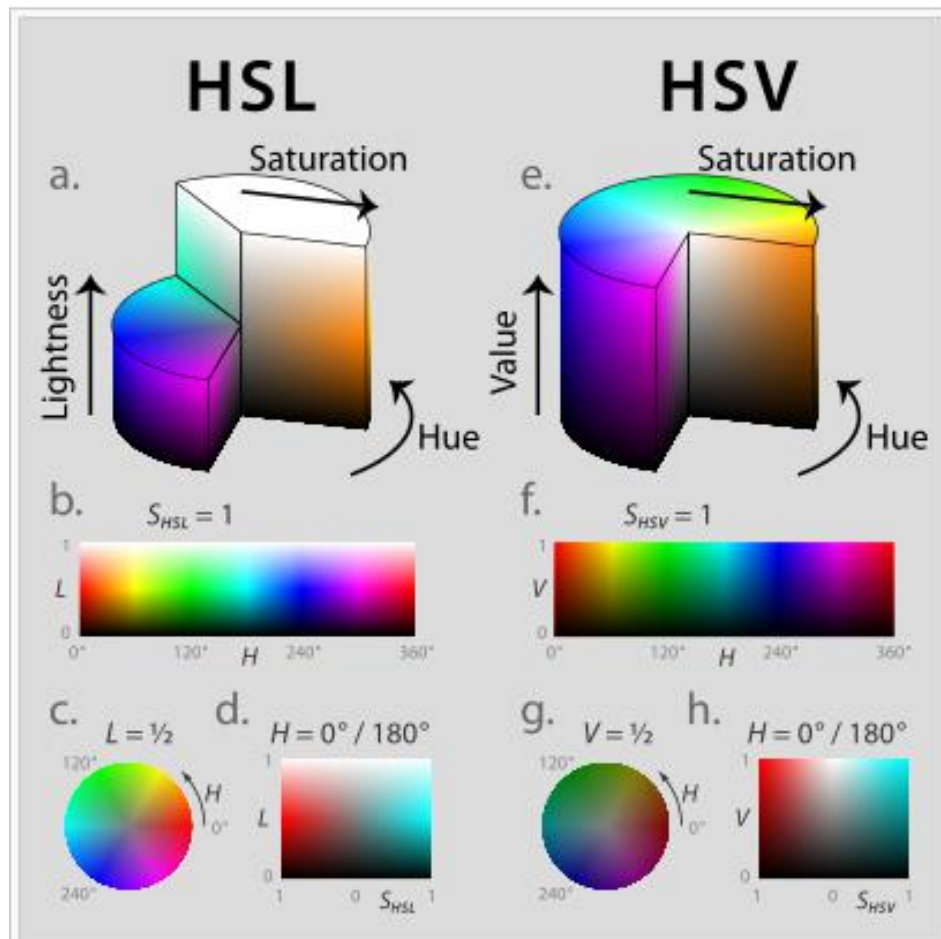
2. Digital Image



2. Color Space



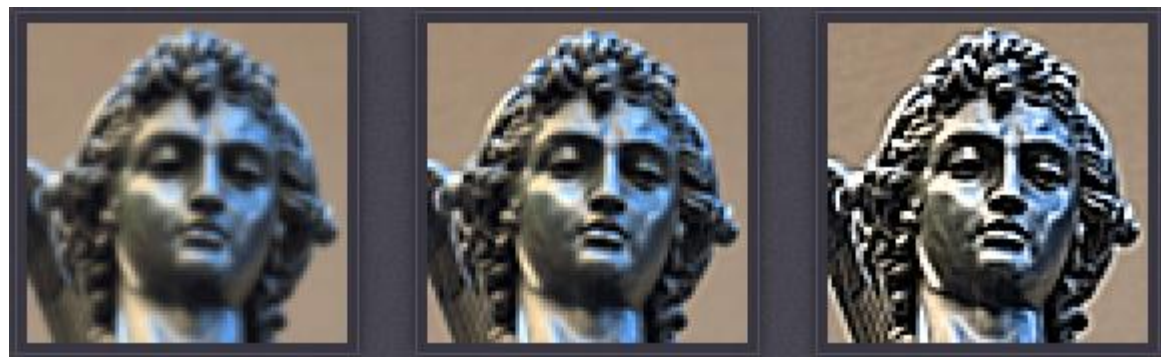
YUV



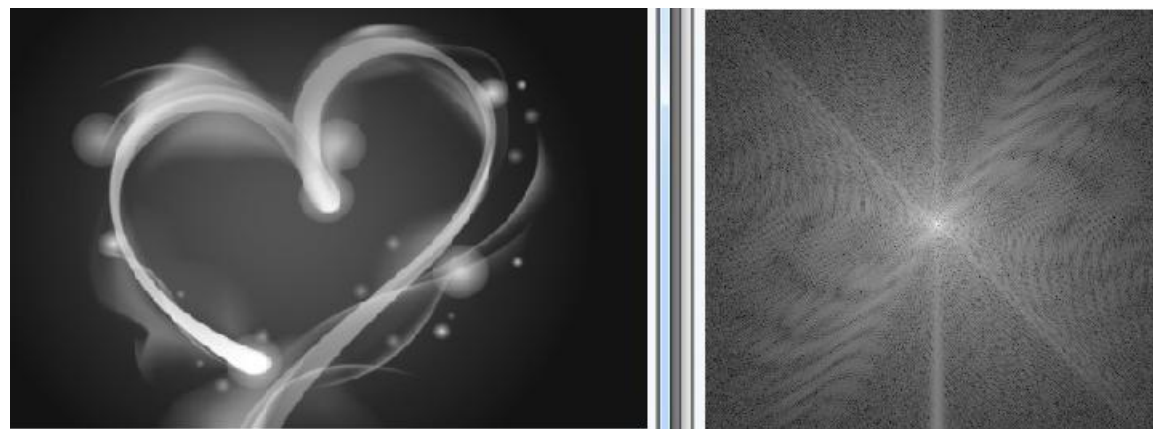
2. Filtering and Fourier Transform



Blur



Sharpening

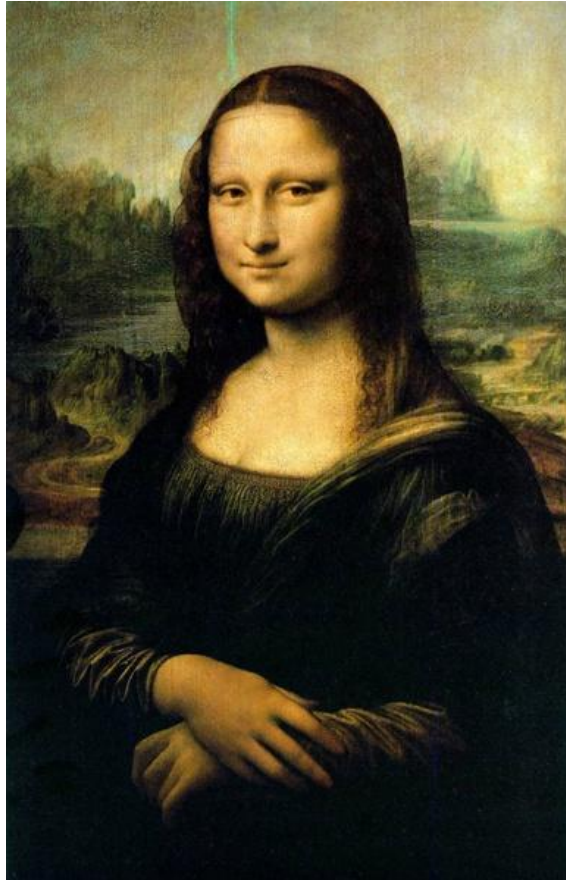


Fourier Transformation

3. Poisson Image Editing



3. Poisson Image Editing



3. Interactive Photomontage



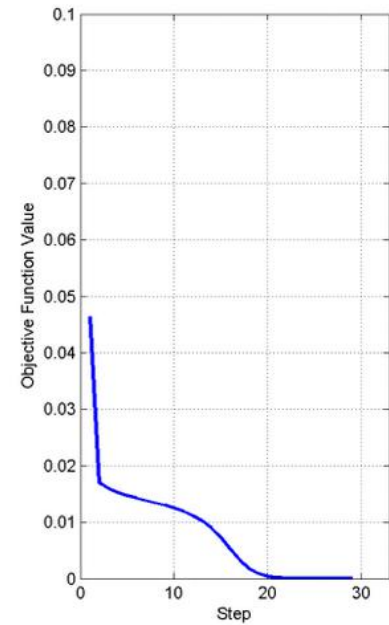
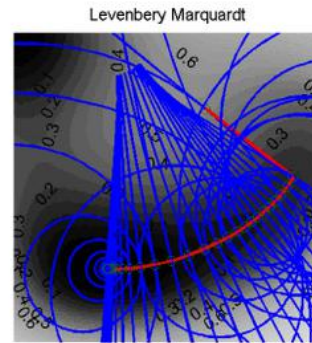
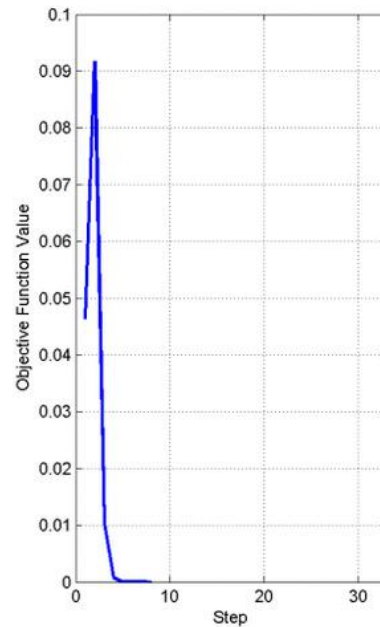
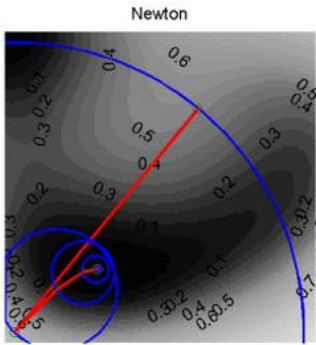
3. Interactive Photomontage

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

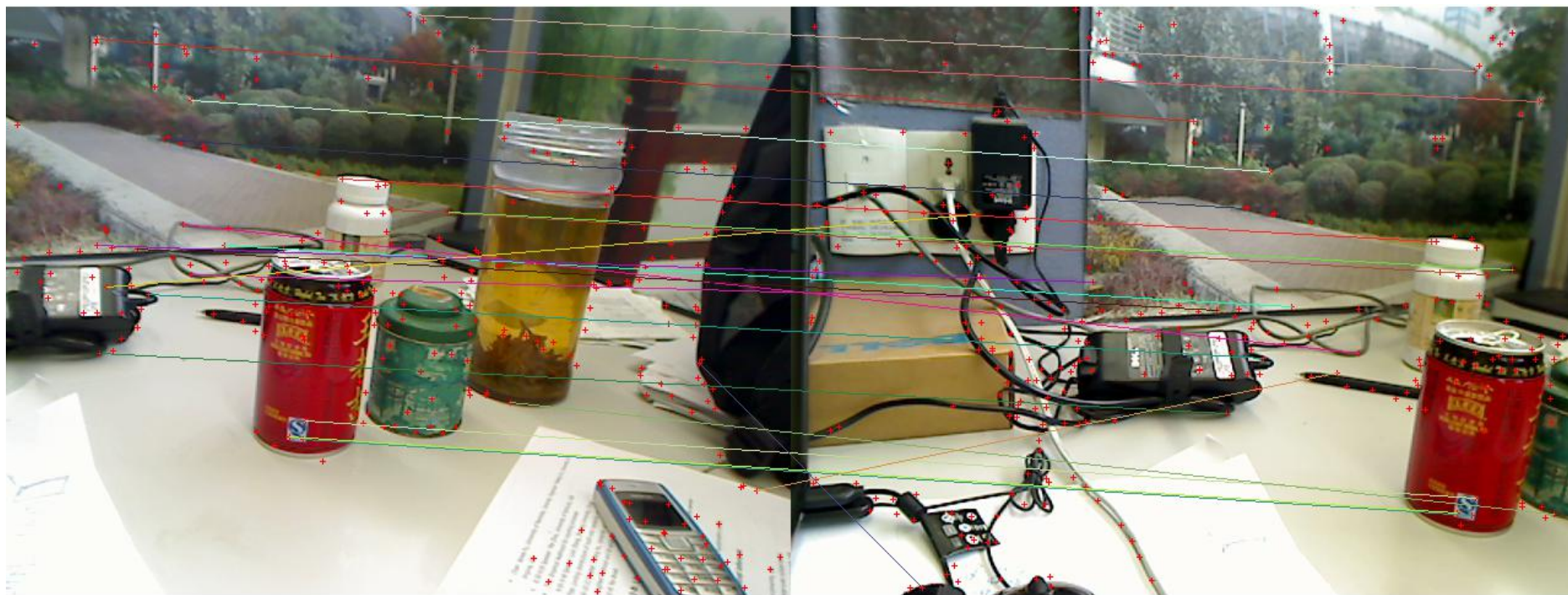


(assume given set of discrete labels)
{dog, cat, truck, plane, ...}



cat

6 . Feature Matching



6. Optical Flow

Input Frames



Warped Frames



flow Map



7. Recognising Panoramas



7. Multiview Panorama Stitching



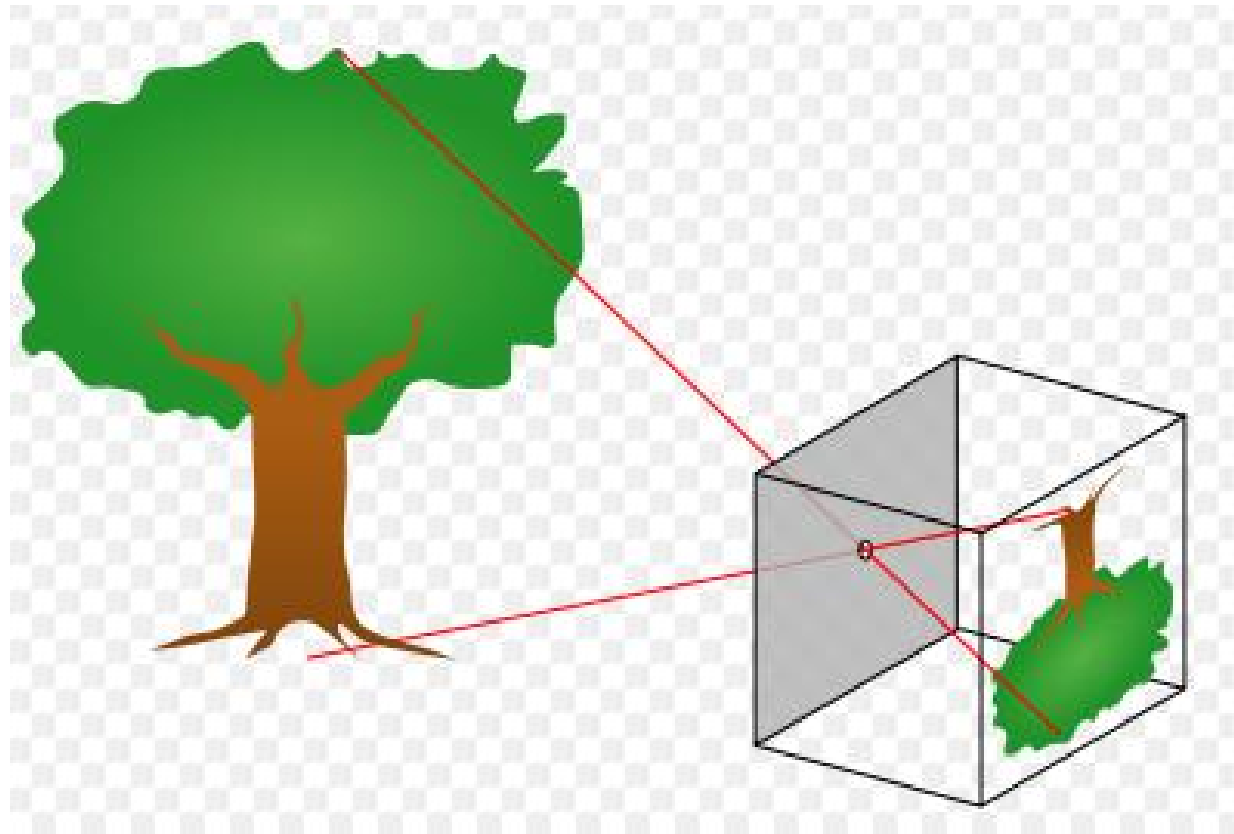
优酷

Street Slide

Browsing Street Level Imagery

8. Camera Model

- Pinhole Camera



8. Structure from Motion

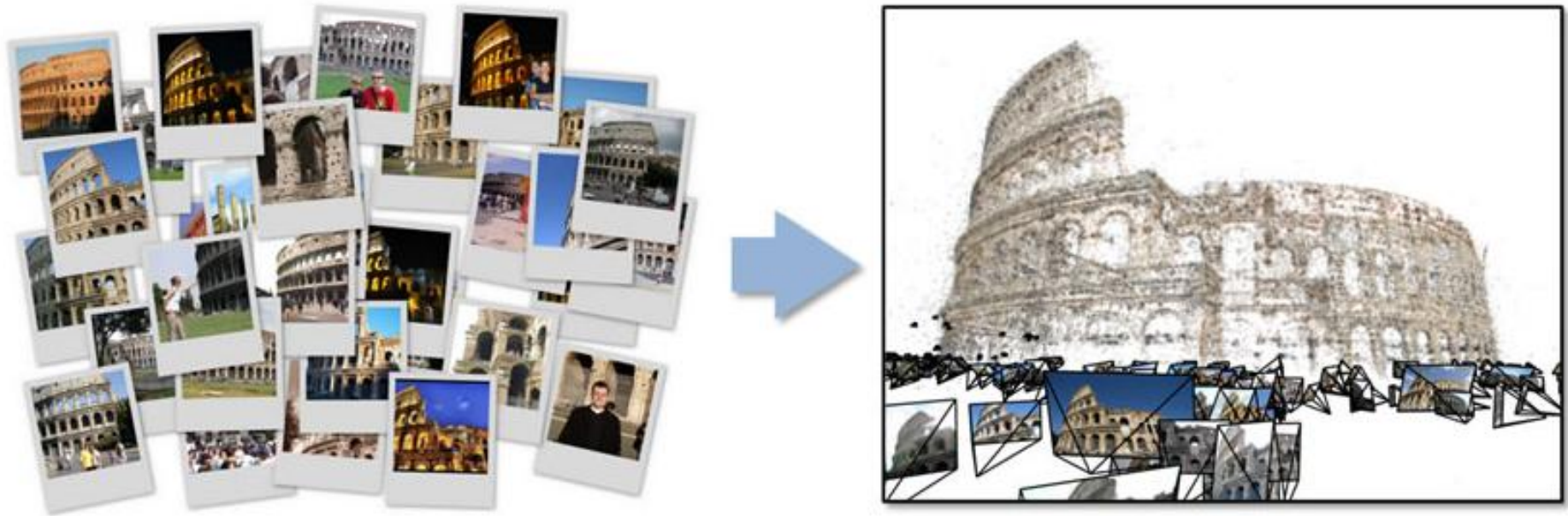


Photo Tourism

Exploring photo collections in 3D

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

SIGGRAPH 2006

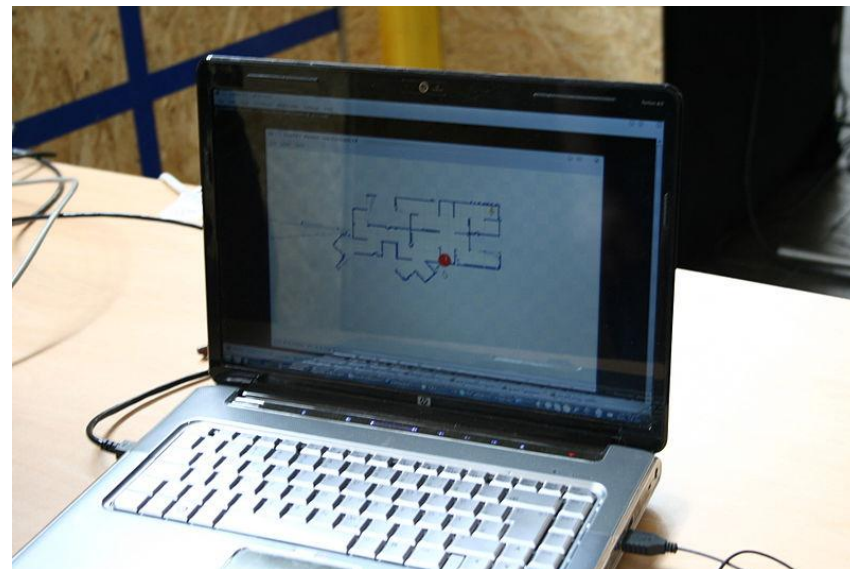
Input Sequences

Speed: $\times 2$



...

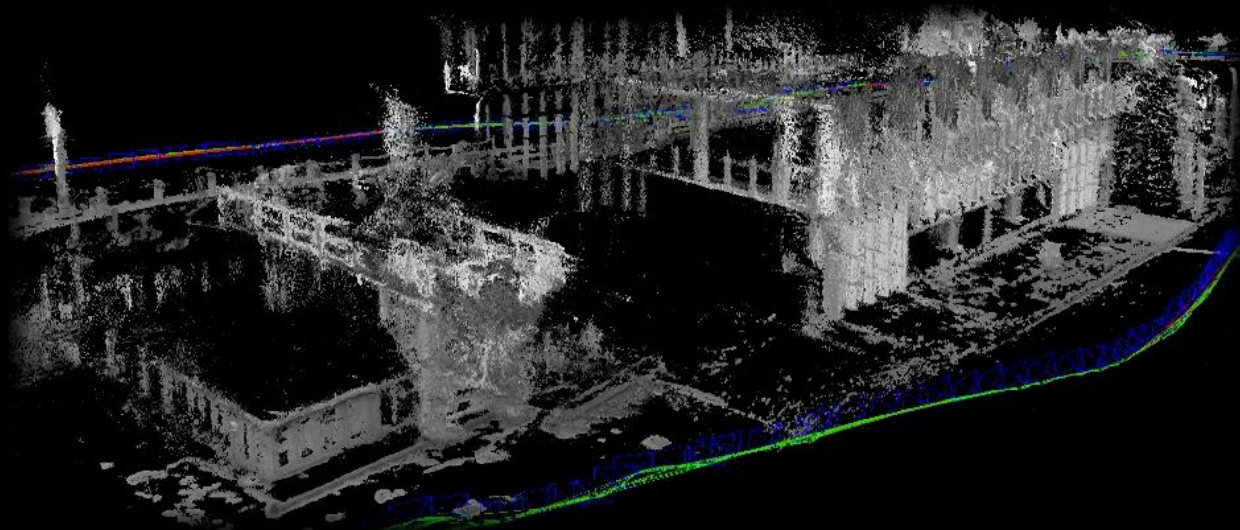
9. 实时摄像机跟踪



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

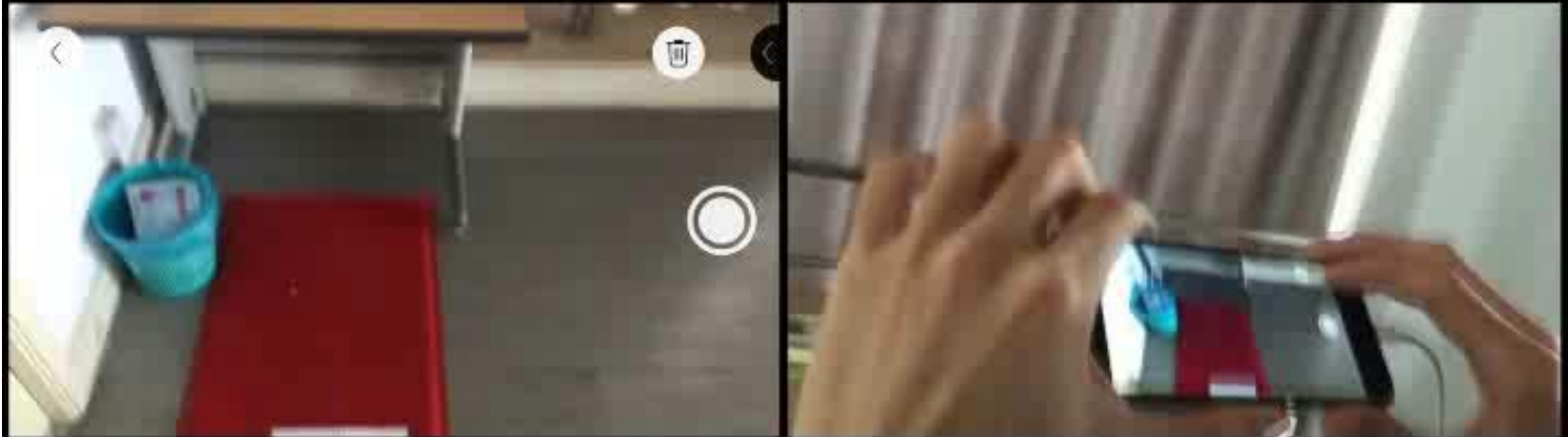


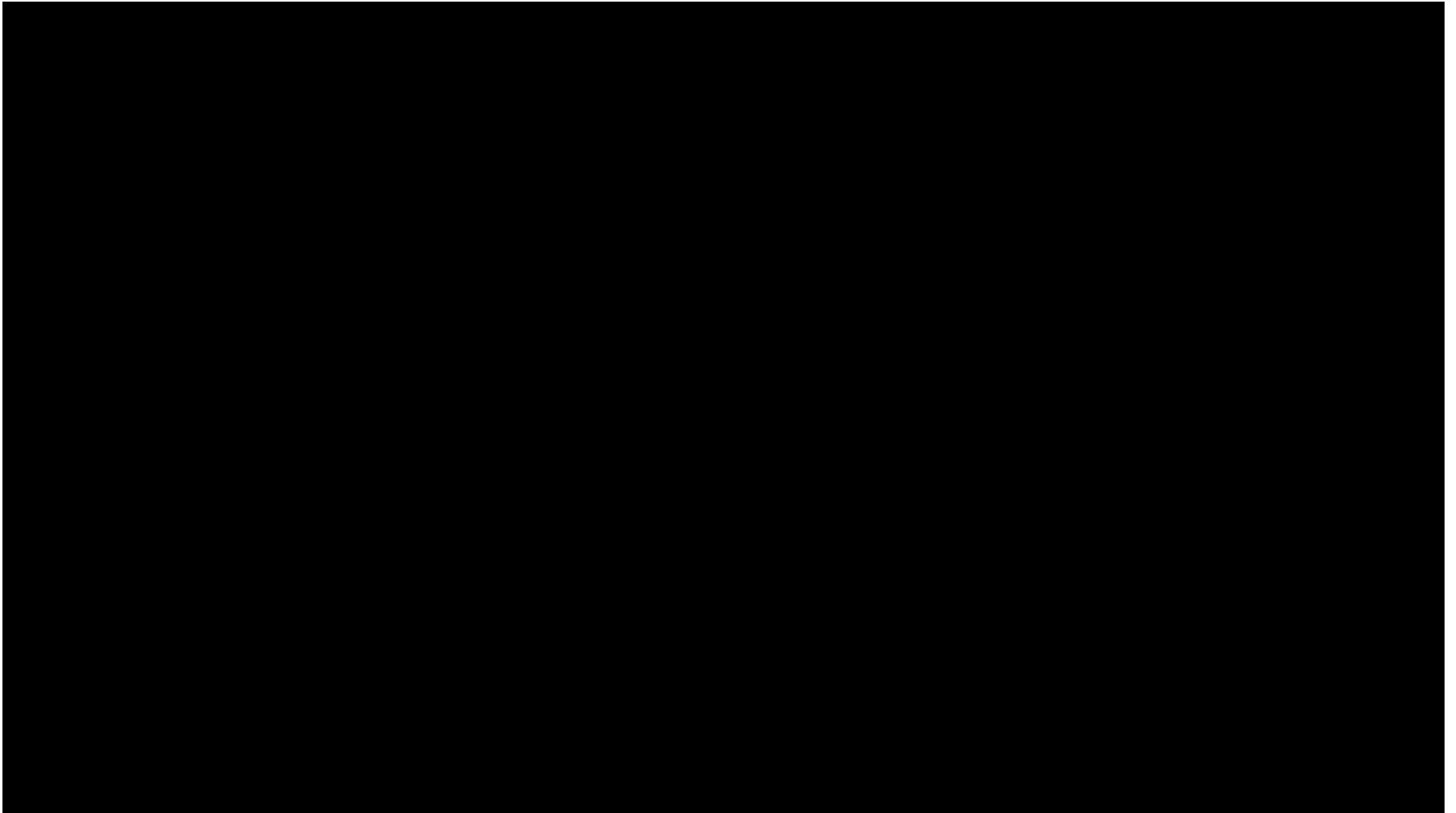
ENFT-SLAM



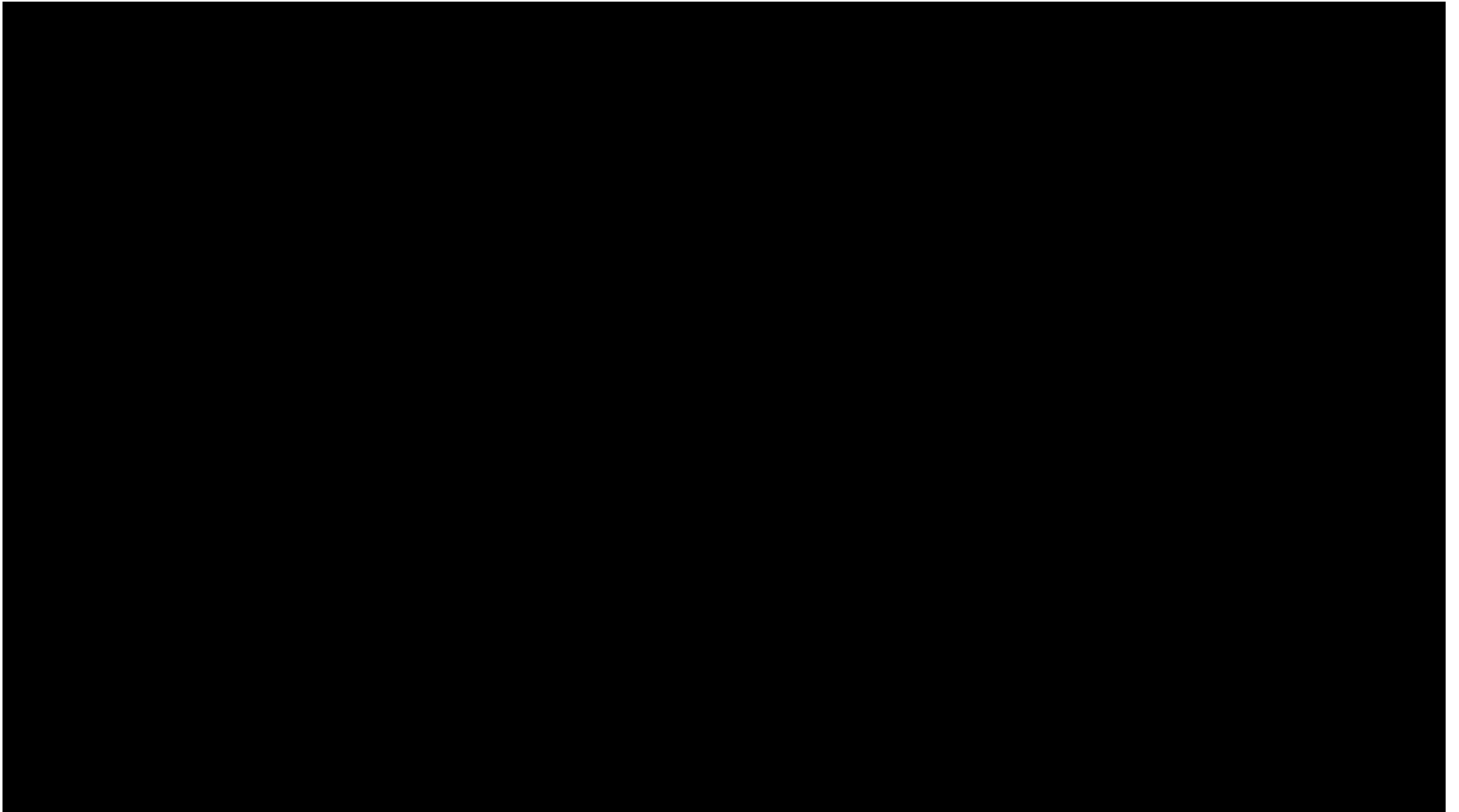
SLAM for AR Applications

AR Application

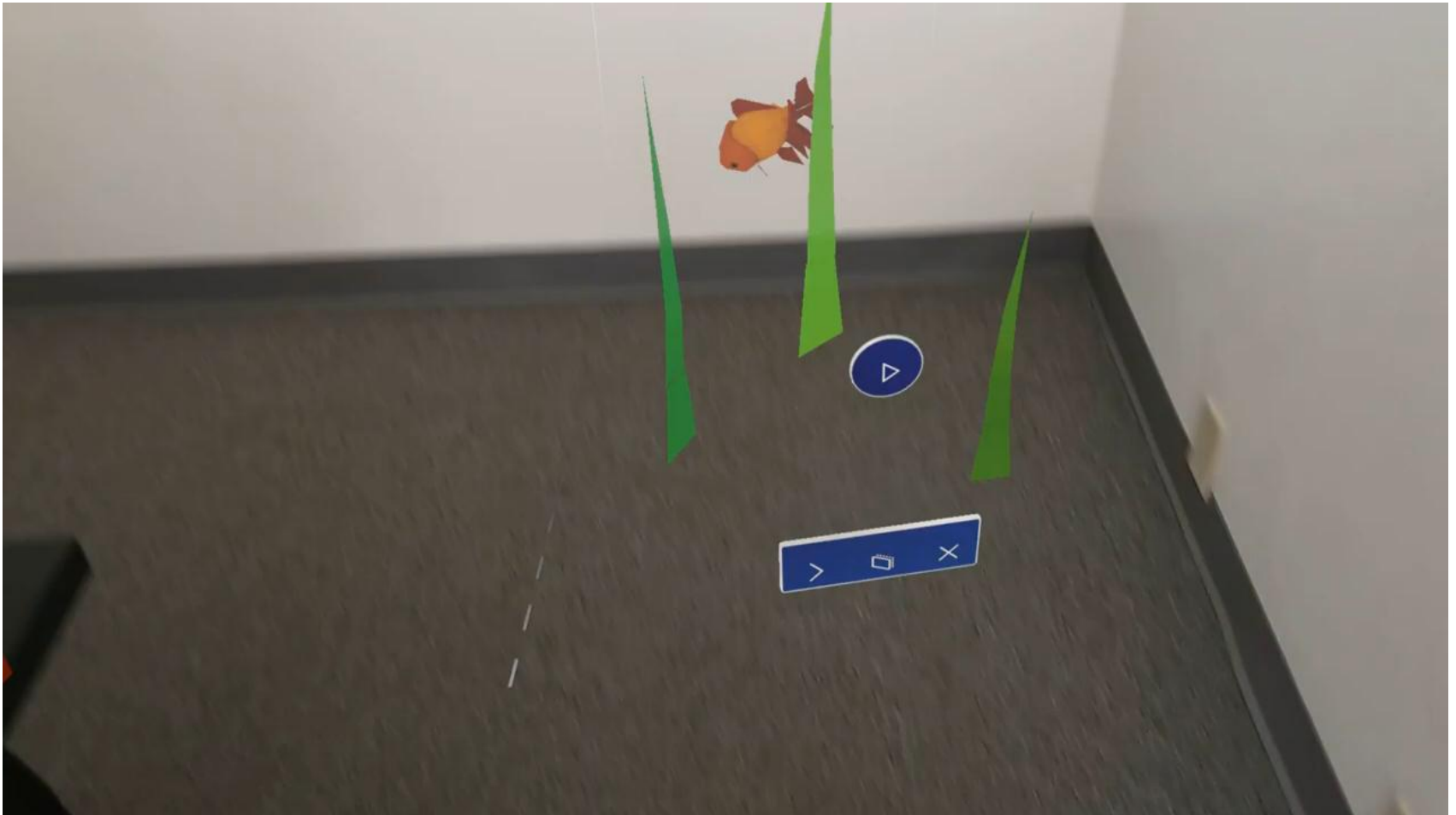




Huawei Cyberverse



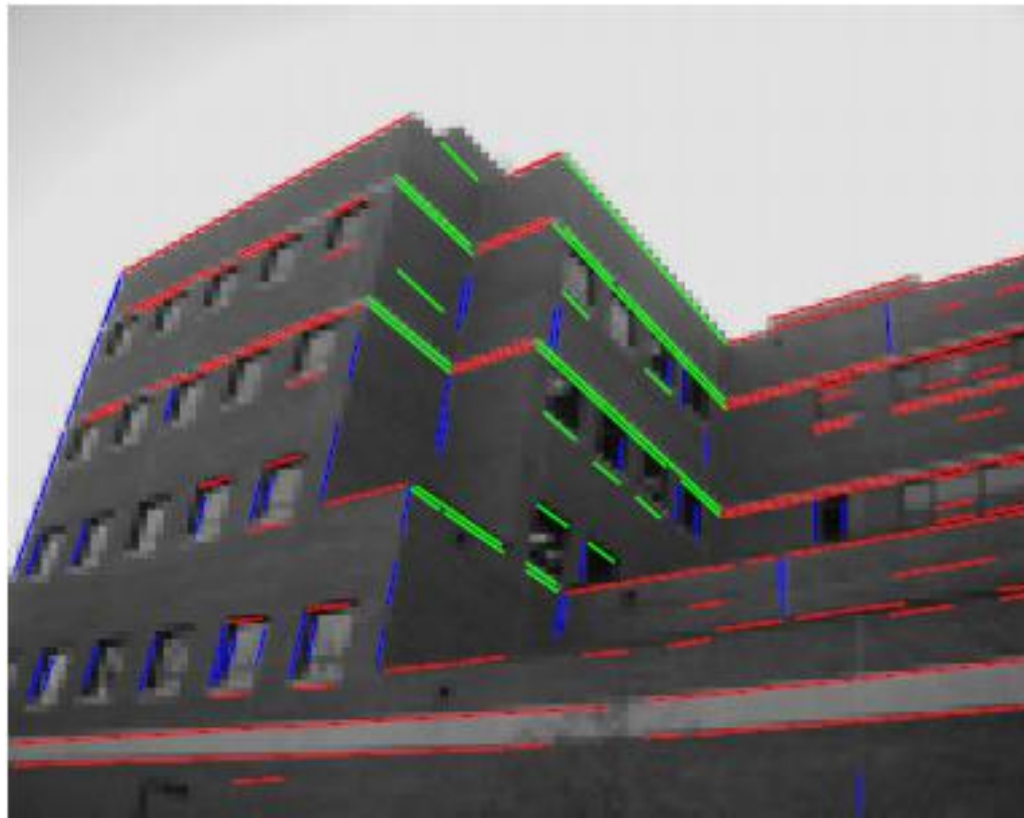
Microsoft HoloLens2



微软HoloLens Mesh



10. Single-View 3D Reconstruction



Automatic Photo Pop-up

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

10. Multi-View 3D Reconstruction



Acute3D
Technology preview
Aerial and street-level imagery fusion

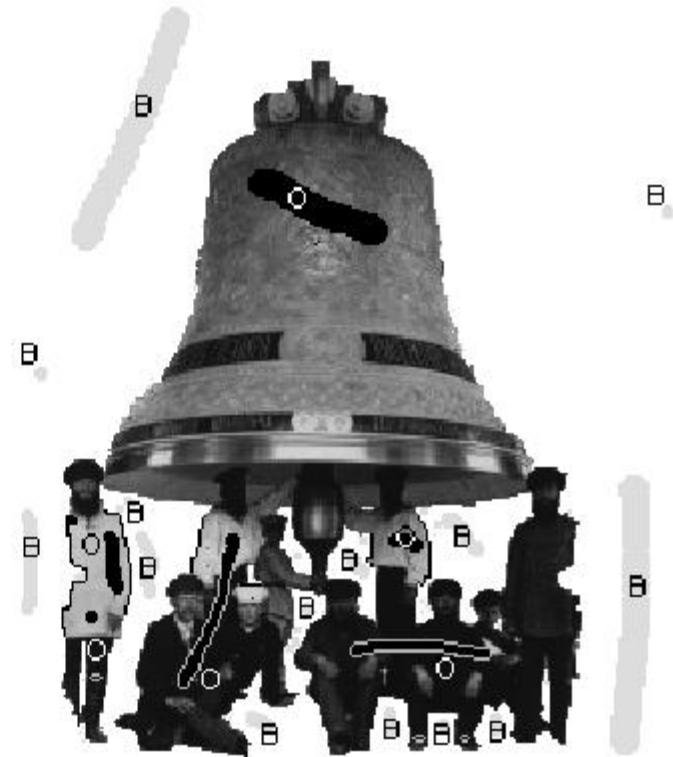


11. Interactive Image Segmentation

- 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

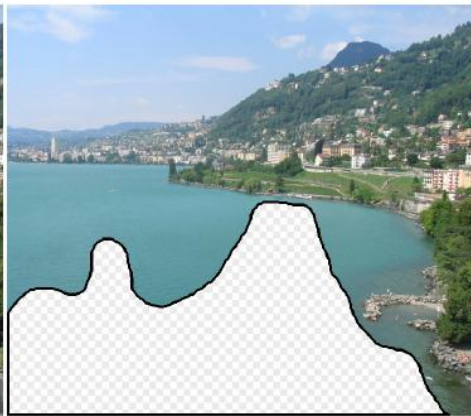


Shai Avidan
Mitsubishi Electric Research Lab
Ariel Shamir
The interdisciplinary Center & MERL

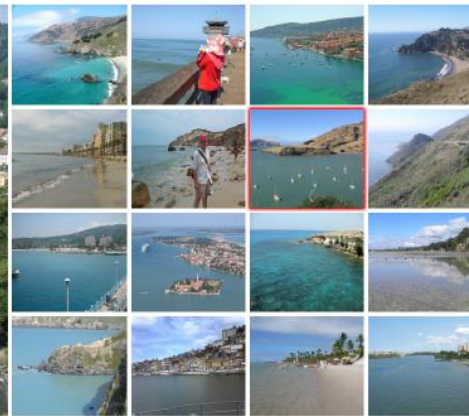
12. Image Completion



Original Image



Input



Scene Matches



Output

12. Image Completion

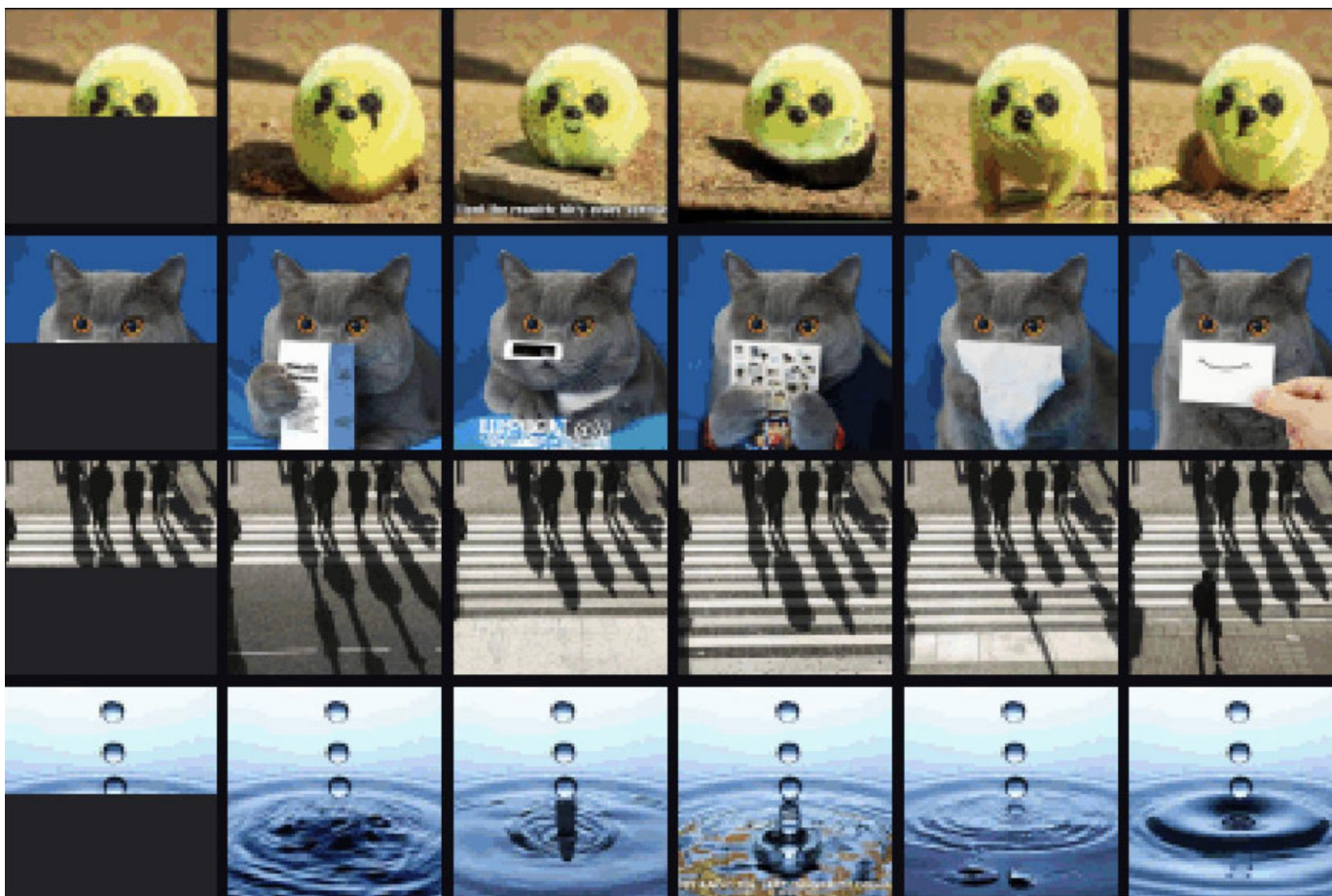


a



b

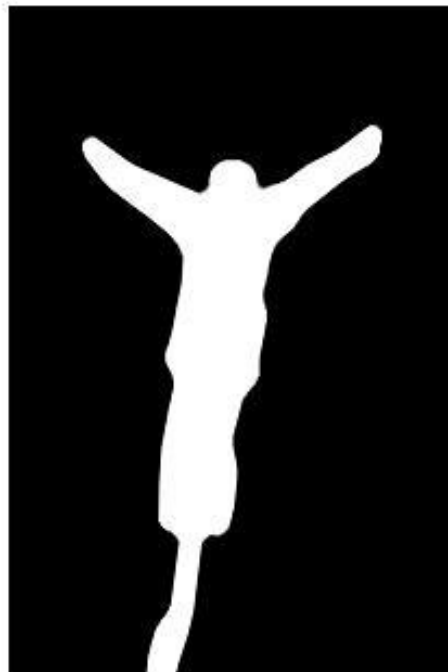
12. Image Completion



12. Image Completion



+



=



Statistics of Patch Offsets for Image Completion

Demo

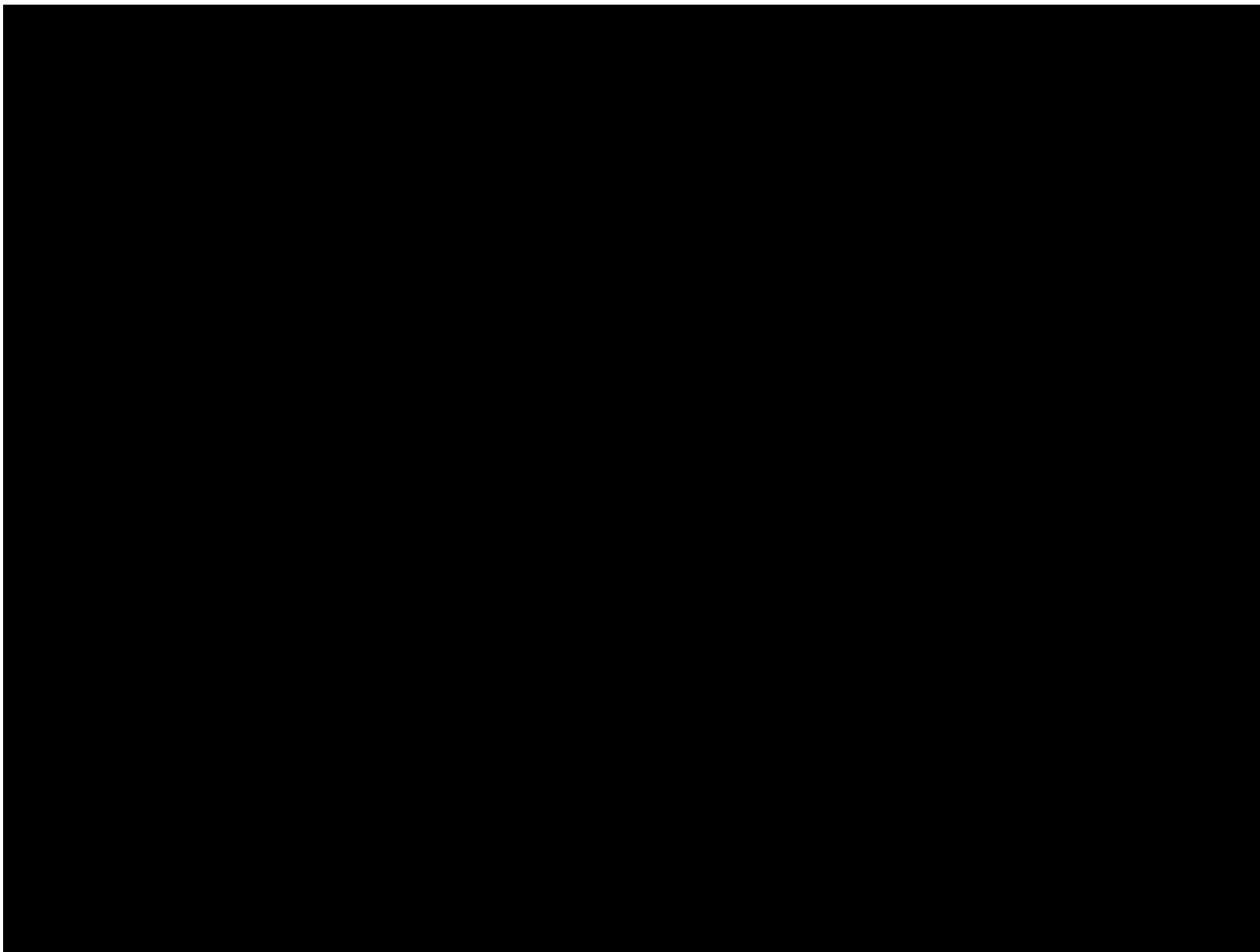
Kaiming He and Jian Sun
Microsoft Research Asia

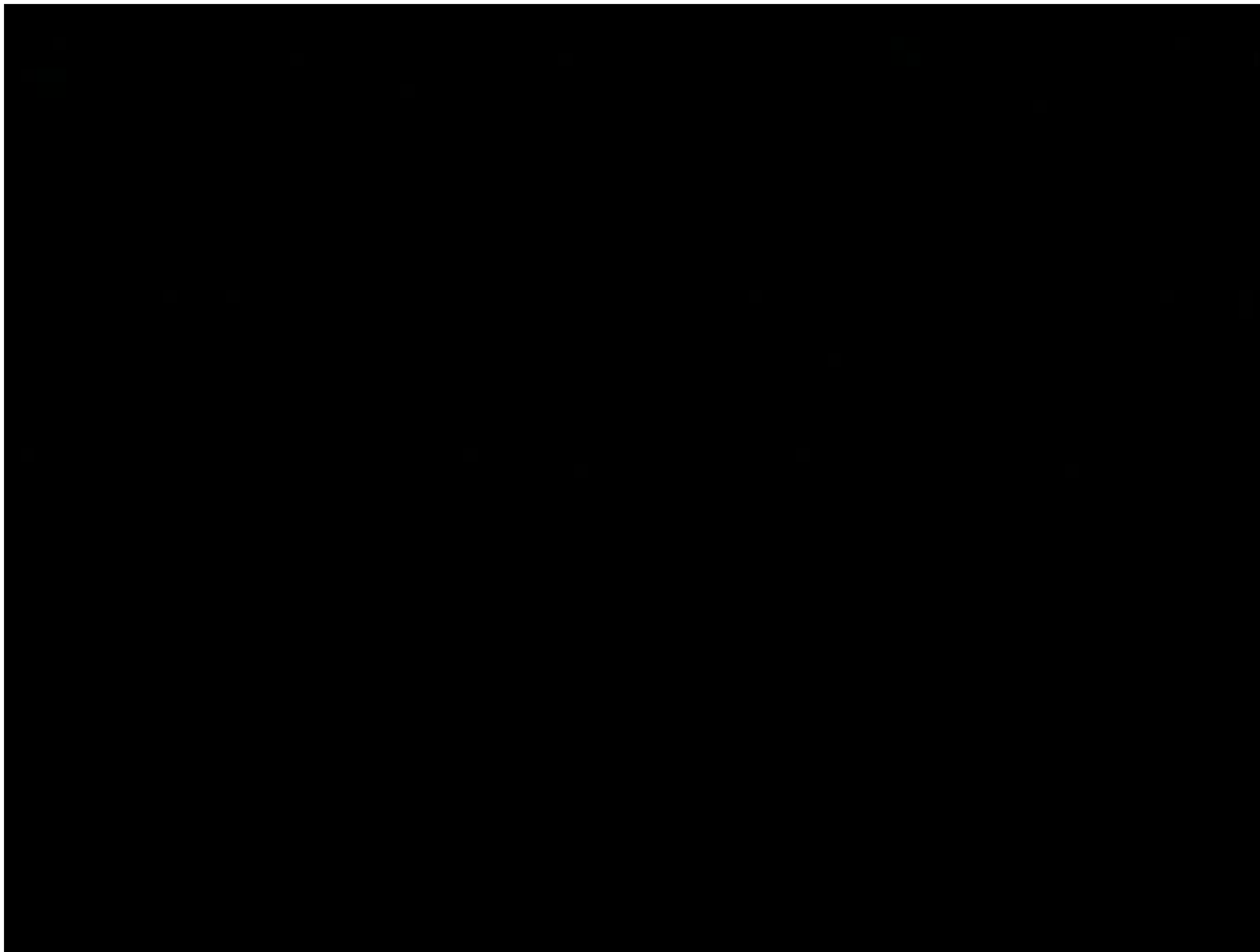
12. Texture Synthesis



input images

quilting results





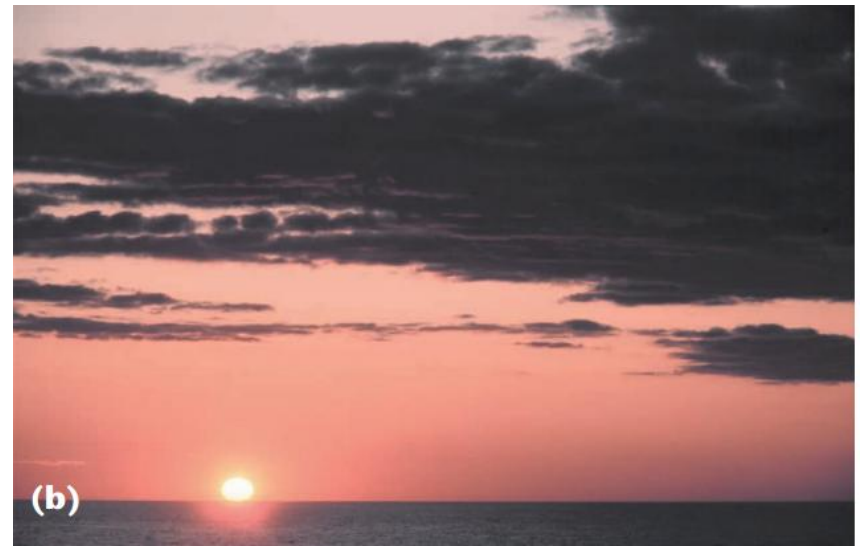
13. Image Colorization & Recolorization



Crater Lake

grayscale input
(83 frames)

13. Image Colorization & Recolorization



14. Image Deblurring

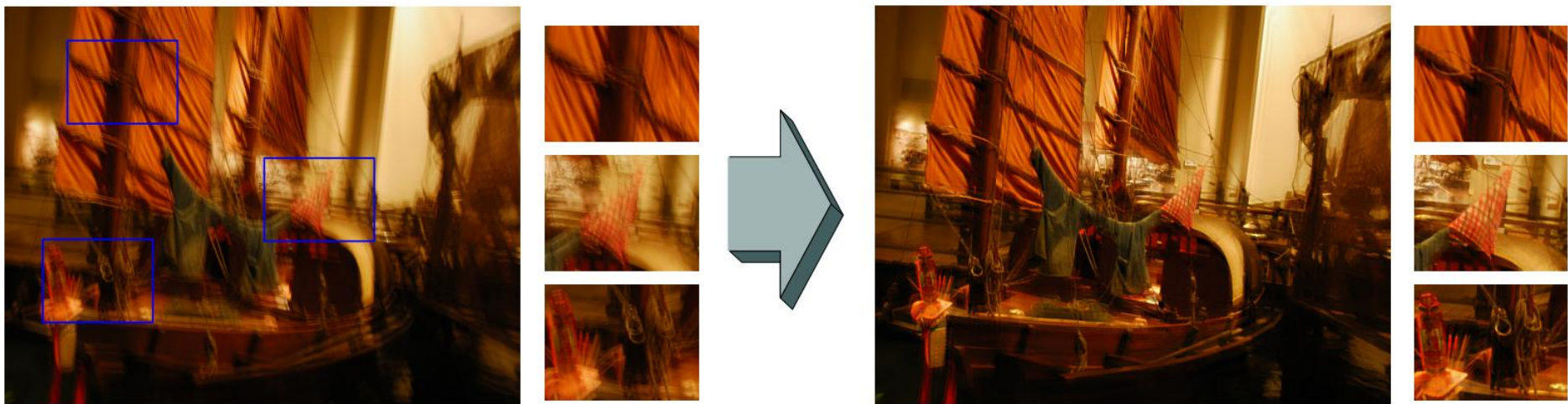


Real Image Input



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）
 - 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：
 - 王鹤（11921089@zju.edu.cn）
 - 陈祥辉（11921090@zju.edu.cn）
 - 彭思达（pengsida@zju.edu.cn）
 - 翟宏佳（zhj1999@zju.edu.cn）
 - 陈硕（chenshuo.eric@zju.edu.cn）
 - 时间地点：
 - 每周三下午9-10节（上机课）曹西503

Questions?