计算摄影学

章国锋、周晓巍

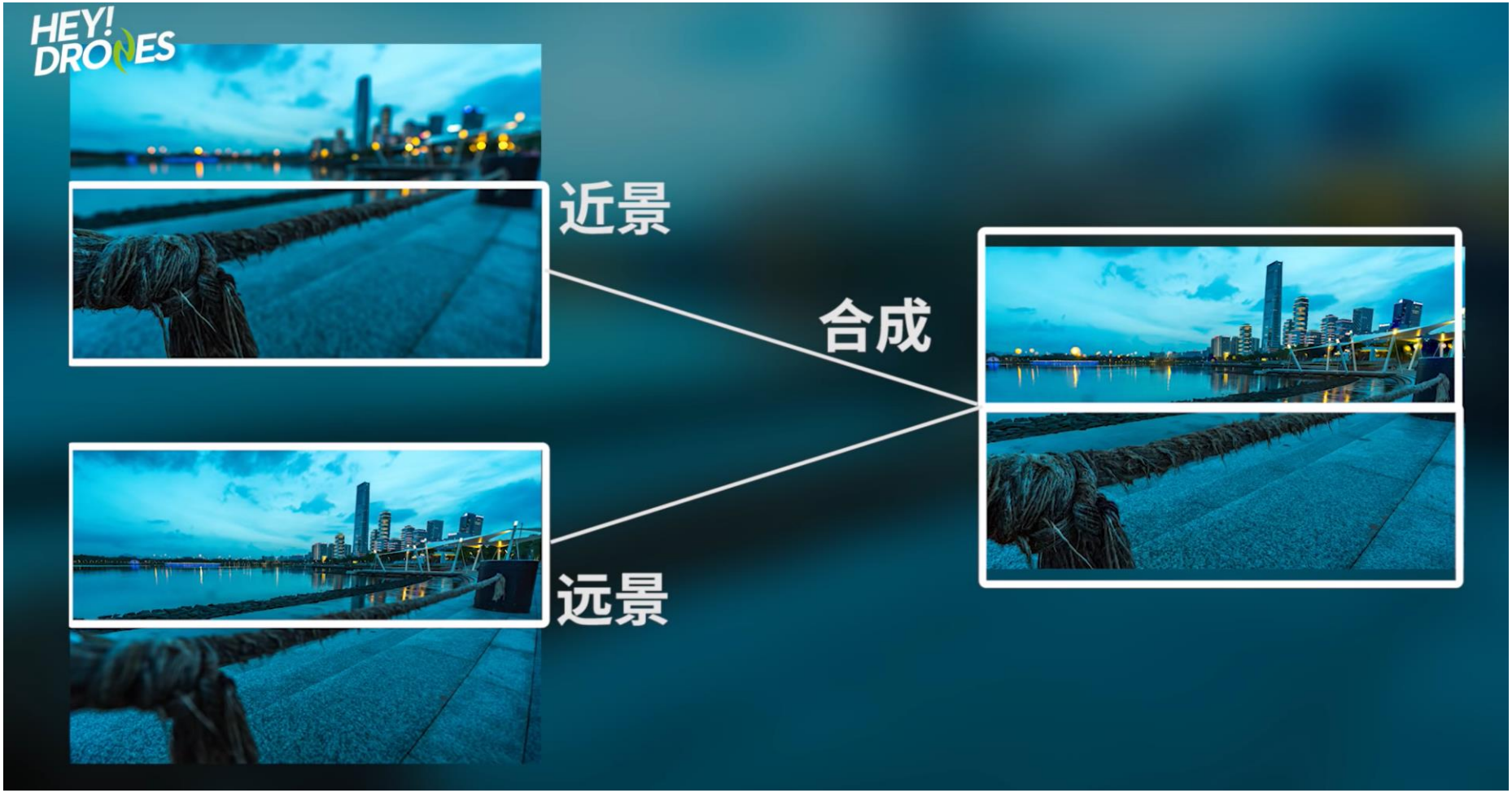
课程简介和目标

- 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

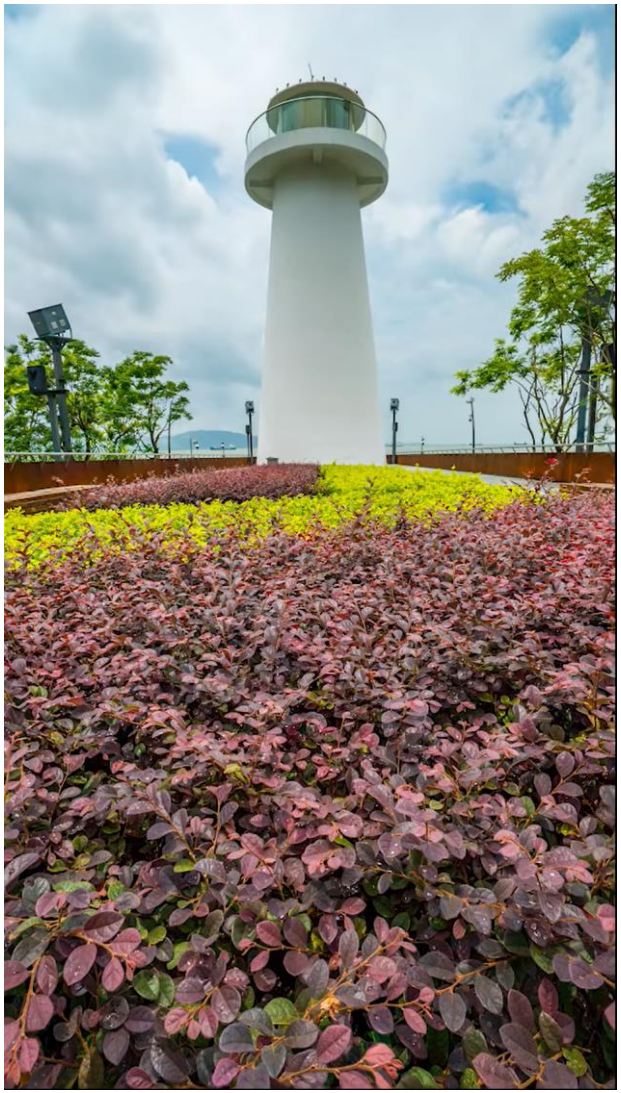
- 如何拍出完美的照片？

景深融合



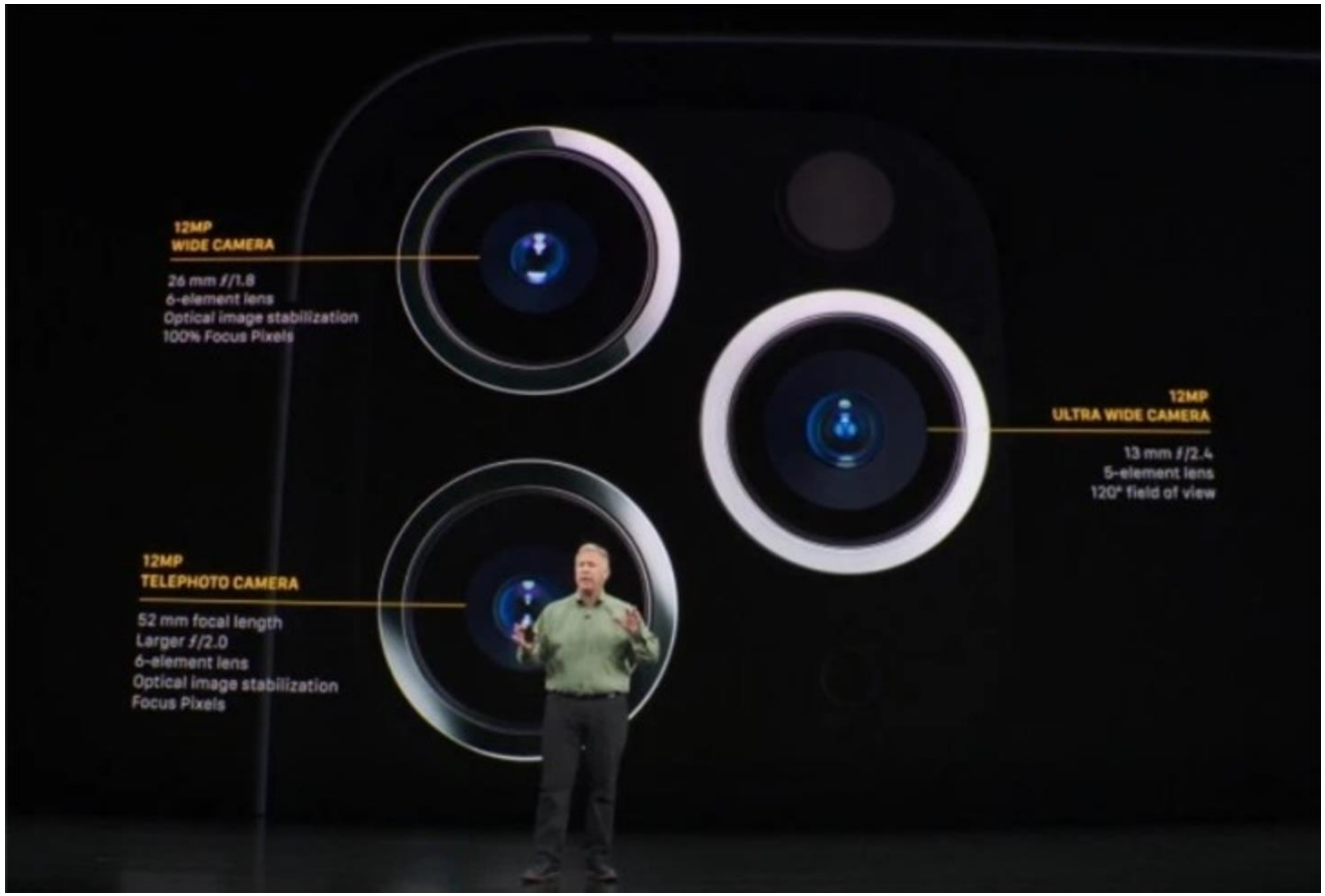
http://dy.163.com/v2/article/detail/DNM3F3U40511AIM3.html

景深融合



http://dy.163.com/v2/article/detail/DNM3F3U40511AIM3.html

多摄像头合成


12MP
WIDE CAMERA
26 mm ƒ/1.8
6-element lens
Optical image stabilization
100% Focus Pixels
12MP
ULTRA WIDE CAMERA
13 mm ƒ/2.4
5-element lens
120° field of view
12MP
TELEPHOTO CAMERA
52 mm focal length
Larger ƒ/2.0
6-element lens
Optical image stabilization
Focus Pixels

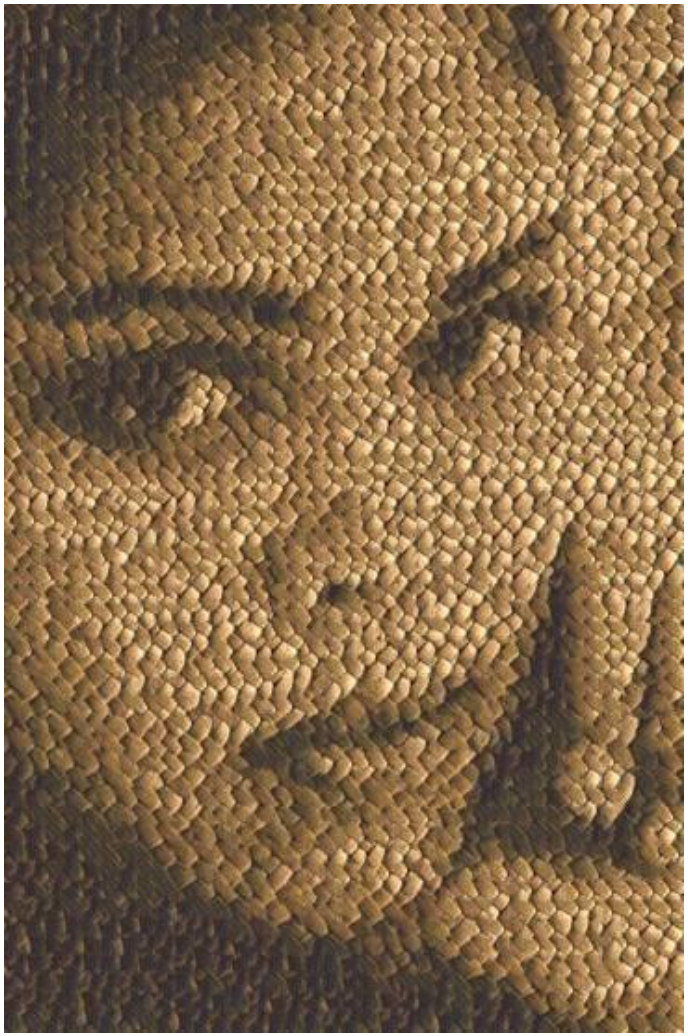
多摄像头合成

Deep Fusion

https://baijiahao.baidu.com/s?id=1646548291761638348&wfr=spider&for=pc

Deep Fusion

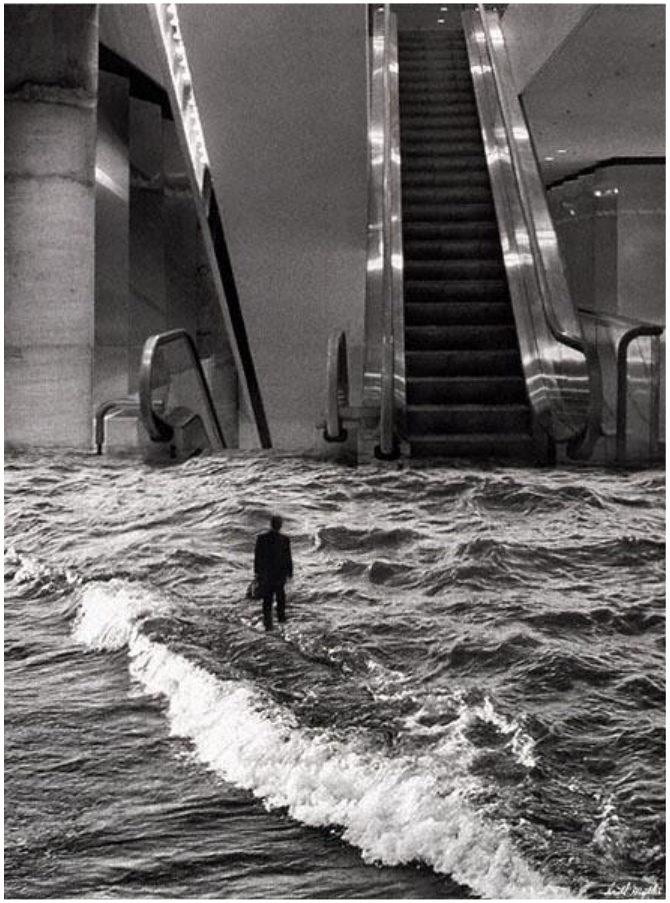
Creating Stylized Images



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

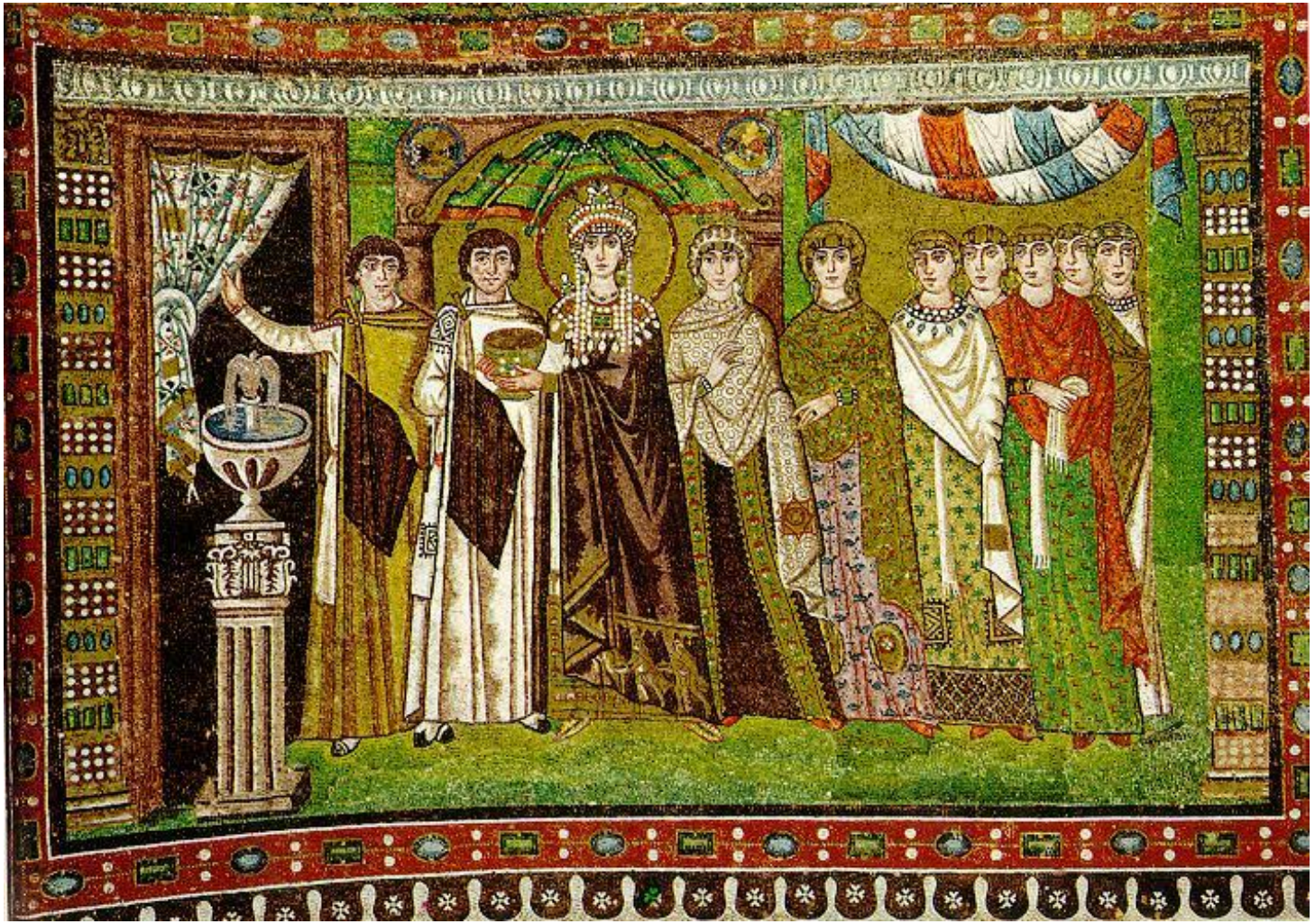
- 摄影历史
- 什么是计算摄影学？
- 课程目标
- 课程大纲
- 作业和大程

可视媒体历史简要回顾

Depicting Our World: The Beginning

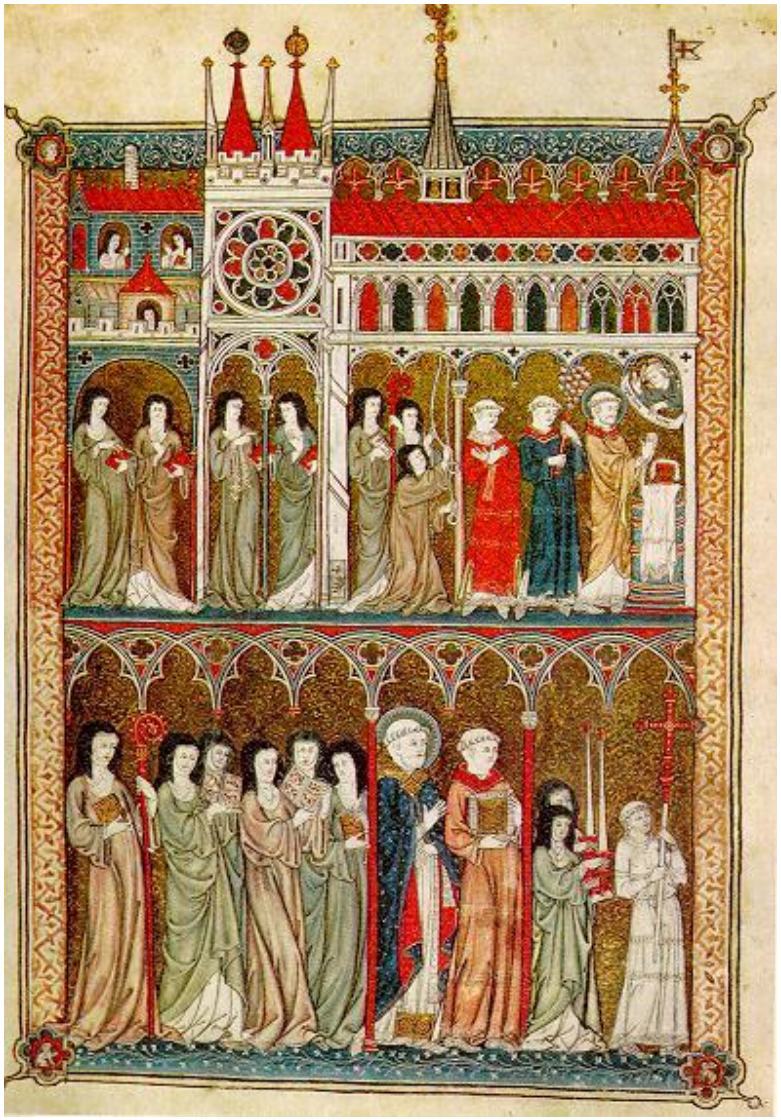
Prehistoric Painting, Lascaux Cave, France
~ 13,000 -- 15,000 B.C.

Depicting Our World: Middle Ages



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

Depicting Our World: Middle Ages



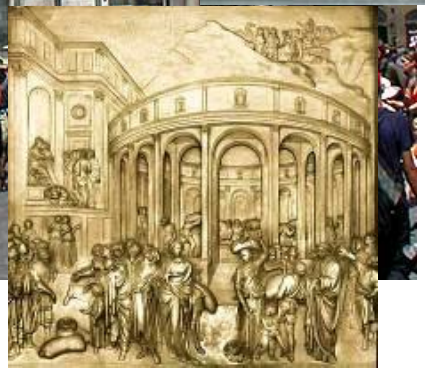
Nuns in Procession. French ms. ca. 1300.

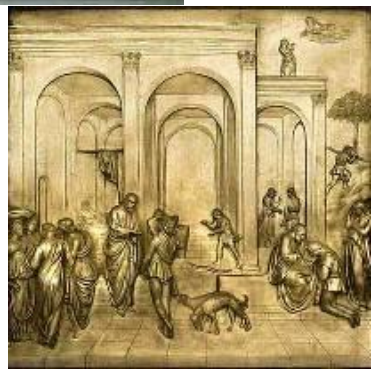
Depicting Our World: Renaissance

North Doors (1424)

Lorenzo Ghiberti (1378-1455)

East Doors (1452)

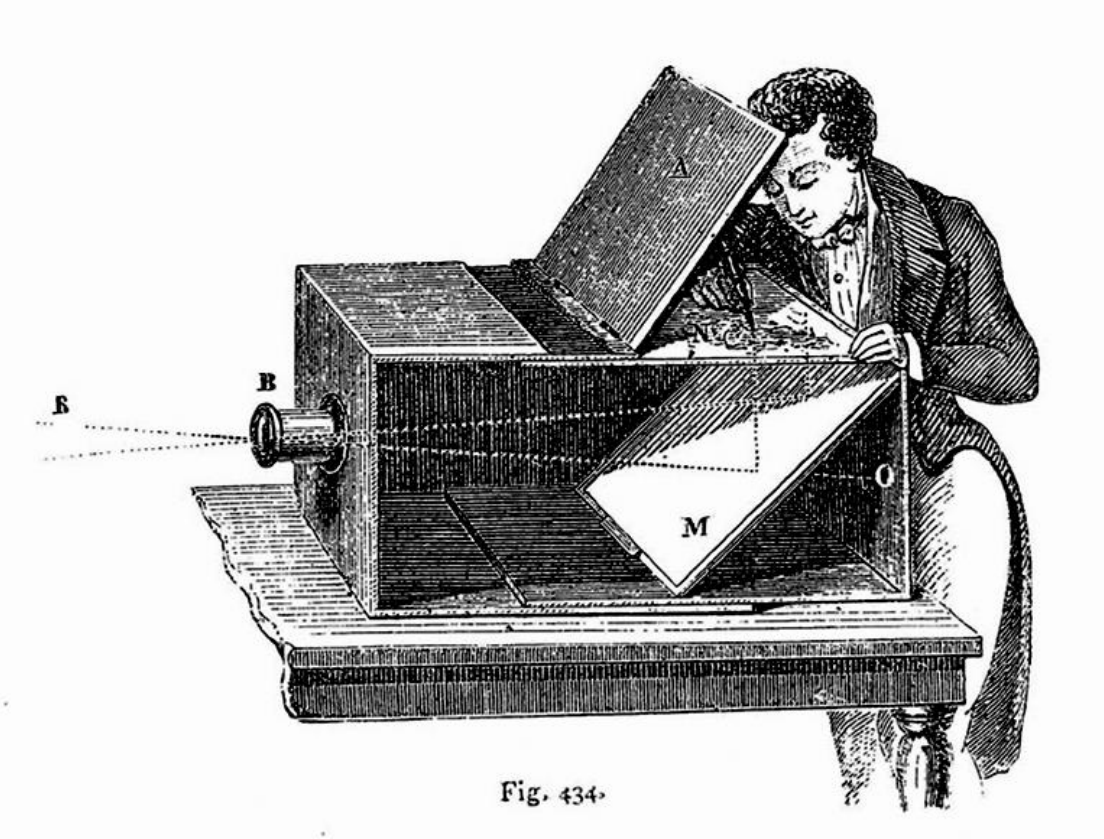




Depicting Our World: Renaissance

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

Depicting Our World: Toward Perfection

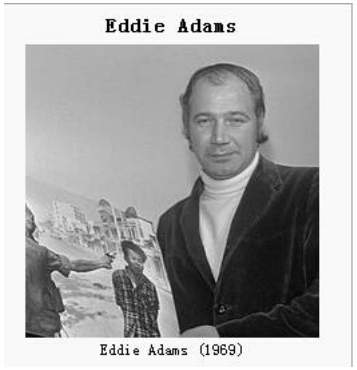


Lens Based Camera Obscura, 1568

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

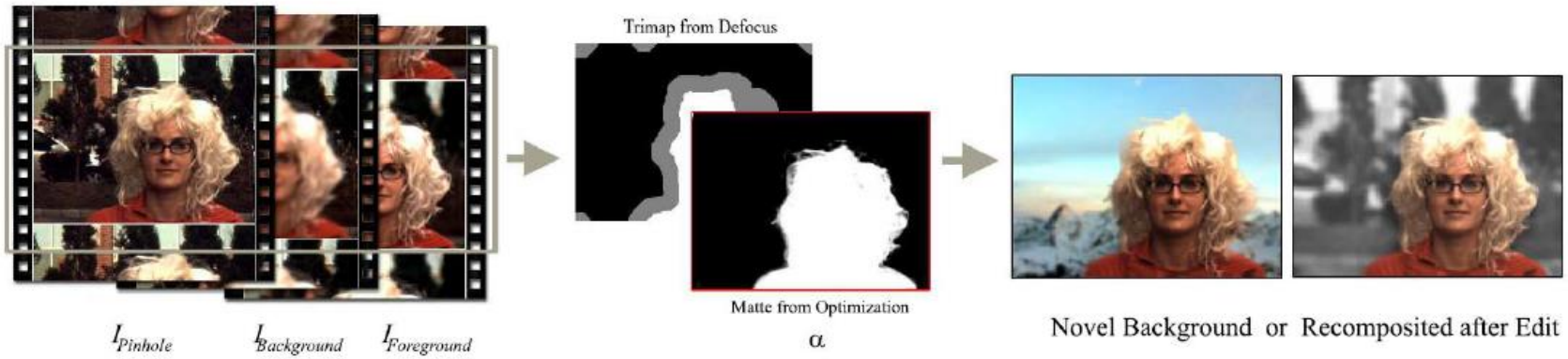
- **Tone mapping**
- **Defocus Matting**
- **Multi-Modal Imaging**

Tone mapping

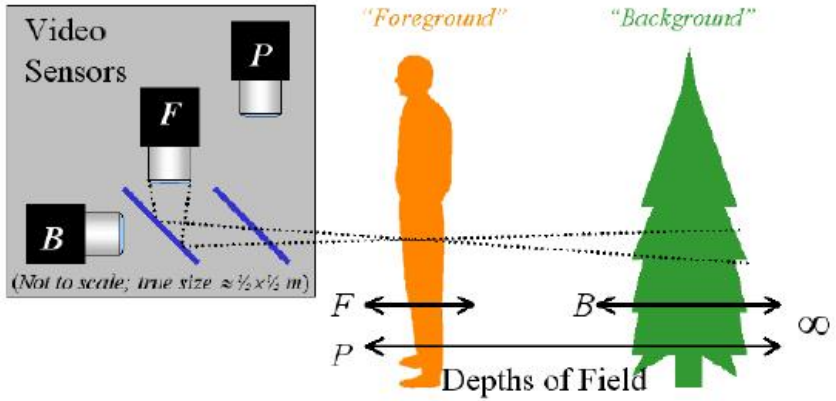
Suitable for HDR images

Defocus Matting

- **What can be achieved**



- **Design: use 3 streams with different focus**

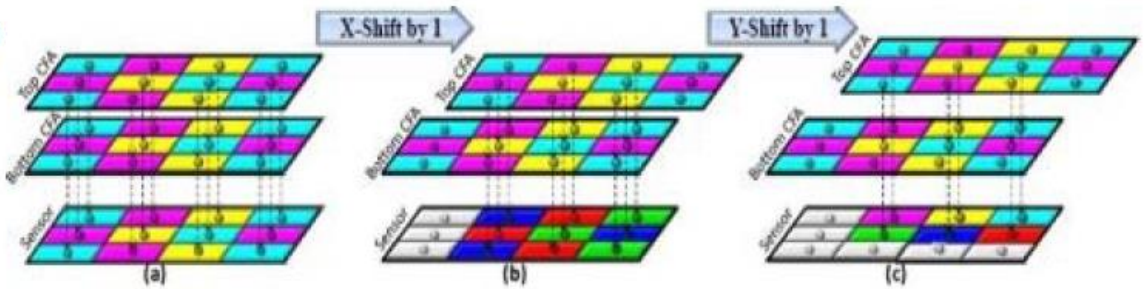


http://people.csail.mit.edu/wojciech/DefocusVideo/index.html

Multi-Modal Cameras

- **What can be achieved**

- **How it works?**



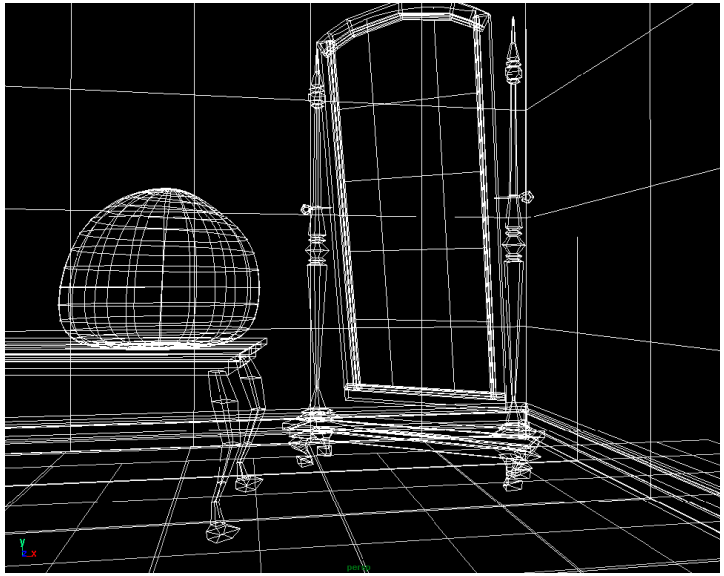
http://www.ics.uci.edu/~bsajadi/SwitchableCam.html

什么是计算摄影学?
——从软件的视角

从软件的视角看

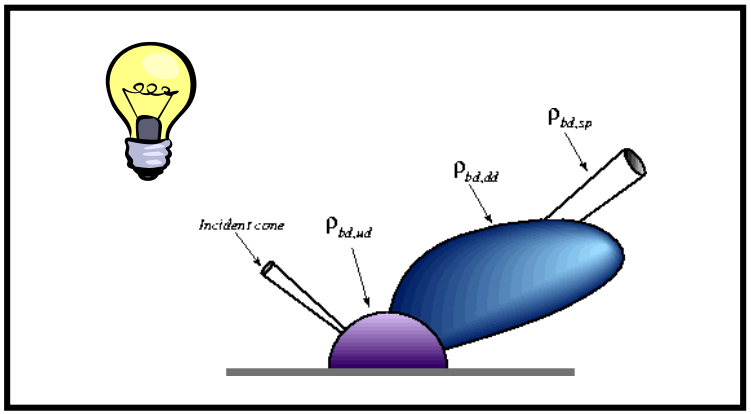
- 定义一：使用摄影图像来生成图形内容。

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 l LA

Slide credit: A. Efros

4. Nature

River Cherwell, Oxford

Slide credit: A. Efros

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

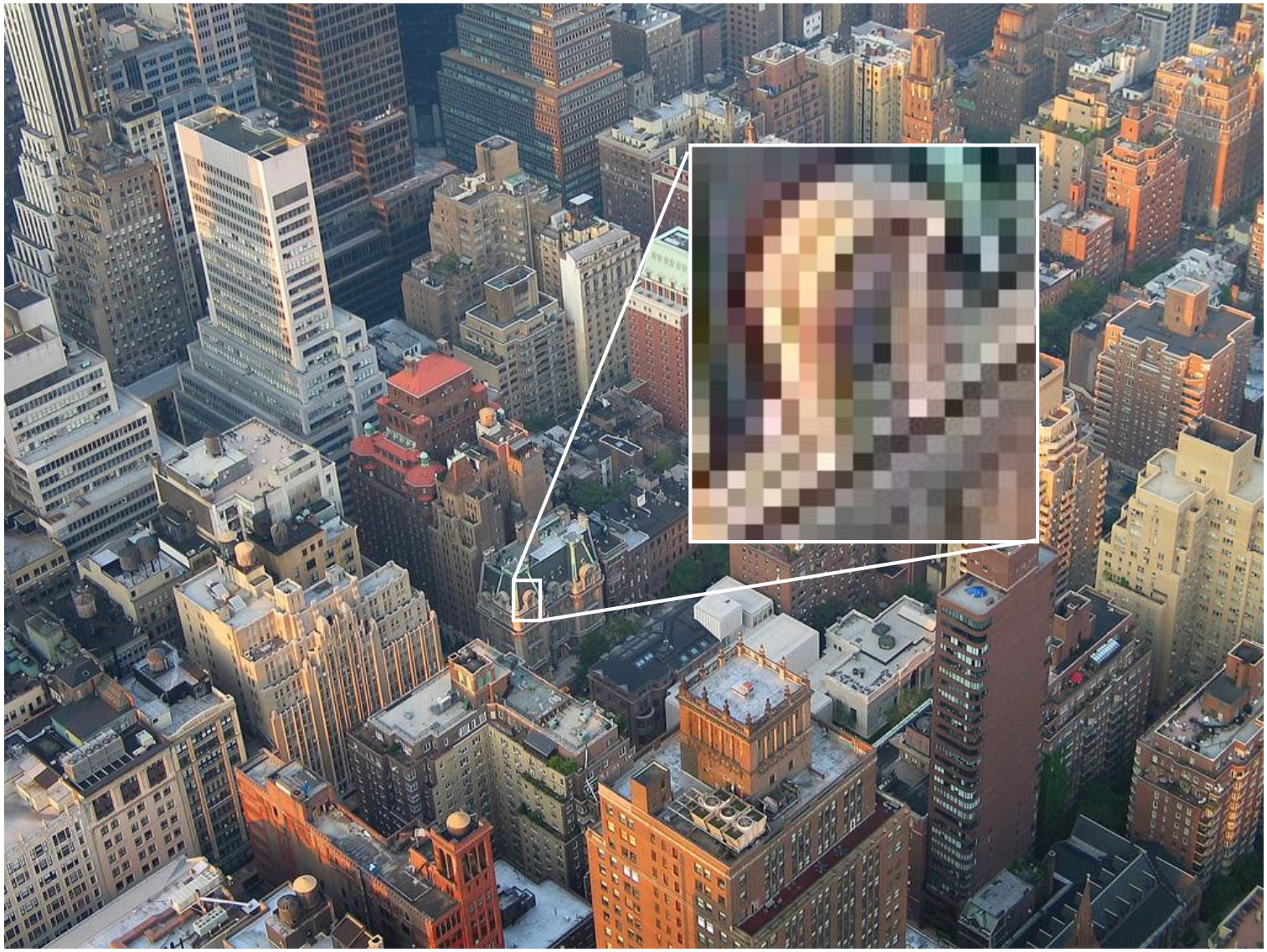
- 定义一：使用摄影图像来生成图形内容。
- 定义二: 使用计算技术来克服传统摄影的局限性。

Limitations of traditional photography

- Blur, camera shake, noise, damage

Limitations of traditional photography

- Limited resolution

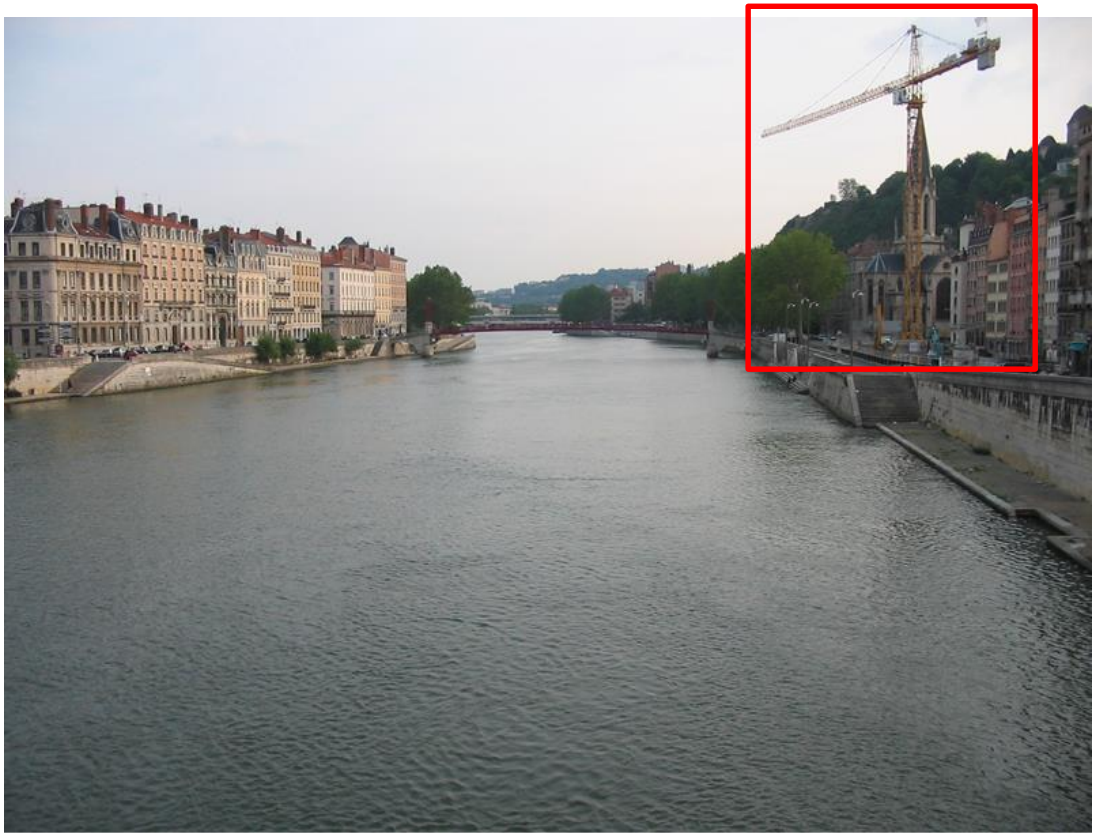


Limitations of traditional photography

- 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

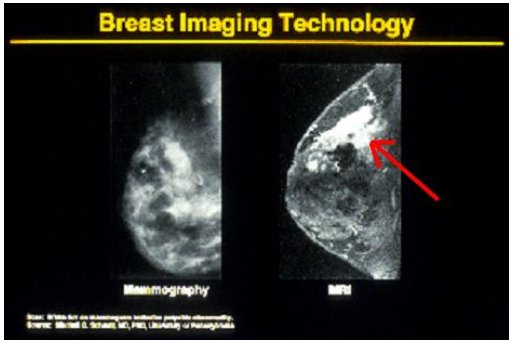
1. You will have new abilities for visual creation.

Graphic by James Hays

Course objectives

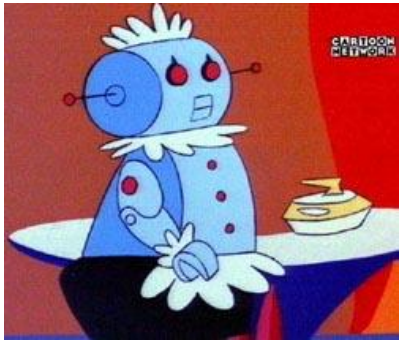
2. You will get a foundation in computer vision.

Safety



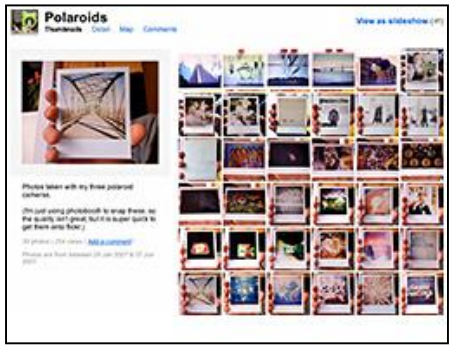
Health

Security



Comfort

Fun



Access

Course objectives

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

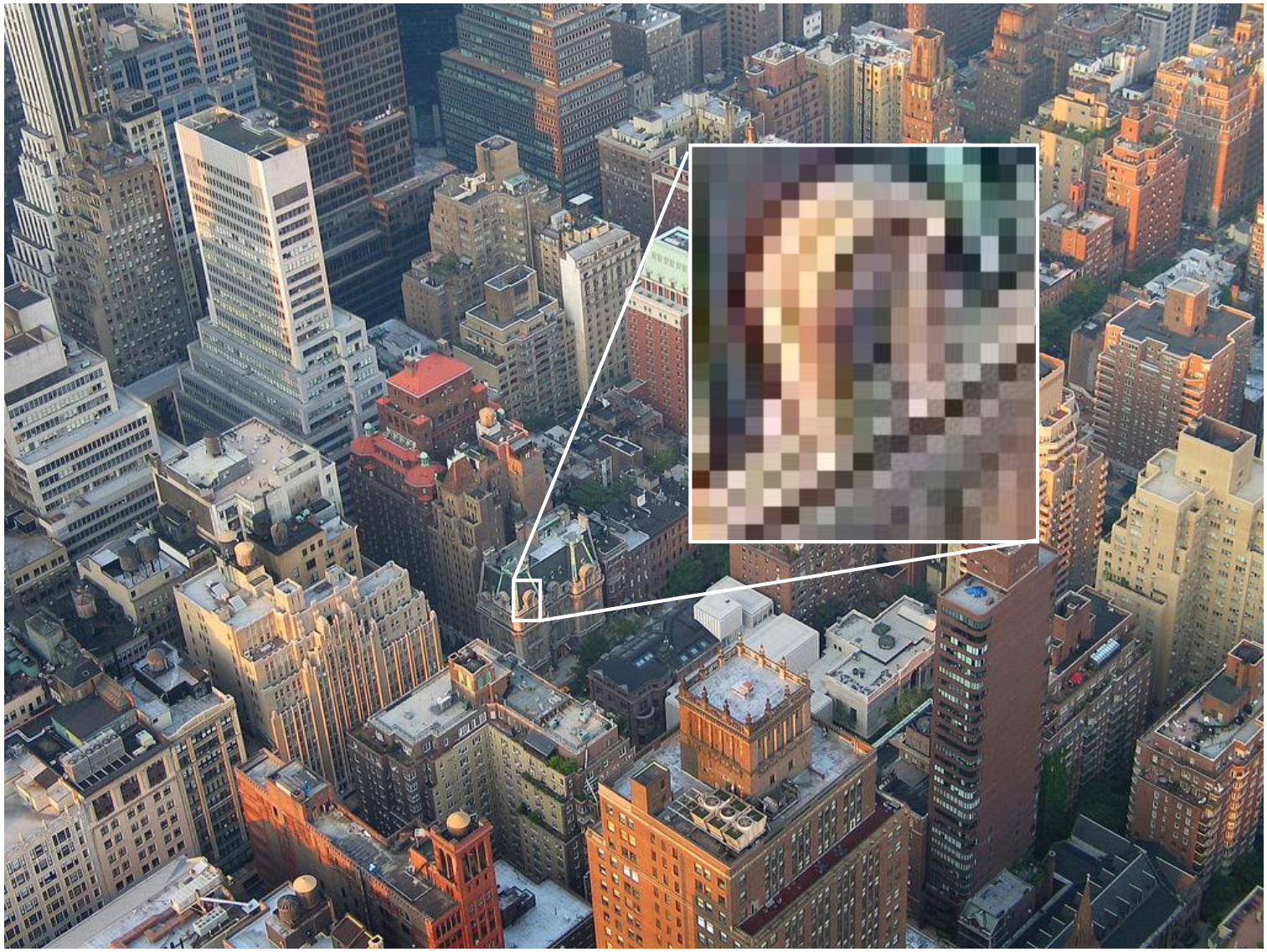
Course objectives

4. You'll have fun doing cool stuff!

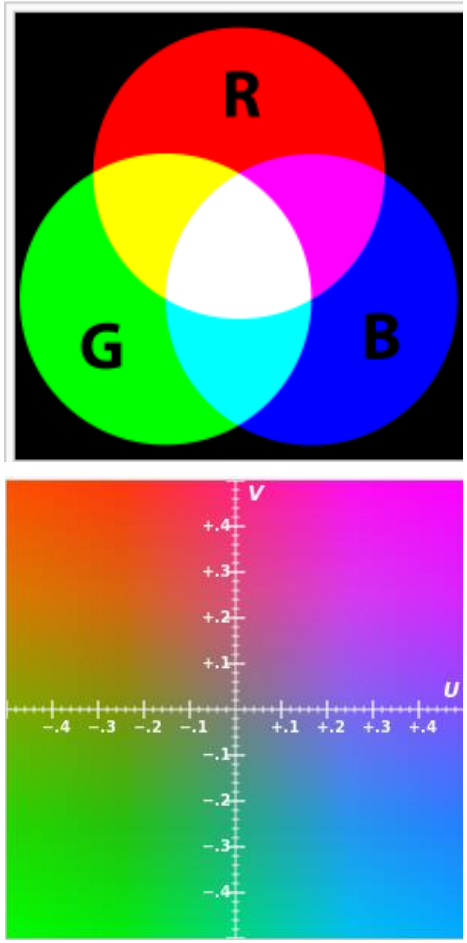
Courses Overview

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. 交互式图像分割与抠像
5. 图像补全、纹理合成与图像缩放
6. 图像去模糊与非线性数值优化方法
7. 非线性数值优化
8. 深度学习
9. 特征匹配与光流
10. 相机模型与运动恢复结构
11. 实时摄像机跟踪
12. 单视图与多视图三维重建
13. 全景图拼接
14. 上色与重上色
15. 课程讨论与项目答辩

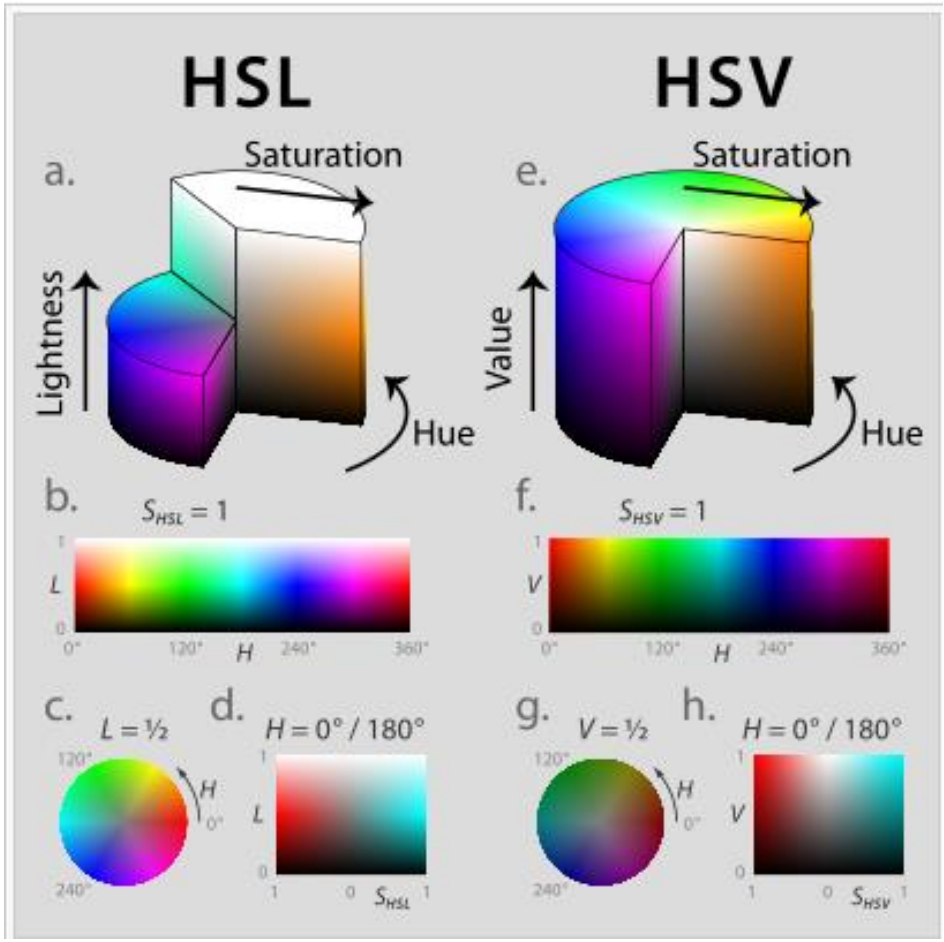
2. Digital Image



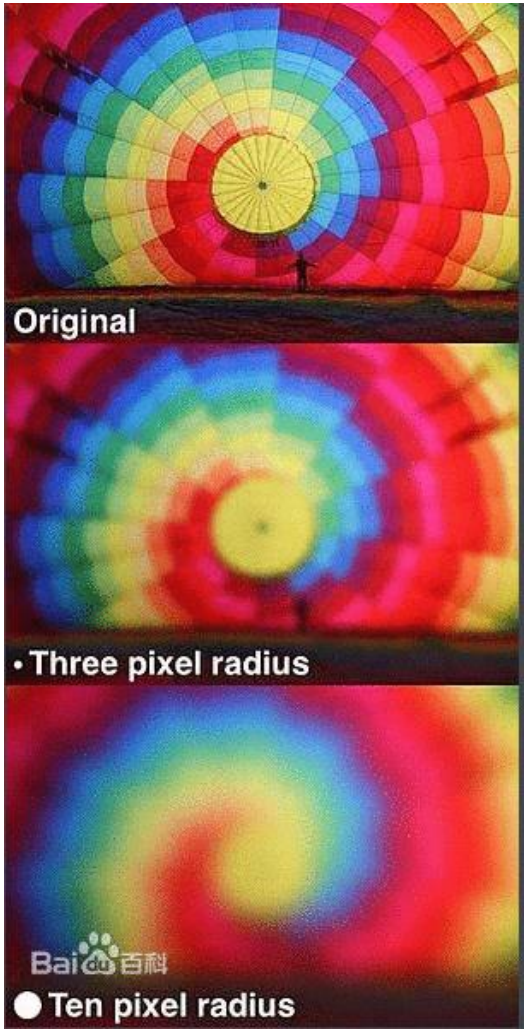
2. Color Space



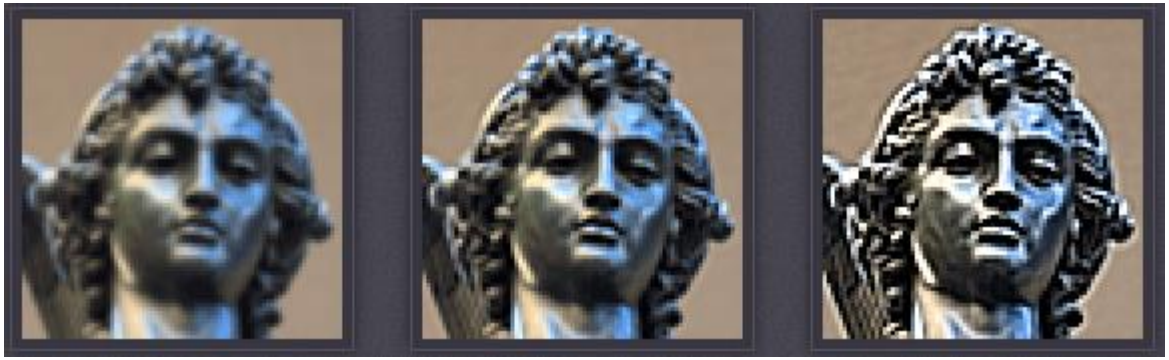
YUV



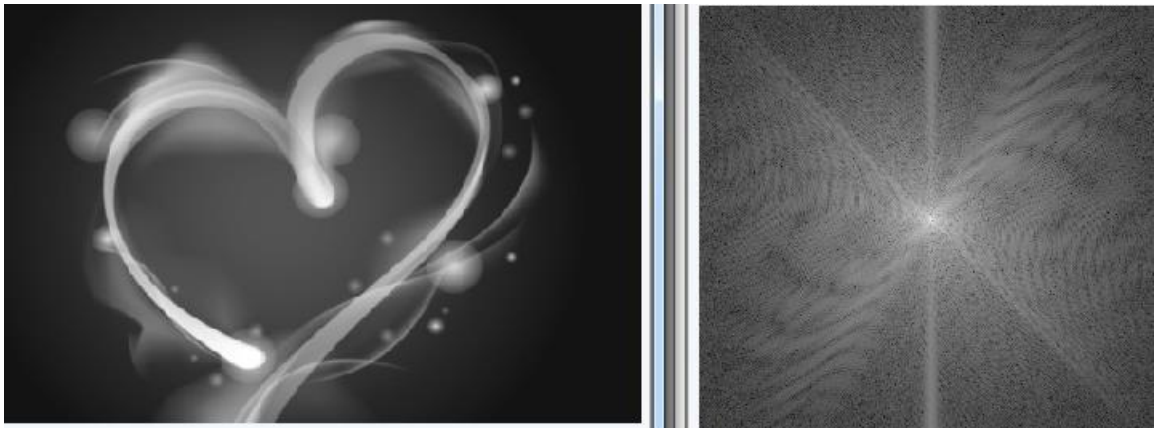
2. Filtering and Fourier Transform



Blur

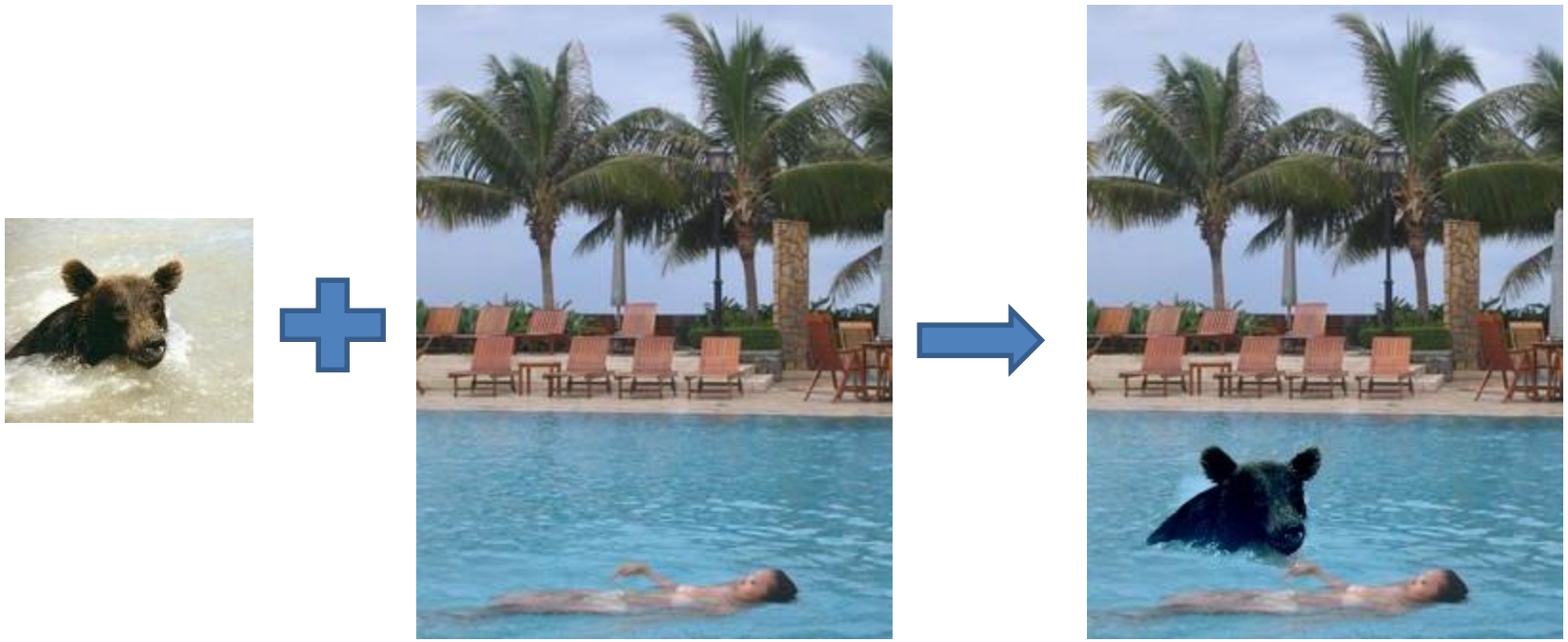


Sharpening



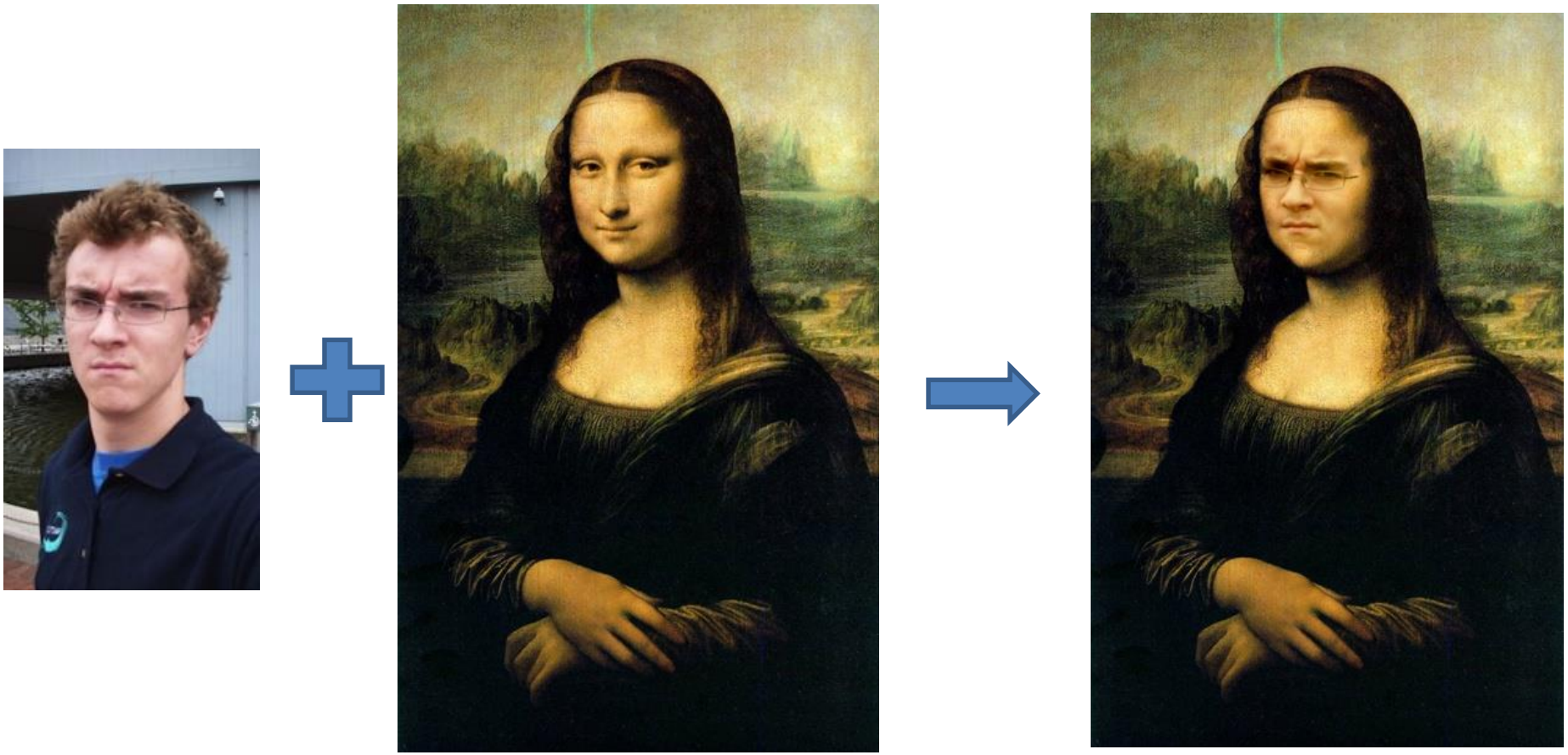
Fourier Transformation

3. Poisson Image Editing



Photos from James Hays

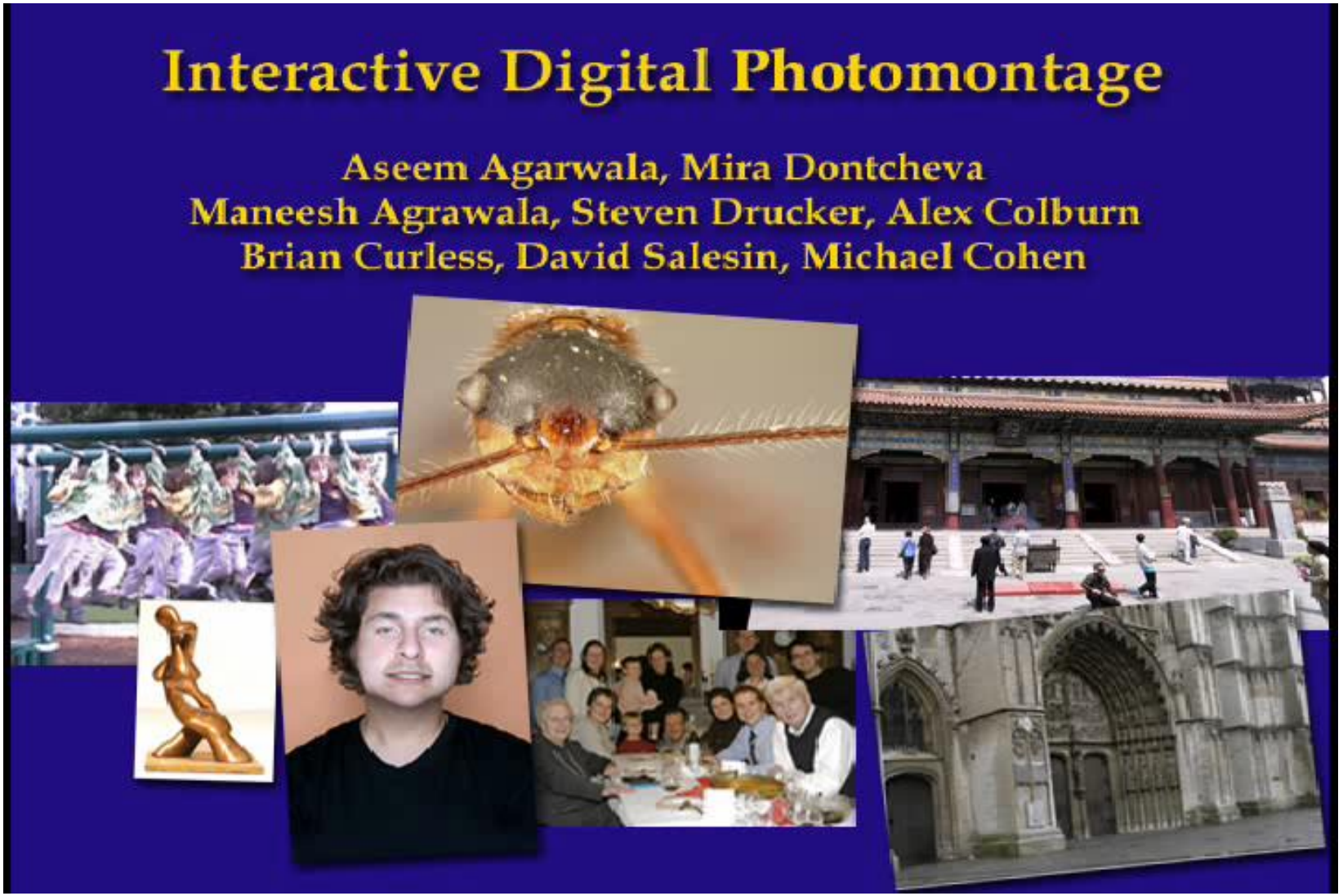
3. Poisson Image Editing



Photos from Evan Wallace

3. Interactive Photomontage

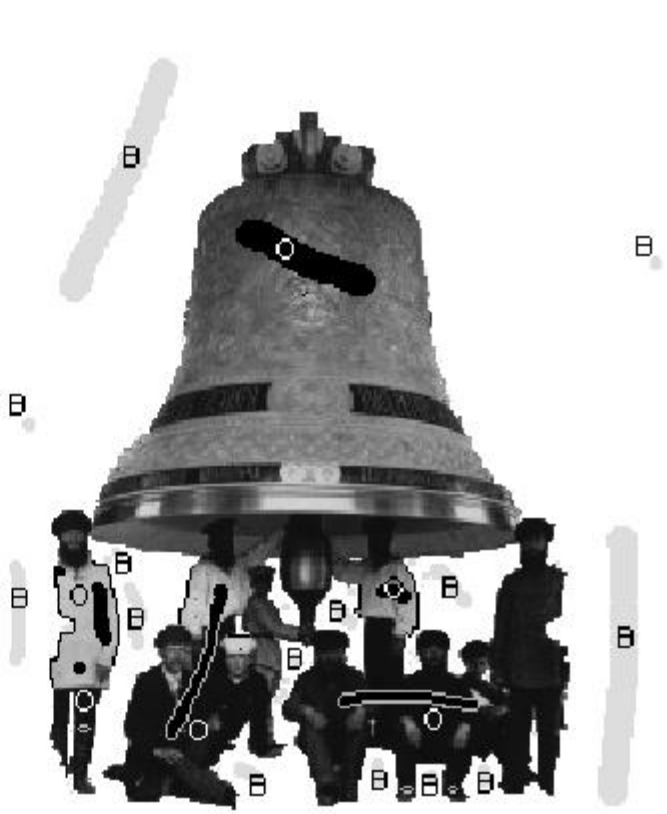
3. Interactive Photomontage



4. Interactive Image Segmentation

- Graph Cut

(a) Original B&W photo



(b) Segmentation results

4. Interactive Image Segmentation

- Grab Cut

GrabCut

Interactive Foreground Extraction using Iterated Graph Cuts

Carsten Rother
Vladimir Kolmogorov
Andrew Blake

Microsoft Research Cambridge

5. Image Completion

Original Image | Input | Scene Matches | Output

5. Image Completion

a

b

Statistics of Patch Offsets for Image Completion

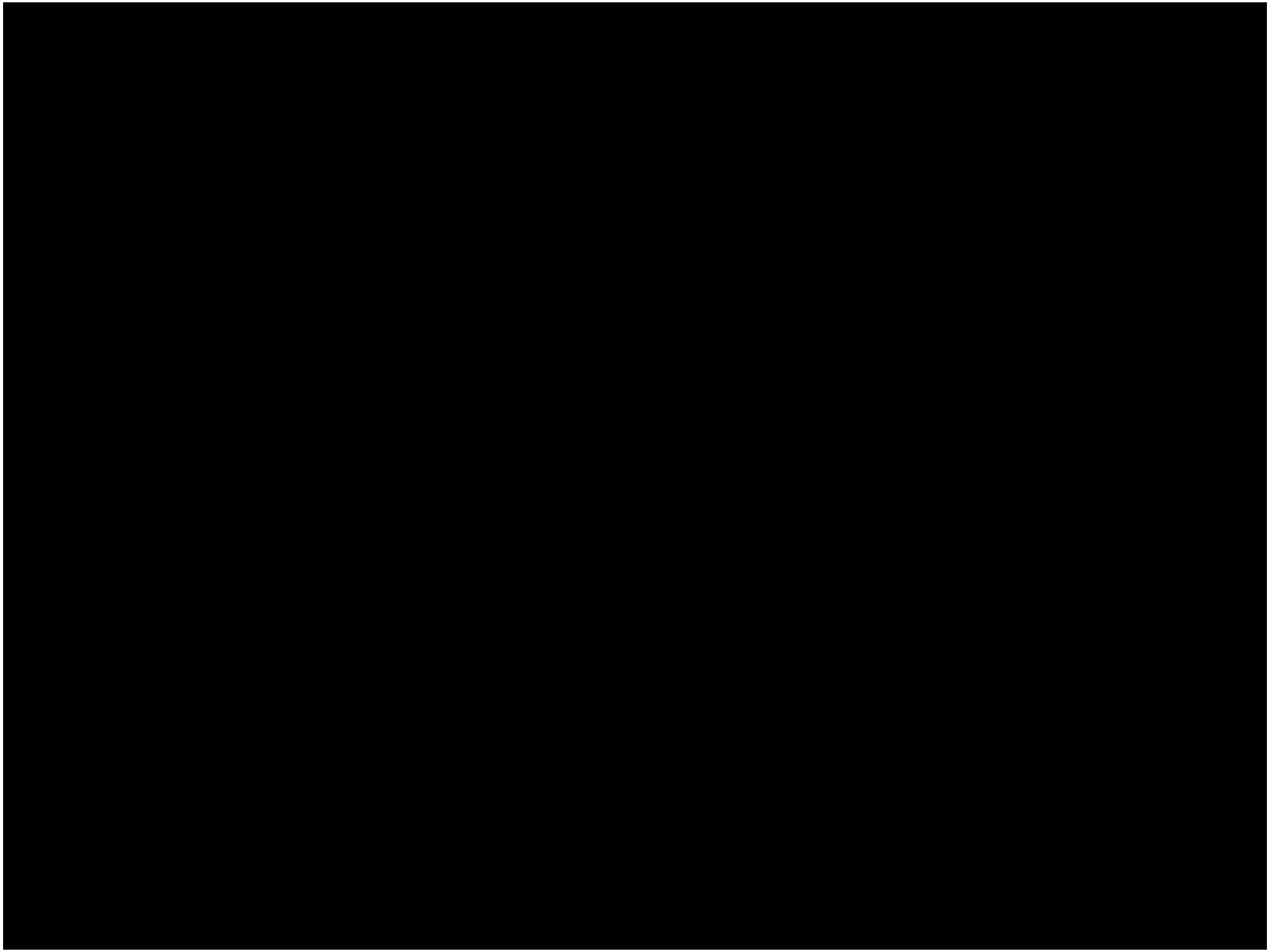
Demo

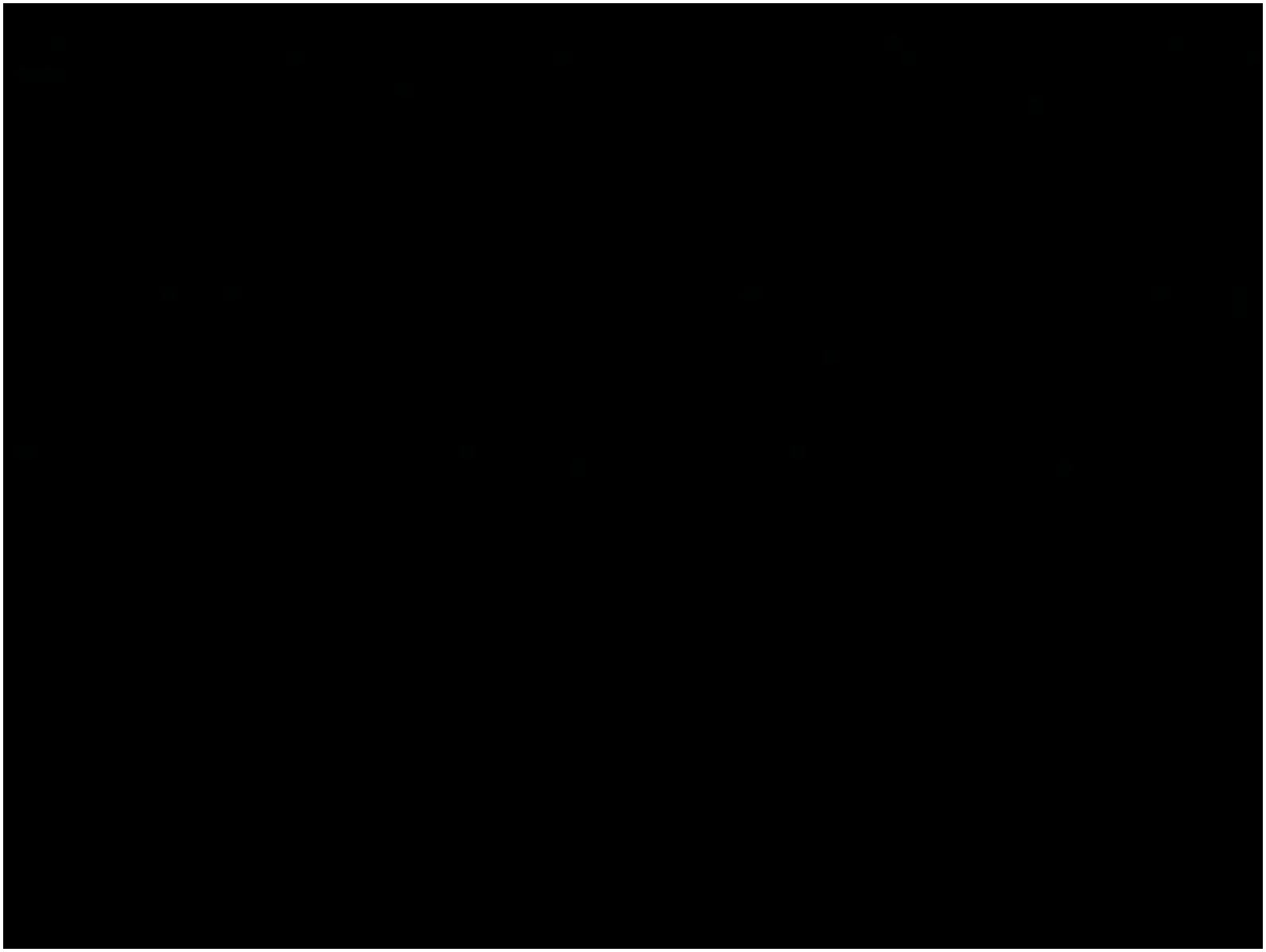
Kaiming He and Jian Sun
Microsoft Research Asia

5. Texture Synthesis

input images

quilting results





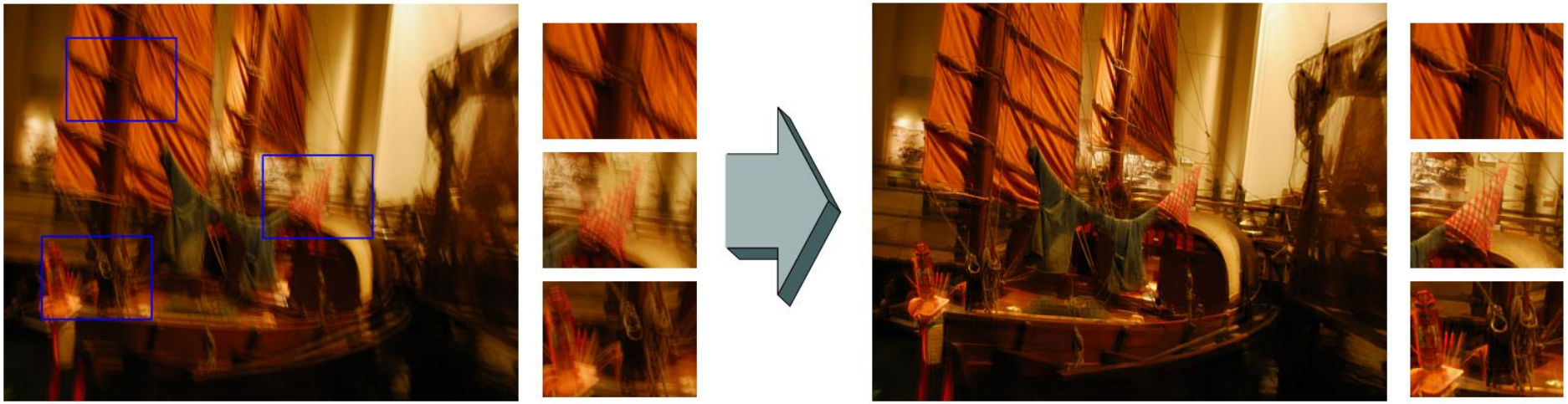
5. Image Resizing

6. Image Deblurring

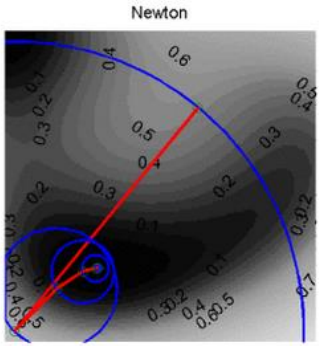
Real Image Input

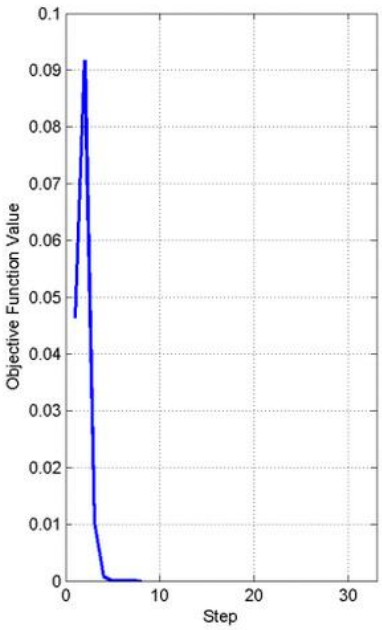
Deblurring Result

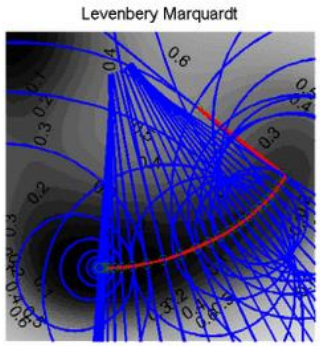
6. Image Deblurring

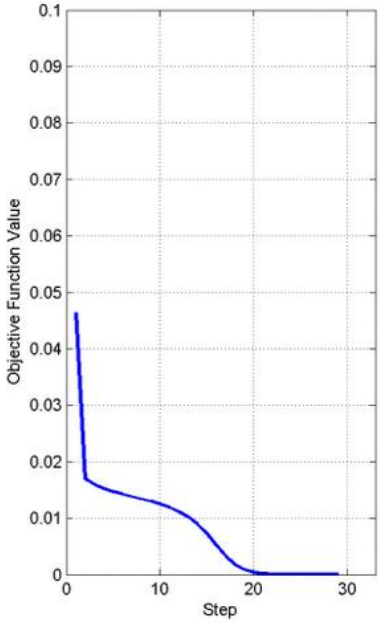


7. Non-Linear Optimization









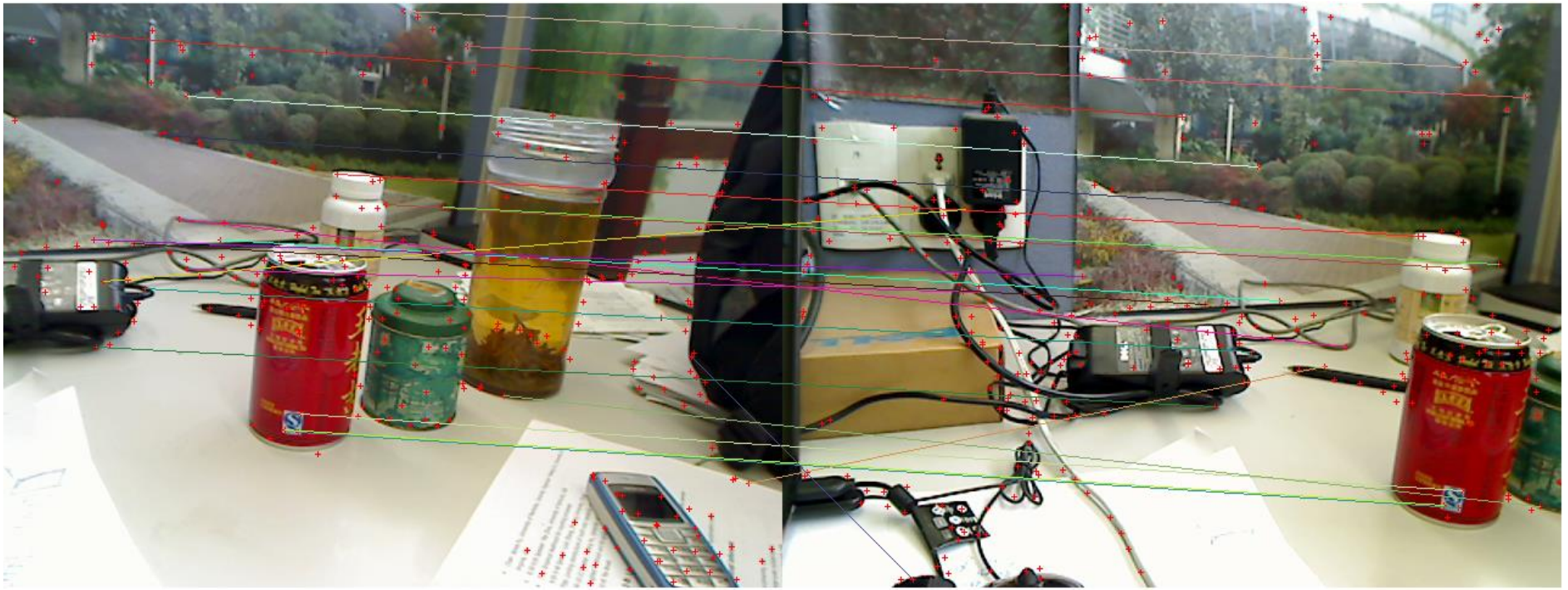
8. Deep Learning

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

cat

Slides from Andrej Karpathy and Fei-Fei Li
http://vision.stanford.edu/teaching/cs231n/

9 . Feature Matching

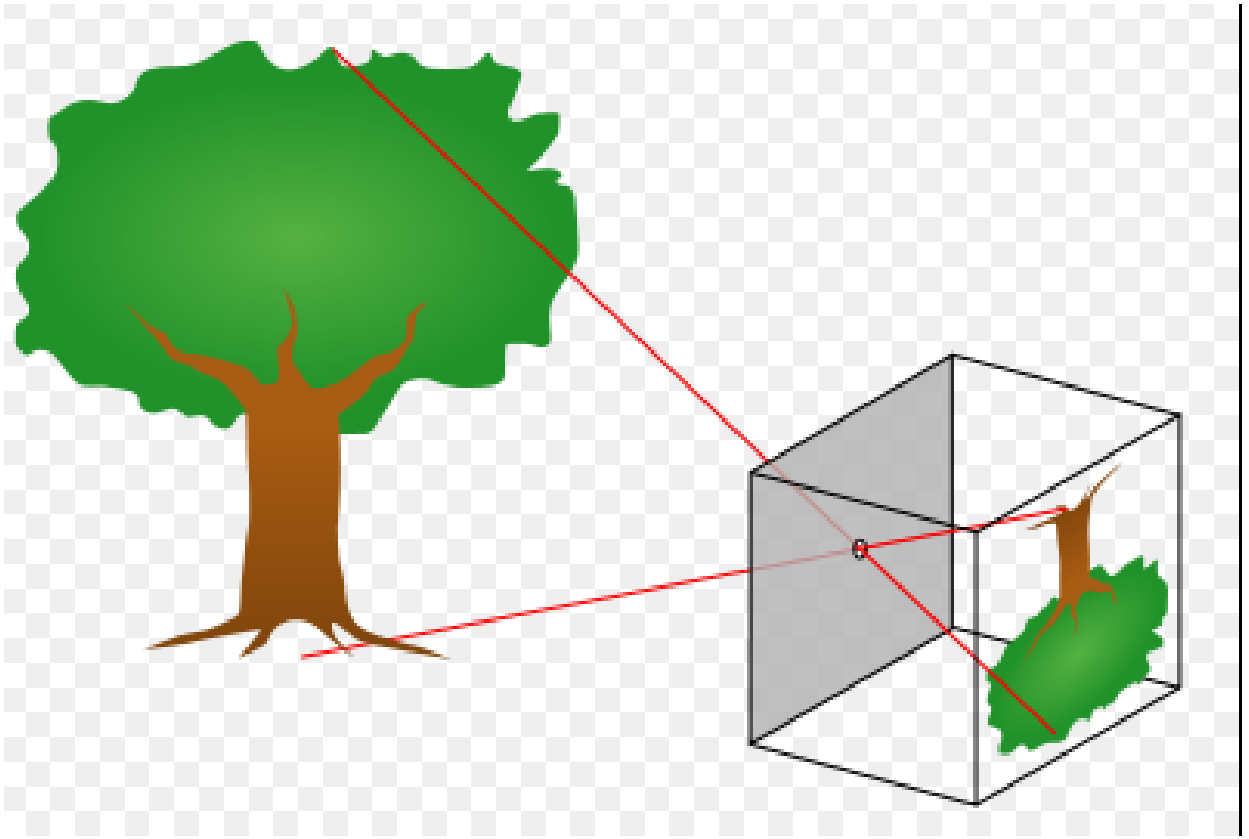


9. Optical Flow

Photos from Ce Liu

10. Camera Model

- Pinhole Camera



10. Structure From Motion

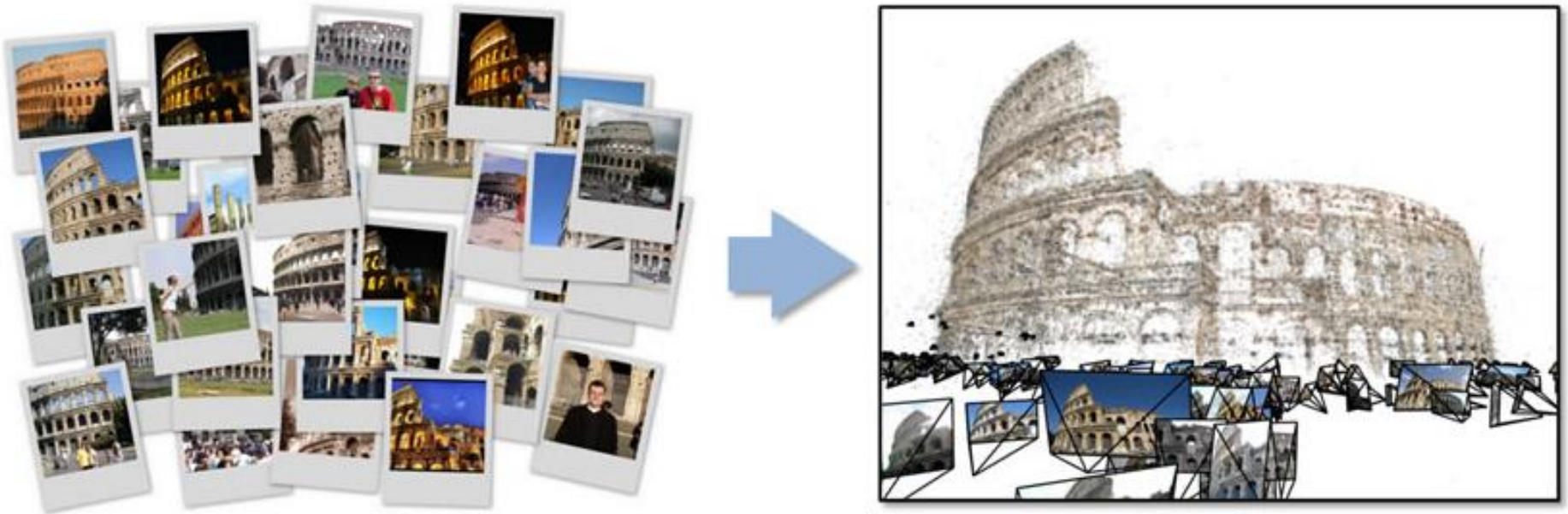


Photo Tourism

Exploring photo collections in 3D

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

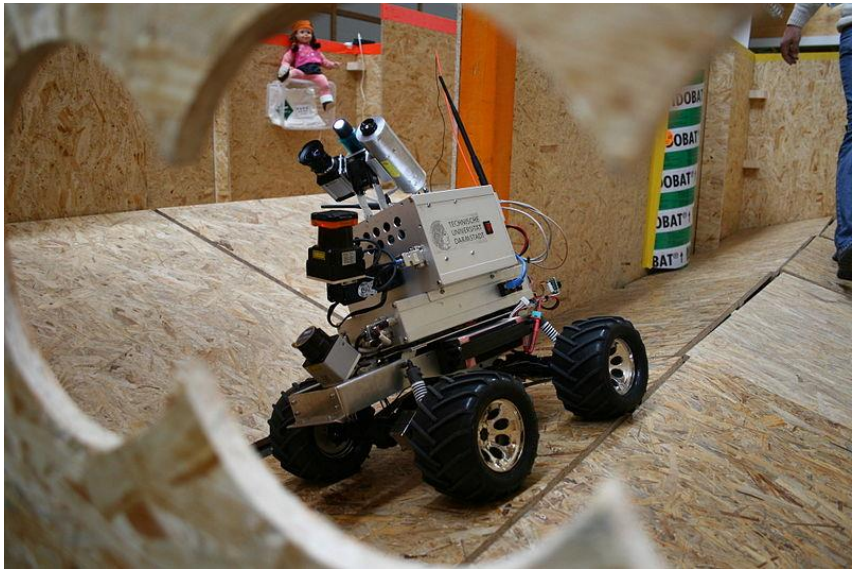
SIGGRAPH 2006

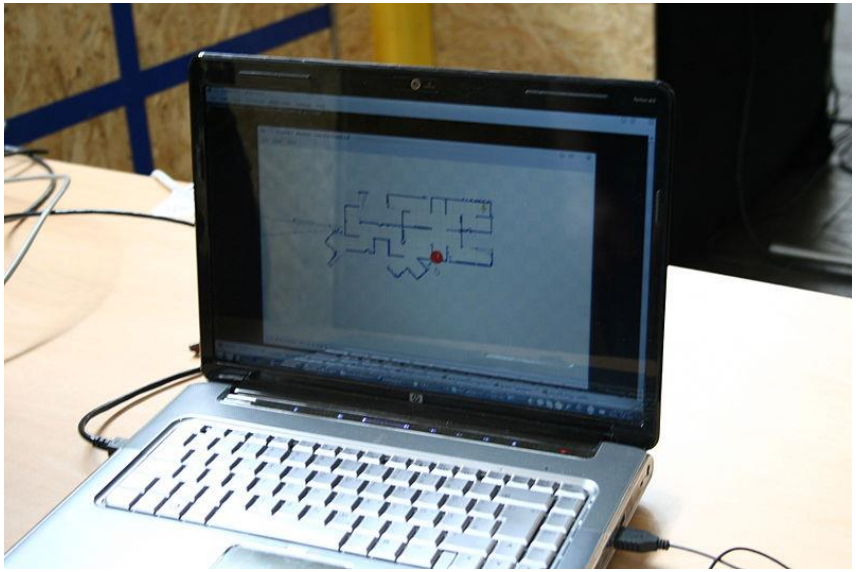
Input Sequences

Speed: ×2

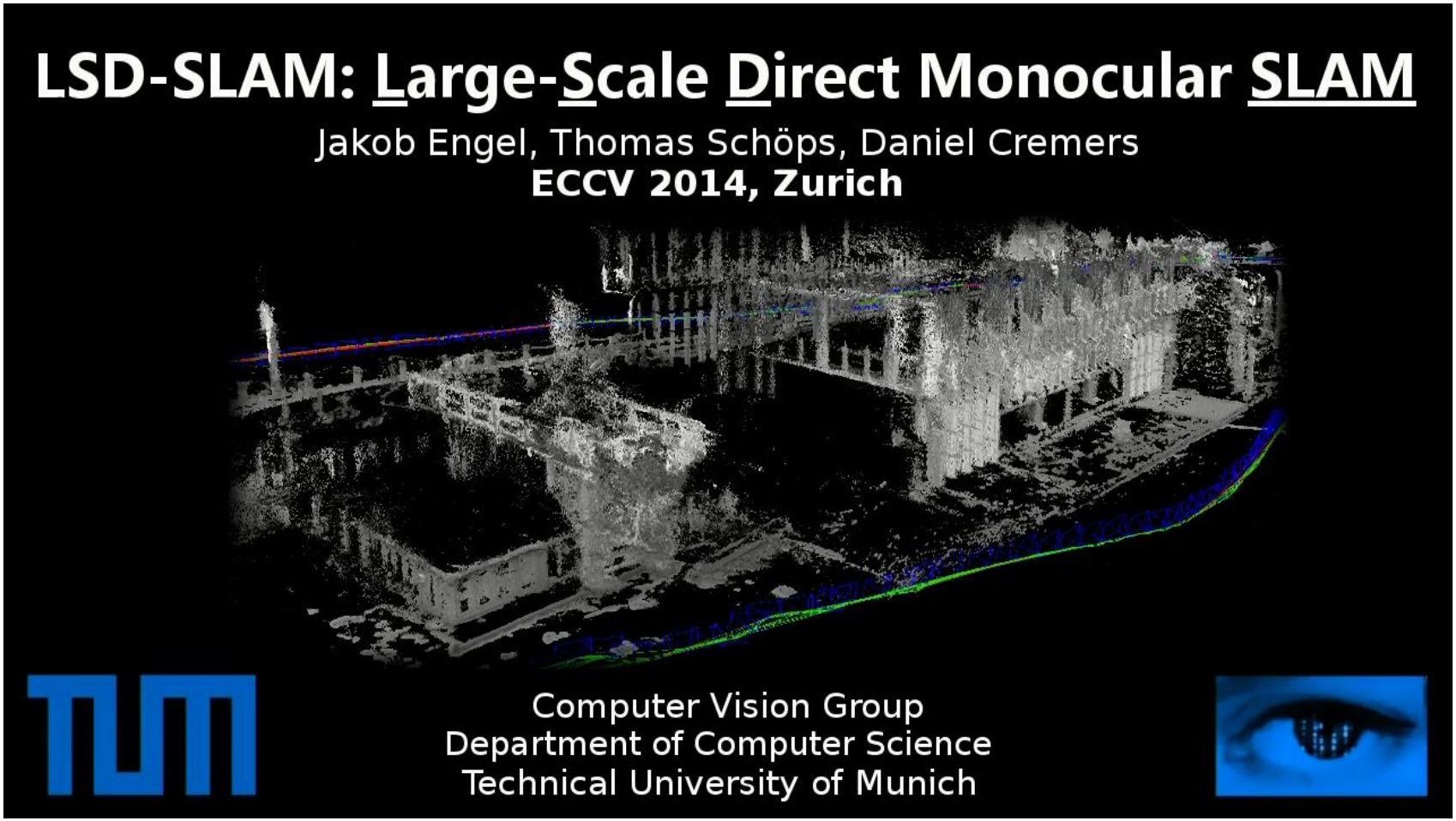
...

11. SLAM & AR



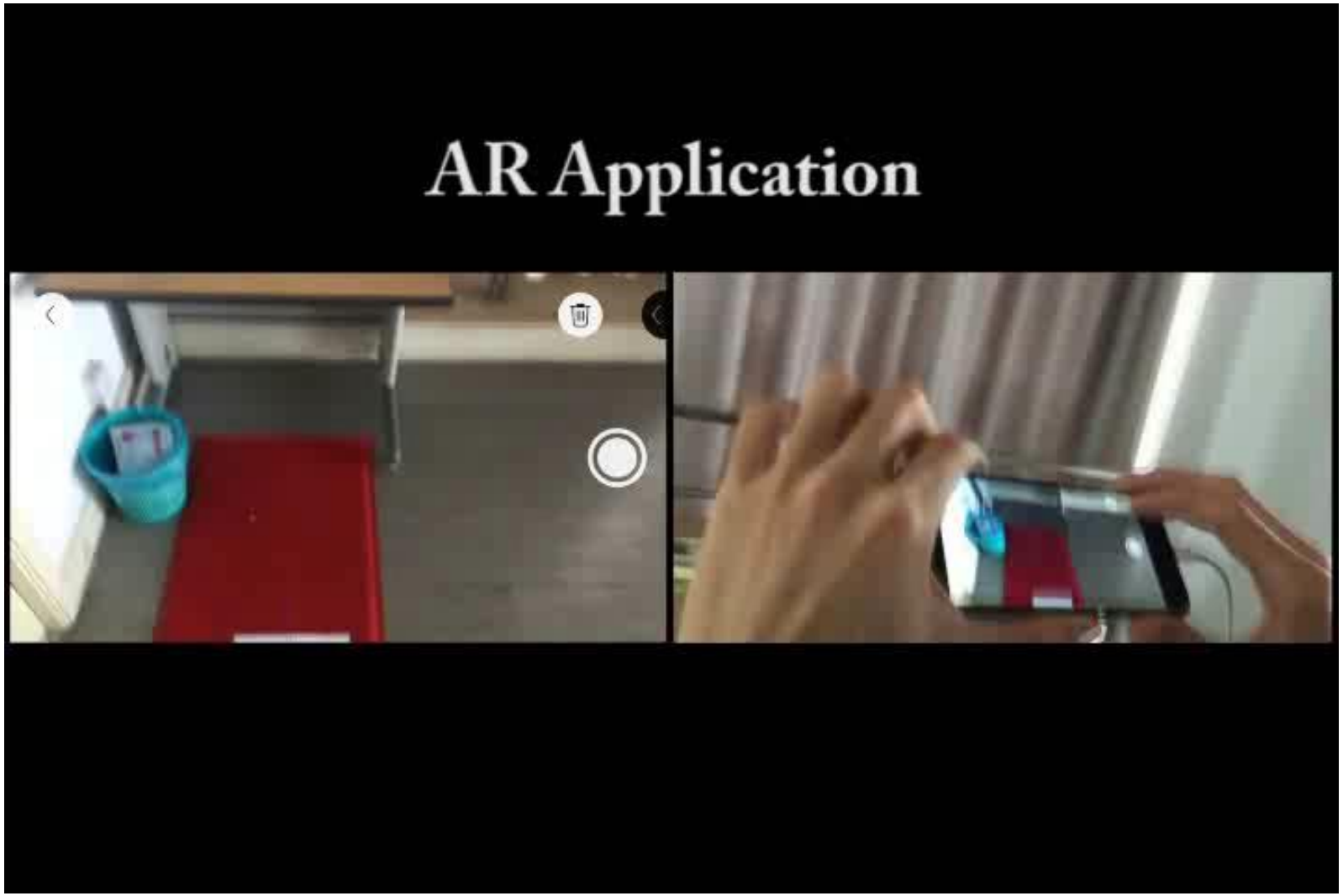


LSD-SLAM

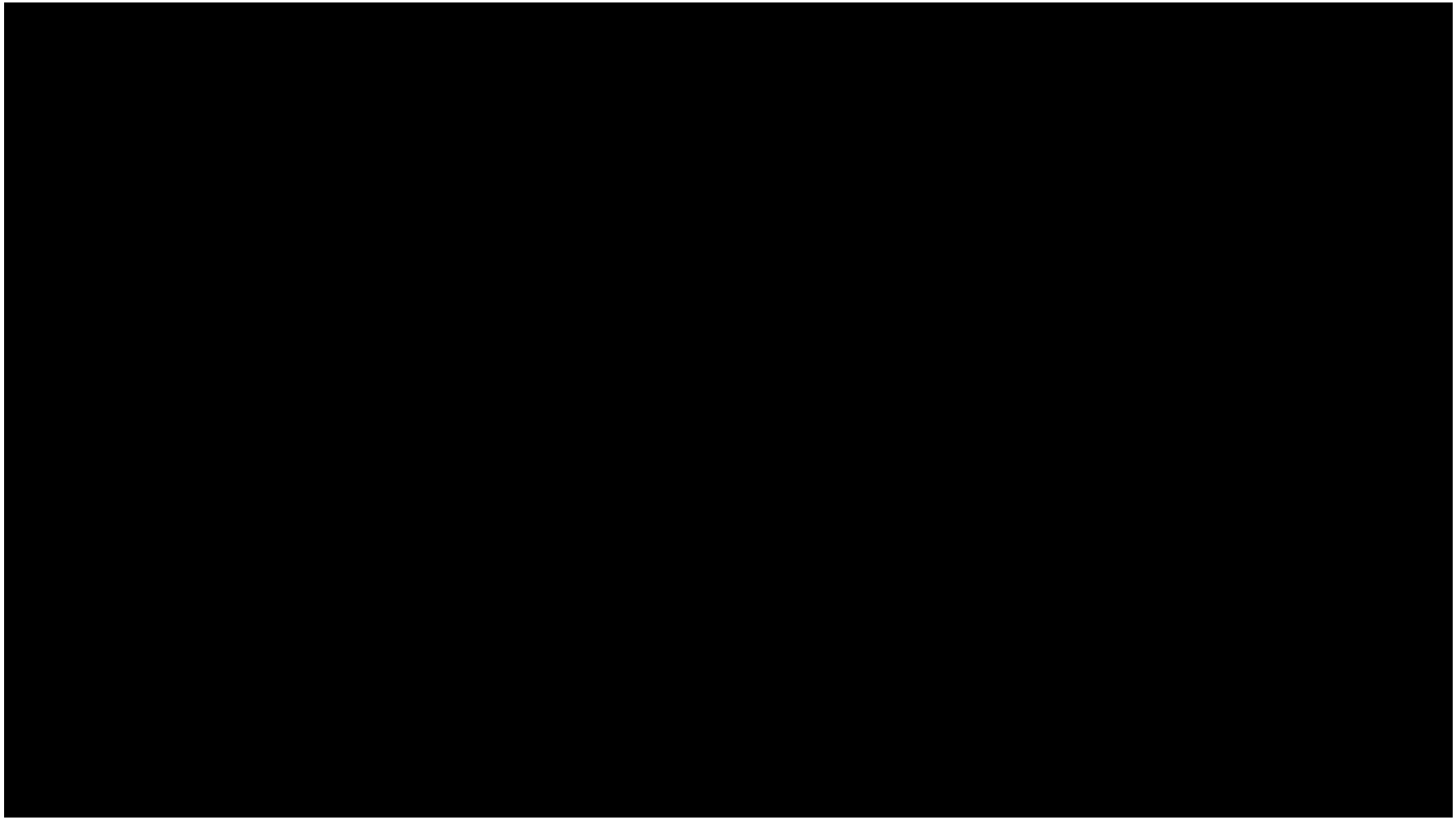

LSD-SLAM: Large-Scale Direct Monocular SLAM
Jakob Engel, Thomas Schöps, Daniel Cremers
ECCV 2014, Zurich
Computer Vision Group
Department of Computer Science
Technical University of Munich

ENFT-SLAM

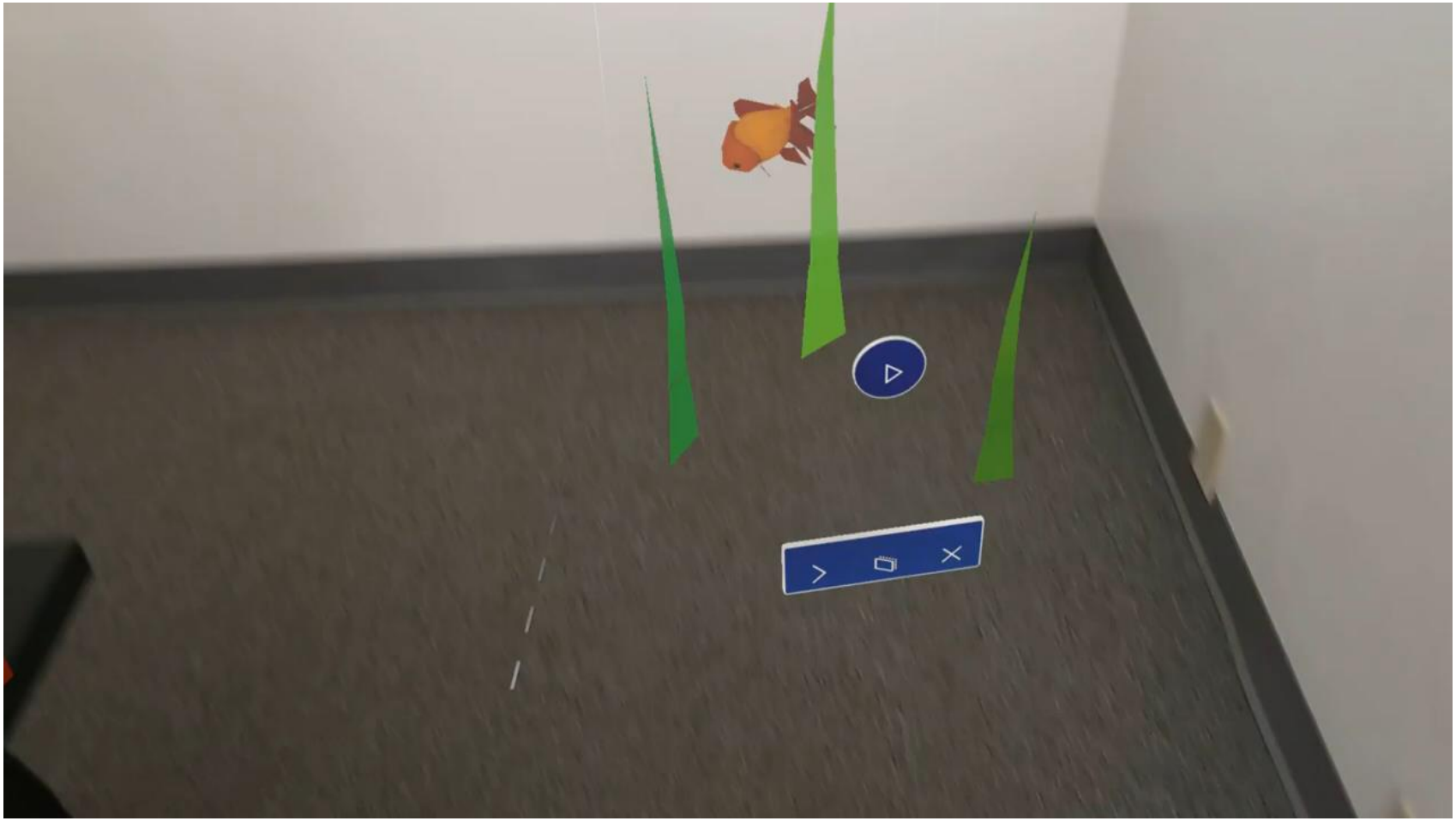
SLAM for AR Applications



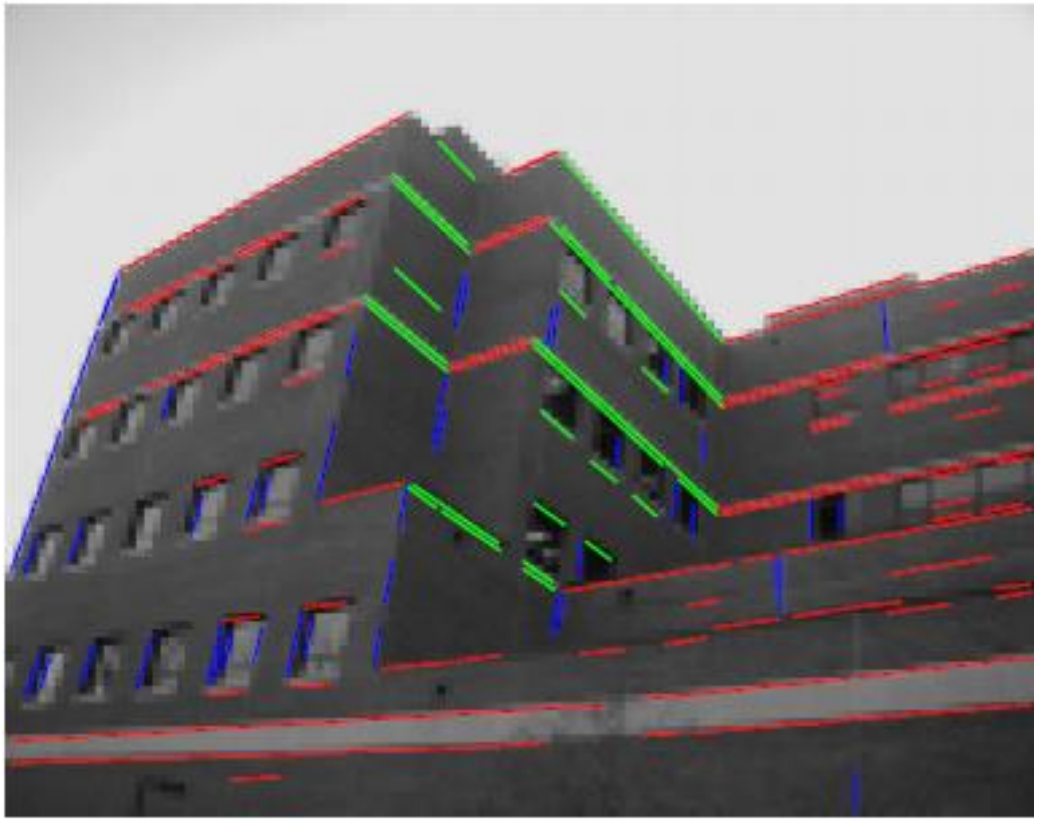
Huawei Cyberverse



Microsoft HoloLens2



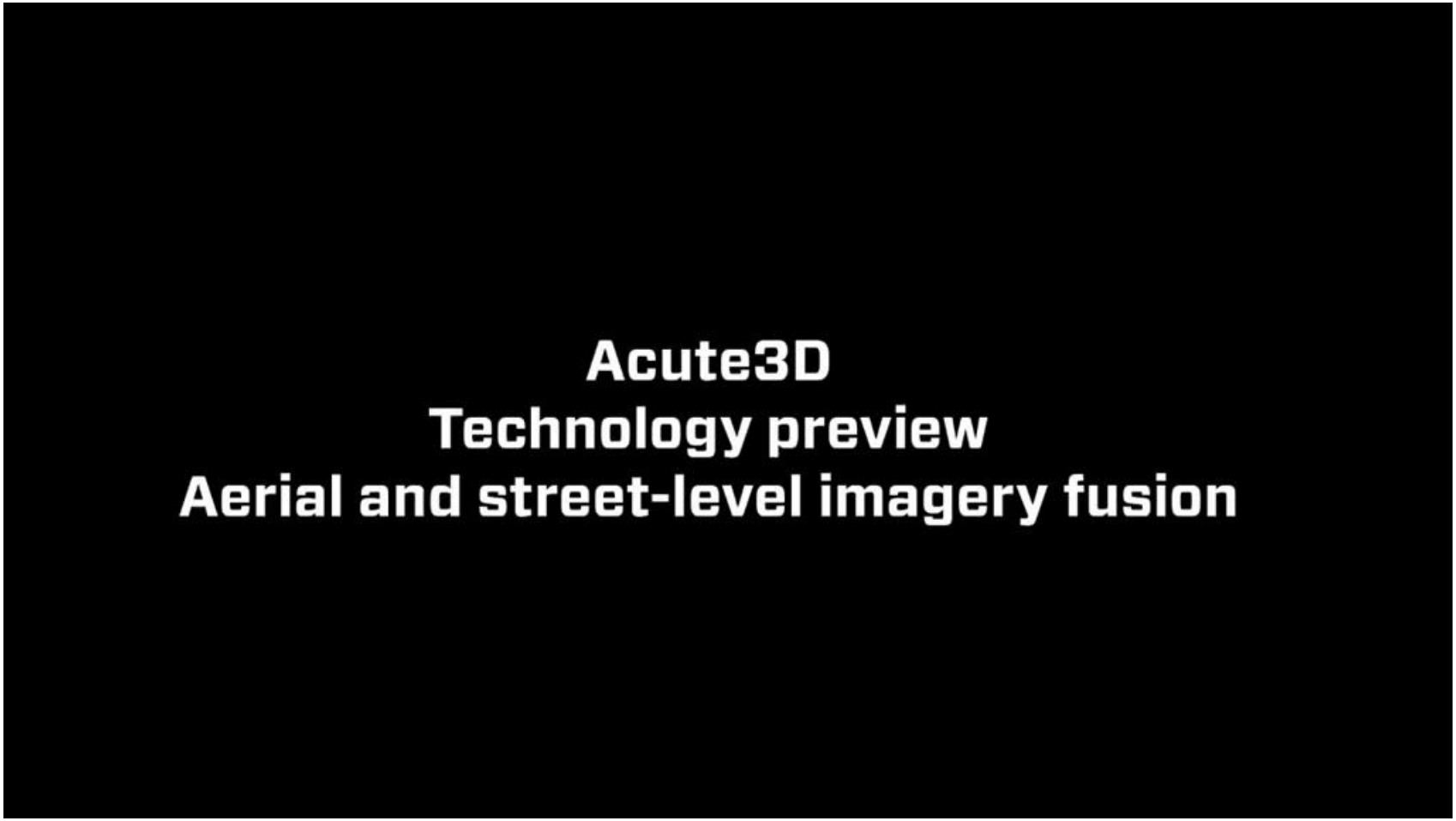
12. Single-View 3D Reconstruction



Automatic Photo Pop-up

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

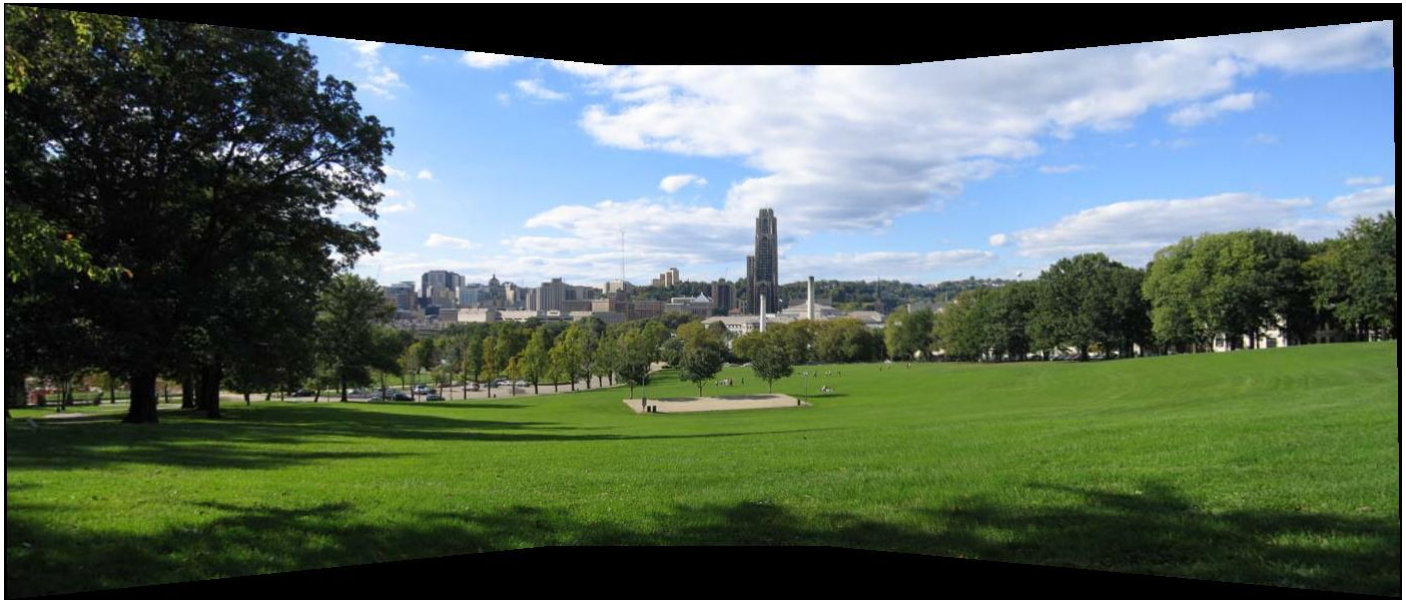
12. Multi-View 3D Reconstruction


Acute3D
Technology preview
Aerial and street-level imagery fusion


smart3Dcapture™

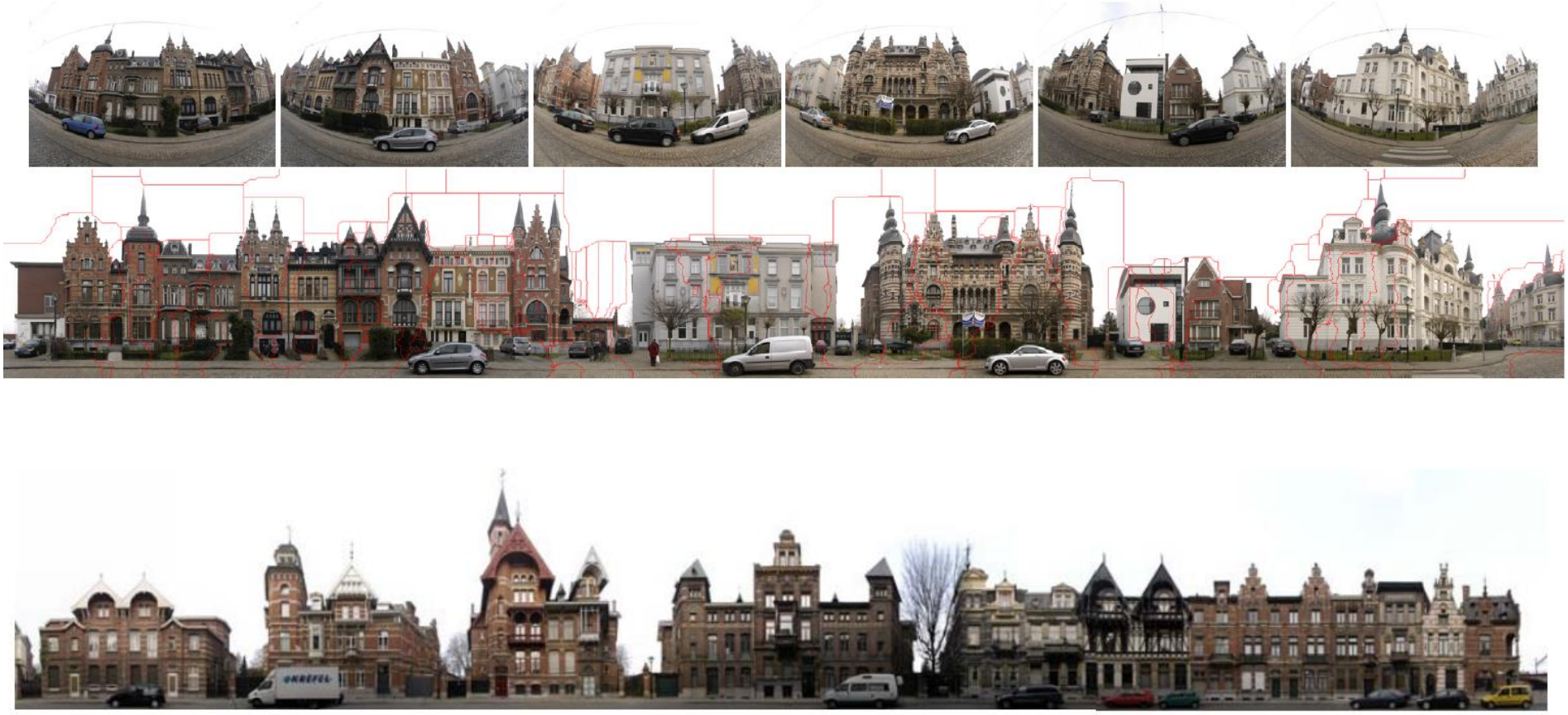
13. Recognising Panoramas



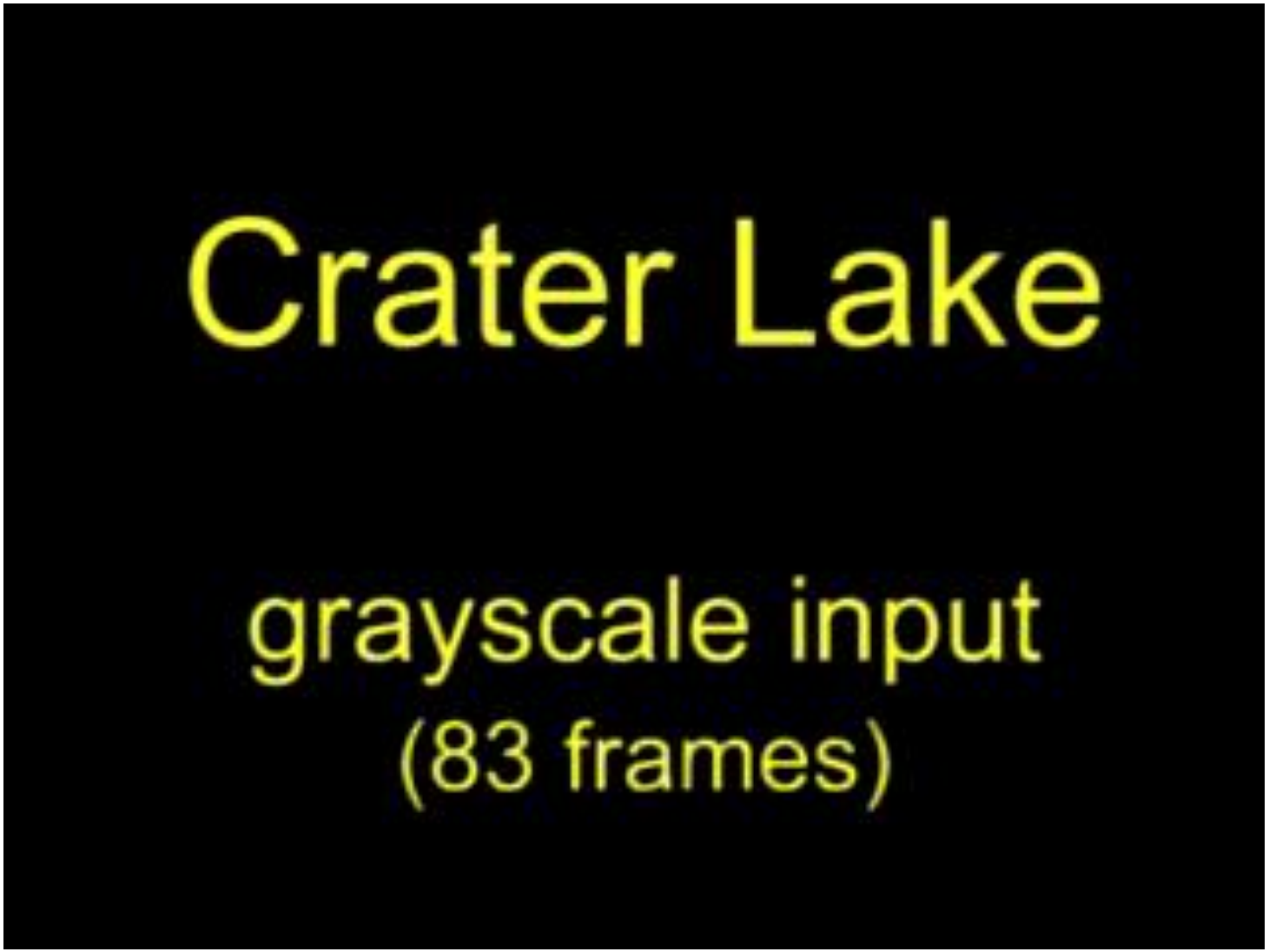
Photos from Derek Hoiem

13. Multiview Panorama Stitching




优酷
Street Slide
Browsing Street Level Imagery

14. Image Colorization & Recolorization


Crater Lake
grayscale input
(83 frames)

14. Image Colorization & Recolorization

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

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：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：
    - 范天行（11821030@zju.edu.cn）
    - 彭思达（pengsida@zju.edu.cn）
    - 陈祥辉（11921090@zju.edu.cn）
    - 王鹤（11921089@zju.edu.cn）
  - 时间地点：
    - 每周二下午9-10节（上机课）曹西503，暂时钉钉群

Questions?