3D Computer Vision:
Where am I?

3D Computer Vision:
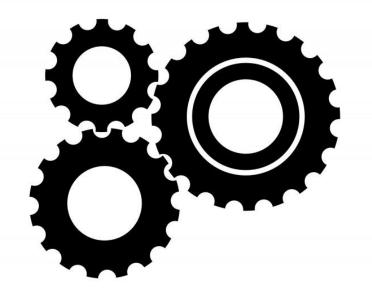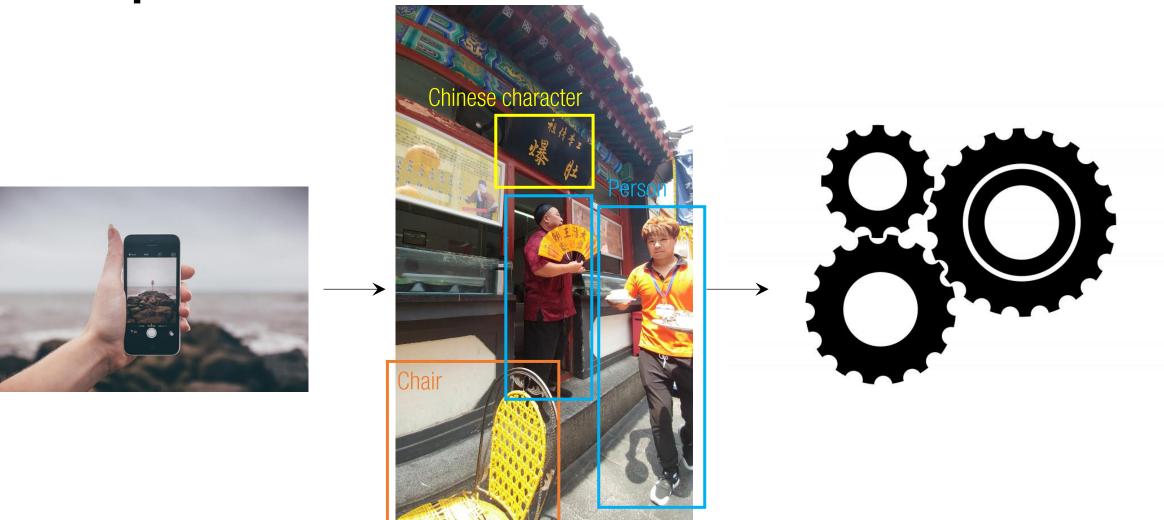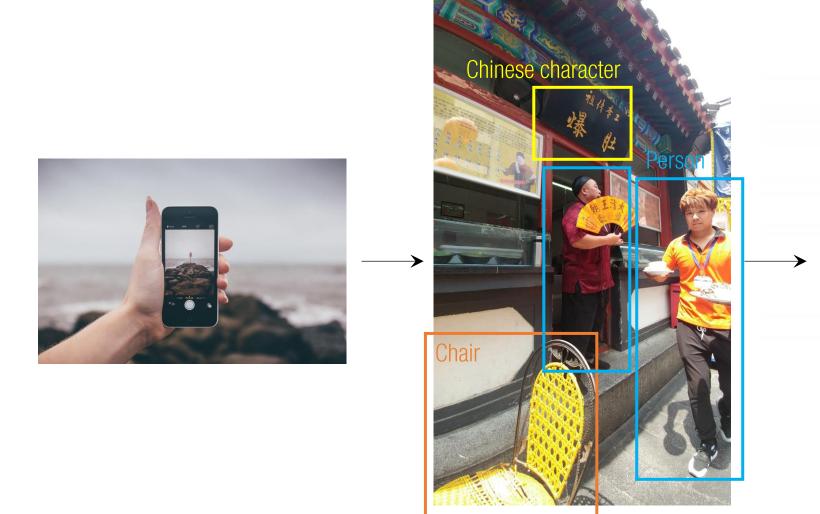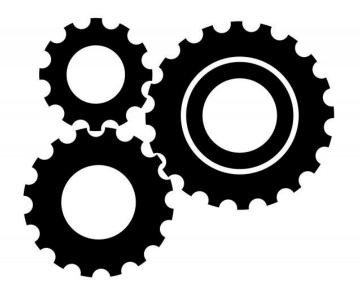## Where am I?

Computer Vision

Computer Vision

Computer Vision: What is Where?

Computer Vision: What is Where?

What is he doing?
Is he delivering a cup of soup?
Is outdoor?
Where will he move next?
Is it warm (temperature)?
Where is he looking at?
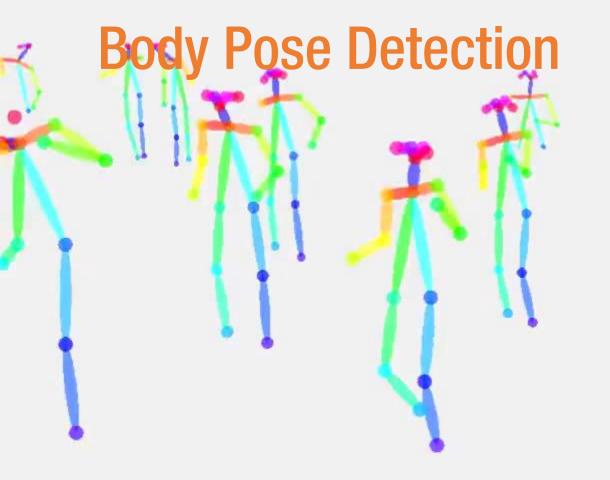
Chinese character

Person

Chair

Video Activity Recognition

Autonomous Vehicle (Mobileye)

Raw
Bullet Time
Footage

Video Interpolation

Hand Pose Detection
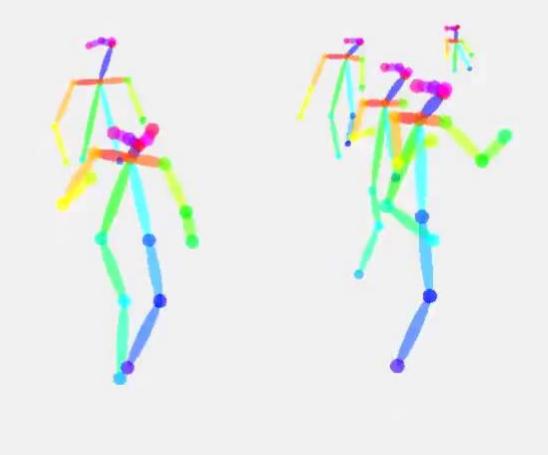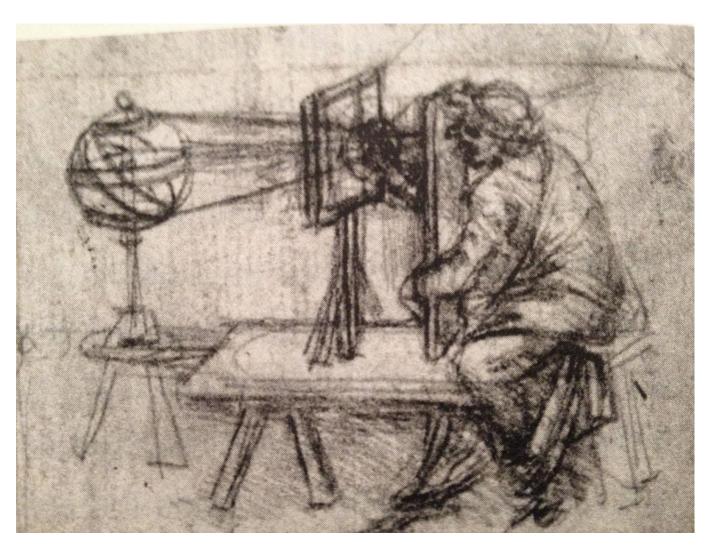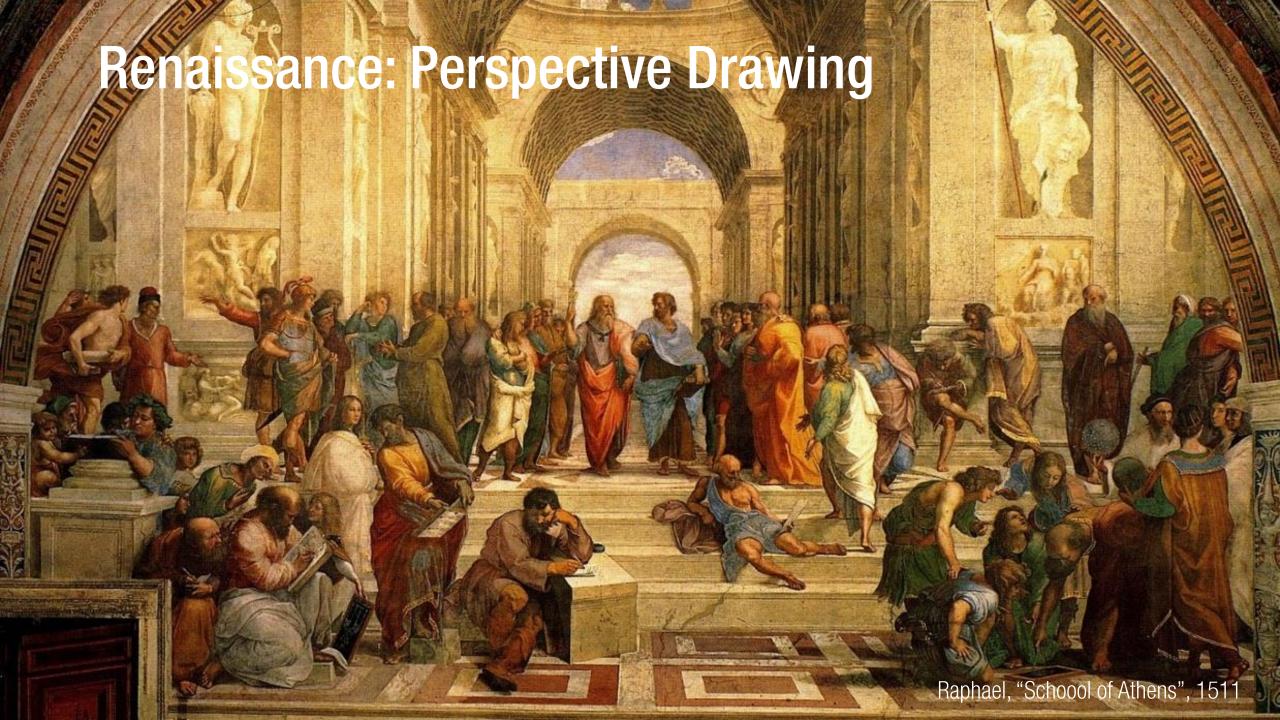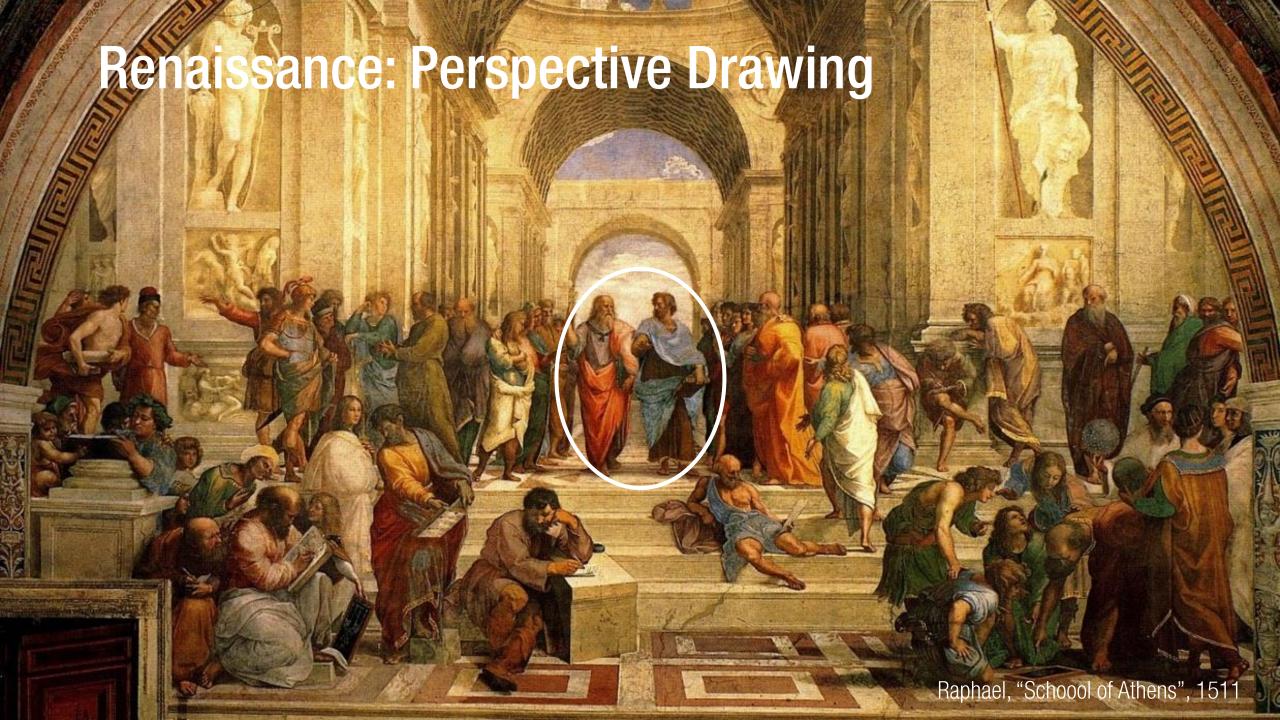
Introduction

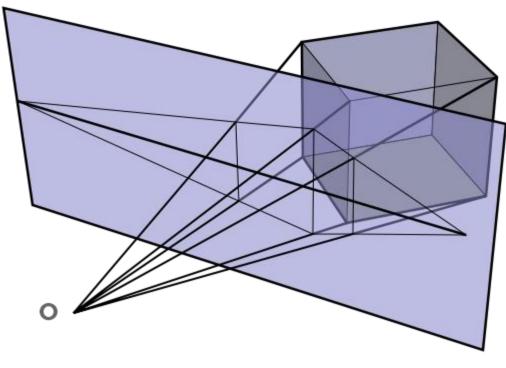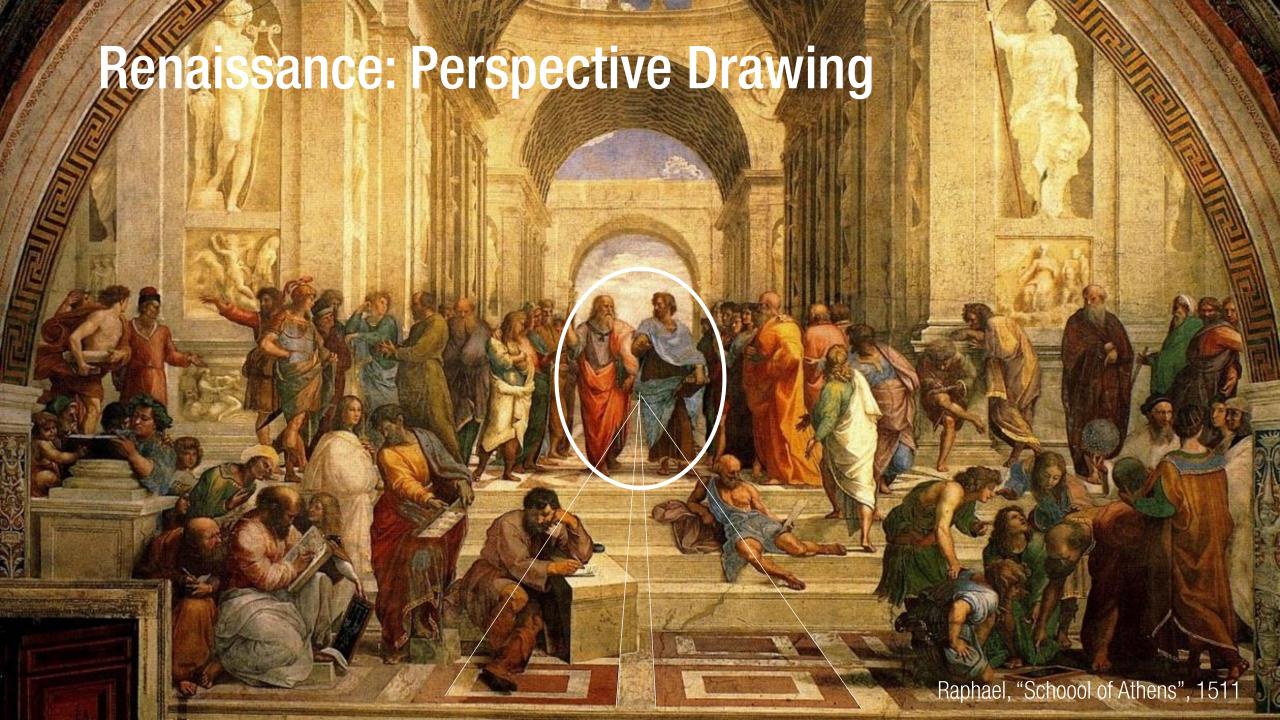# Renaissance: Science into Art

Renaissance: Perspective Drawing

Raphael, "Schoool of Athens", 1511

Renaissance: Perspective Drawing

Raphael, "Schoool of Athens", 1511

Renaissance: Perspective Drawing

Raphael, "Schoool of Athens", 1511

Camera Obscura: Da Vinci

… all objects illuminated by the sun will send their images through this aperture and will appear, upside down, on the wall facing the hole.

- Codex Atlanticus

Camera Obscura: Frisius

Gemma Frisius

First camera obscura drawing

San Francisco, CA

CAMERA OBSCURA
SAN FRANCISCO
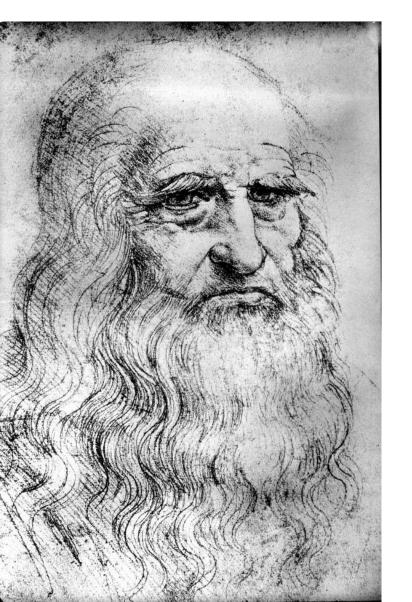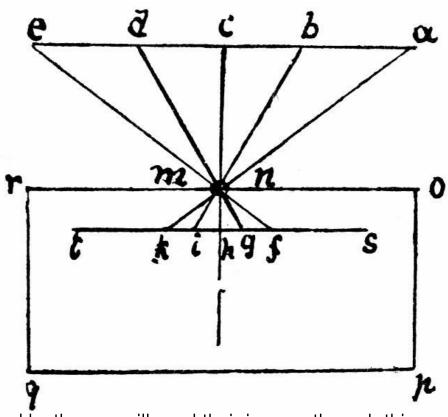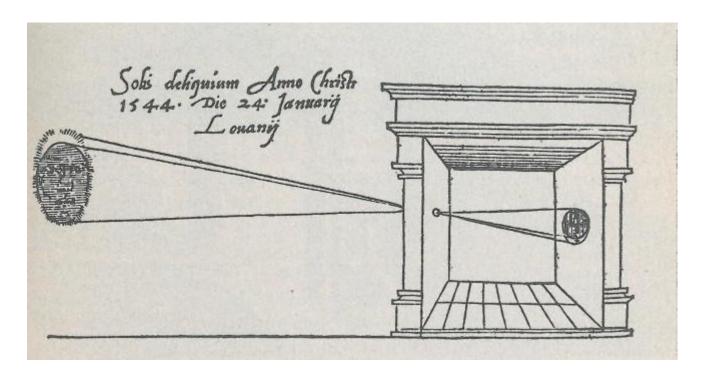1096 POINT LOBOS, SAN FRANCISCO, CA 94121, Tel: (415) 750-0415

Seal Rock area magnified 360°

HISTORY:
The word Camera Obscura is Latin and means translated the 'dark room'. Today it is not quite known, when and by whom exactly the Camera Obscura was invented. In the 11th. century the Arabian scholar Alhazen theorized that light waves travel in straight lines and he tried to proof it with a pinhole. What happened between then and the end of the 15th. century is obscure. The oldest forms of the Camera Obscura surviving, are sketches by Leonardo da Vinci and others, probably from around the late 15th. century. He was most likely not the only one, because around 1490 John Baptista della Porta revealed the phenomena in a book called 'Natural Magic'. While it was to the amusement of those scholars, other people condemned it as an invention of the devil.
In the following centuries, the Camera Obscura became a wonderful tool for artists and astronomers. Artists, such as Vermeer, used the Camera Obscura as portable instruments for their paintings and portrait drawings.

10" DIAMETER FRONT-FACED MIRROR
8" CONVEX LENS
8" CONCAVE LENS
PARABOLIC SCREEN
25' x 25' Building
Exit
Camera Obscura "Giant Camera"
Entrance

Rotating on top of the camera in the copper pyramid is a 10" surface coated mirror of high brilliance which reflects an image through the condensing lenses mounted horizontally directly beneath the mirror. The condensing lenses are simple plano-convex lenses mounted in opposition to each other. They focus the un-focused image from the mirror at a specific distance, in this case 12'. The lens size is 8" and the lens aperture is fixed at F8.

EXPERIENCE THE CAMERA OBSCURA EFFECT
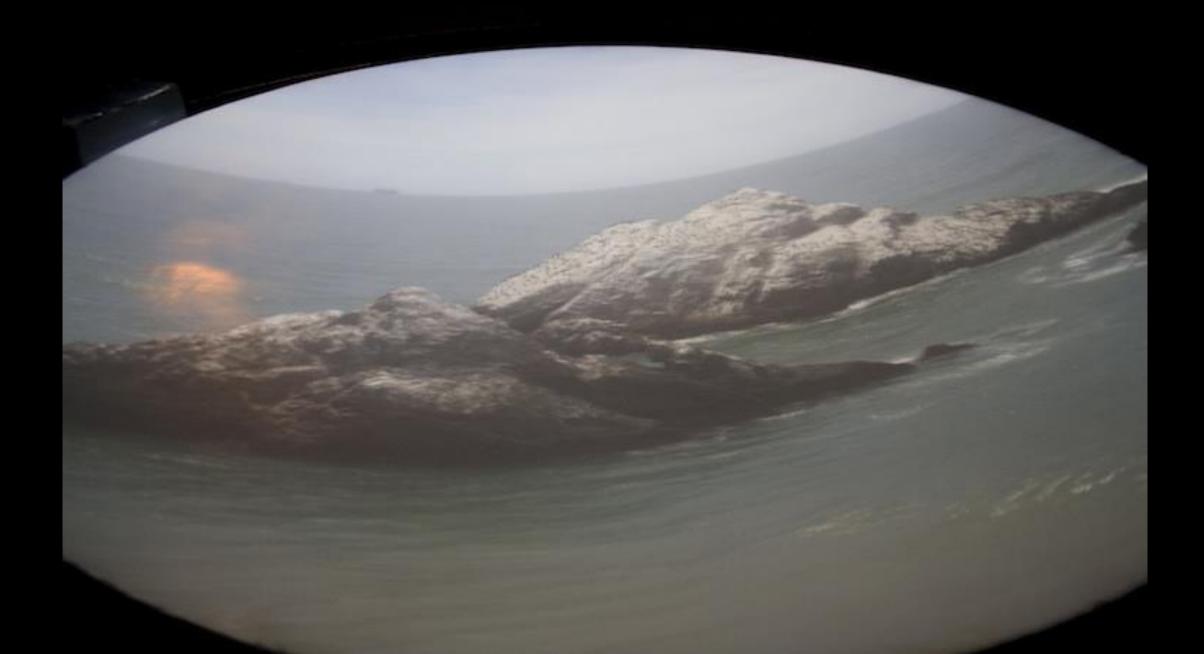
This rare optical device, shows you SEAL ROCK AREA in a new way.
It produces a spectacular LIVE IMAGE, magnified seven times.

History
The Camera Obscura is the last remaining structure of the World Famous Playland at the Beach. Built by Floyd Jennings in 1946. It was built with the permission of George K. Whitney Sr., then owner of the Cliff House, Sutro Baths and Playland. Mr. Whitney later suggested, to making it look like a Camera, hence the name Giant Camera. This rare attraction is in keeping with Sutro's plan for recreational activities at Point Lobos. This structure provides scenic panoramic views,so spectacular with vivid colors. Making it a fun and learning experience. Walk through this optical instrument, which produces 360 degrees of spectacular Live Images of the Seal Rock Area. Magnified Seven Times on a Six foot Parabolic Table. Now you can expeience this Special Effect. You will be truly amazed, the Images standing up and coming at you.After this you will want to learn everything you can about the CAMERA OBSCURA. You will be telling your friends. Don't miss it.

The Giant Camera is now a National Landmark,and is on the National Register of Historic Places. Now, you can share this Treasure box with your family and friends. You have been exposed to the Camera Obscura Effect. Tell everyone to visit today.
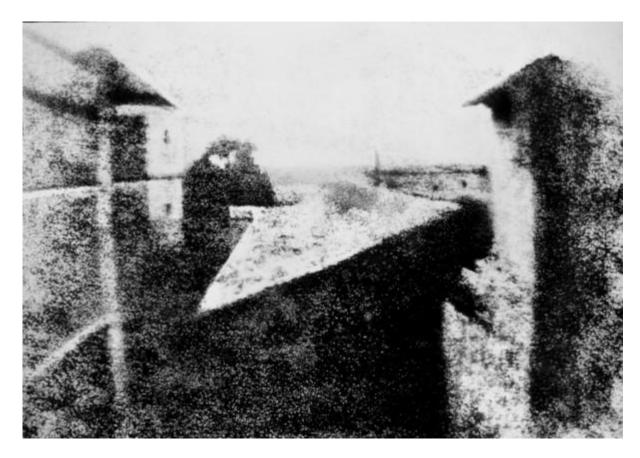
The Camera is Always open from 11:00 am. till 5pm on beautiful days, and probably a little bit shorter on other days. To make sure, give us a call at (415) 750-0415.

General Admission - Three Dollars Each

SUNSETS~Observe the sun with safety and amusement. See sunspots, solar flares and such phenomena as the GREEN FLASH.

CAMERA OBSCURA
AND
HOLOGRAPH GALLERY

First Photography

Joseph Nicéphore Niépce, "View from the Window at Le Gras" Circa 1826   8 hours exposure

First Photography of Human

Louis Daguerrein, "Boulevard du Temple" Circa 1838

10 mins exposure

"Boulevard du Temple", Paris, includes the earliest known candid photograph of a person. The image shows a busy street, but because the exposure had to continue for several minutes the moving traffic is not visible. At the lower left, however, a man apparently having his boots polished, and the bootblack polishing them, were motionless enough for their images to be captured.

-- Wikipedia
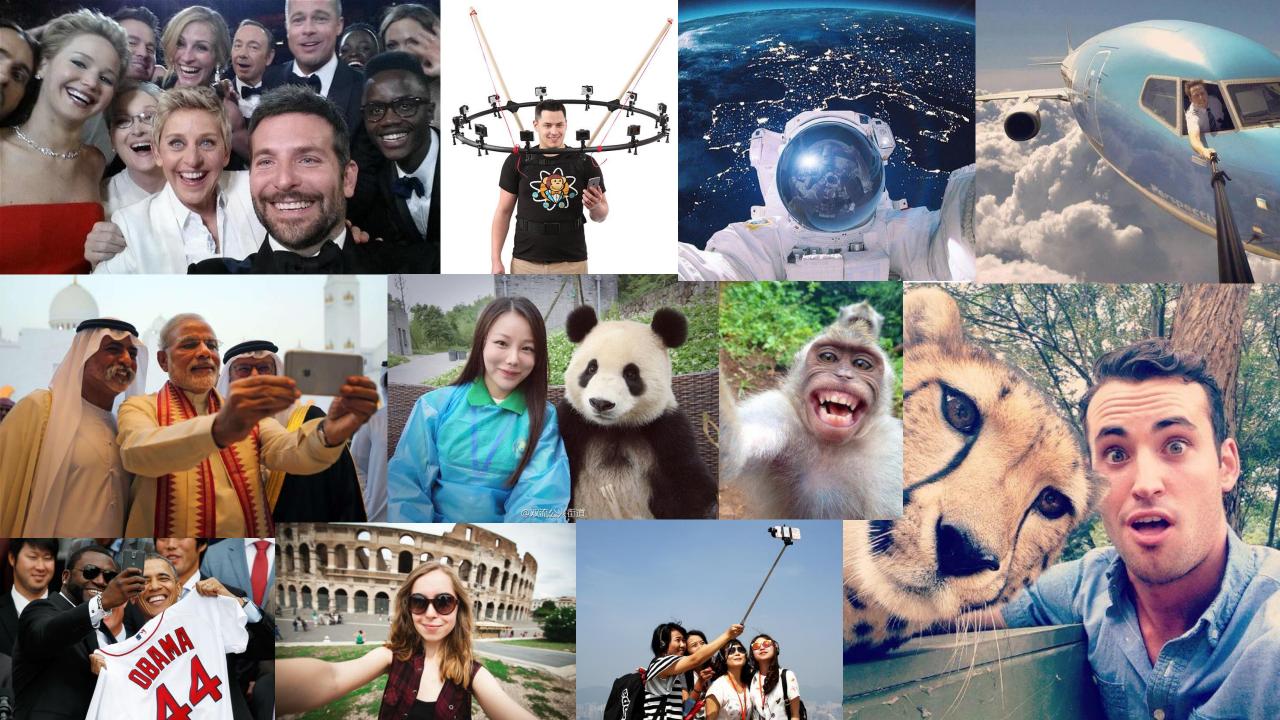
Selfie
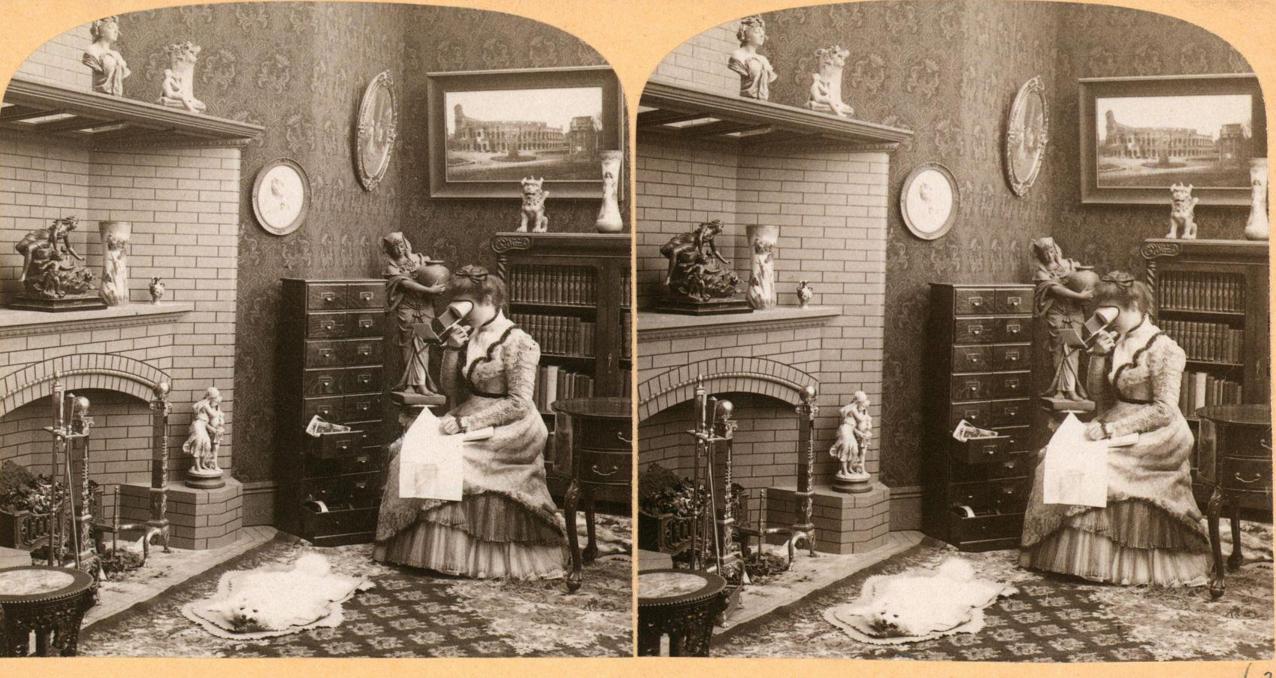
Circa 1920, NY, NY

Snapped in New York on the roof of the Marceau Studio on Fifth Avenue, across the street from St. Patrick's Cathedral, this picture features five mustached photographers holding an antediluvian analog camera at arm's length. Because this camera would have been too heavy to hold with one hand, Joseph Byron is propping it up on the left, with his colleague Ben Falk holding it on the right. In the middle, you have Pirie MacDonald, Colonel Marceau, and Pop Core.
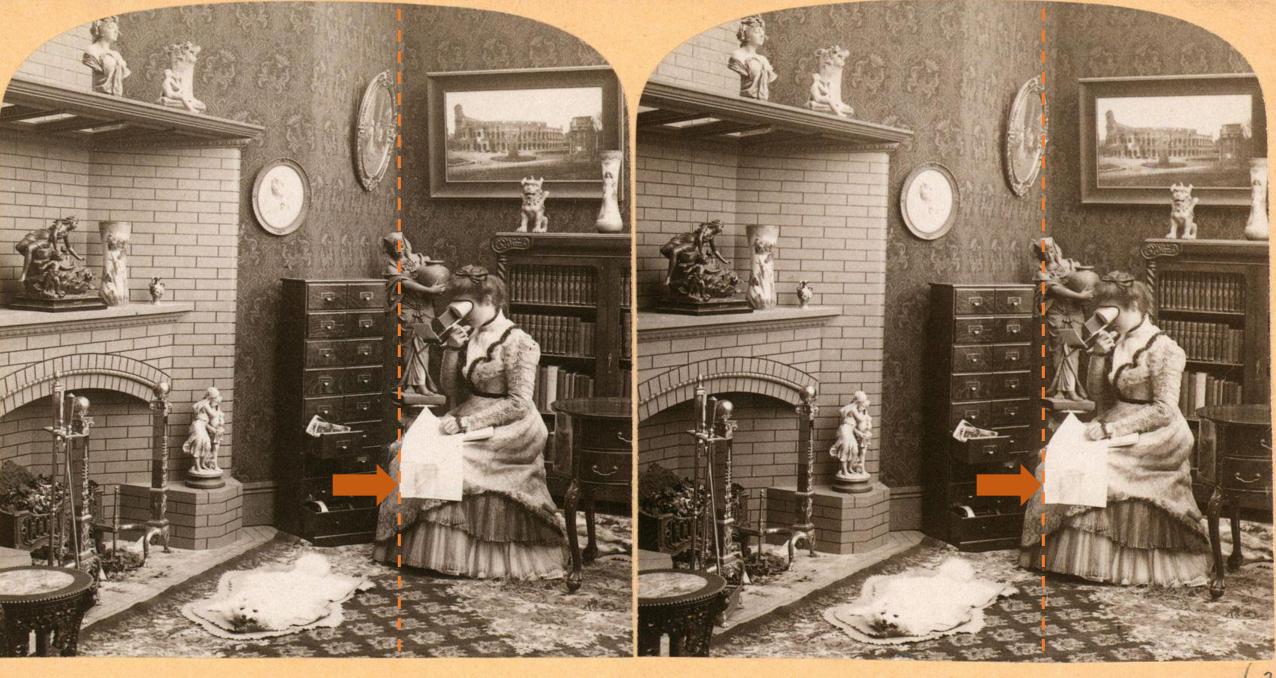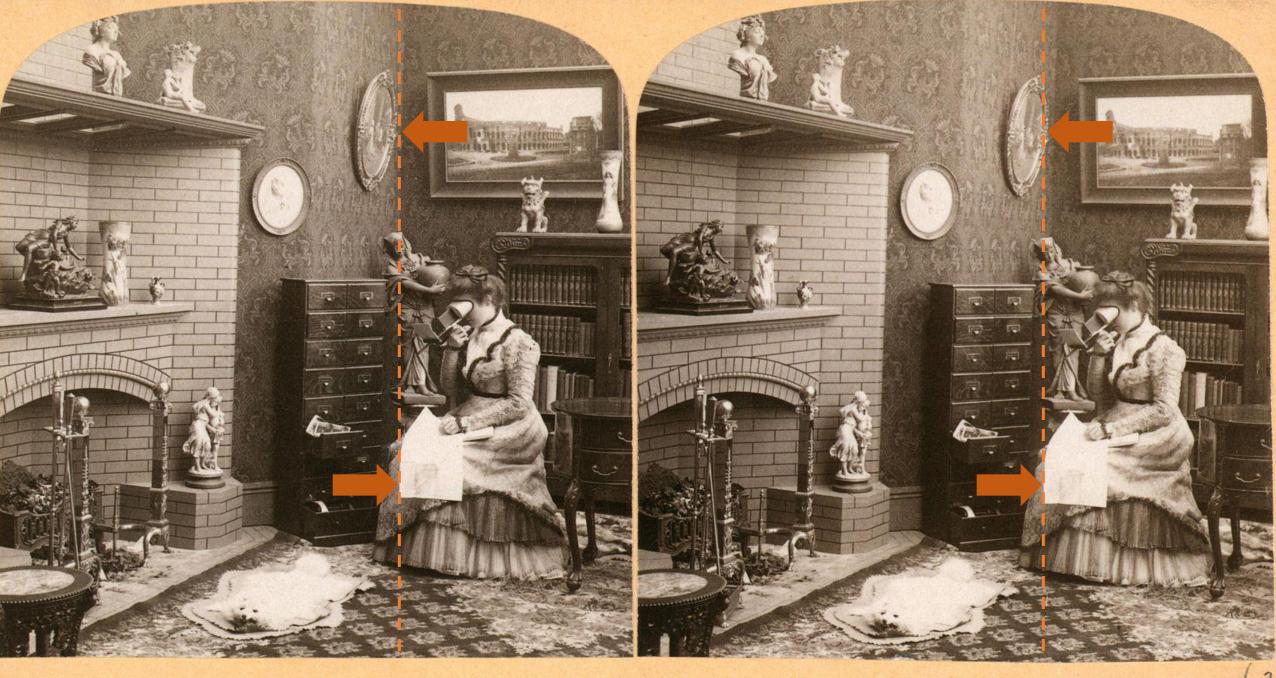
The Stereograph as an Educator—Underwood Patent Extension Cabinet in a home Library.
Copyright 1901 by Underwood & Underwood.

The Stereograph as an Educator—Underwood Patent Extension Cabinet in a home Library.
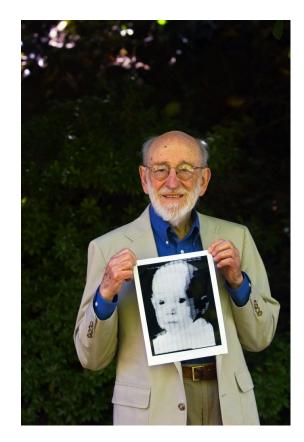Copyright 1901 by Underwood & Underwood.

The Stereograph as an Educator—Underwood Patent Extension Cabinet in a home Library.
Copyright 1901 by Underwood & Underwood.

The Stereograph as an Educator—Underwood Patent Extension Cabinet in a home Library.
Copyright 1901 by Underwood & Underwood.

Circa 1900

Stereo: Holmes Stereoscope

First Digital Photography

Russell Kirsch
Standards Eastern Automatic Computer at NIST (1957)

Assembly of image scanners
176x176 resolution

First Digital Camera

Steve Sasson
Kodak (1975)

0.01 MP

After taking a few pictures of the attendees at the meeting and displaying them on the TV set in the room, the questions started coming. Why would anyone ever want to view his or her pictures on a TV? How would you store these images? <u>What does an electronic photo album look like?</u> When would this type of approach be available to the consumer? …, we had no idea how to answer these or the many other challenges that were suggested by this approach.

-- Steve Sasson

2017

What do you mean by understanding?

What do you mean by understanding?

What do you mean by understanding?

What do you mean by understanding?
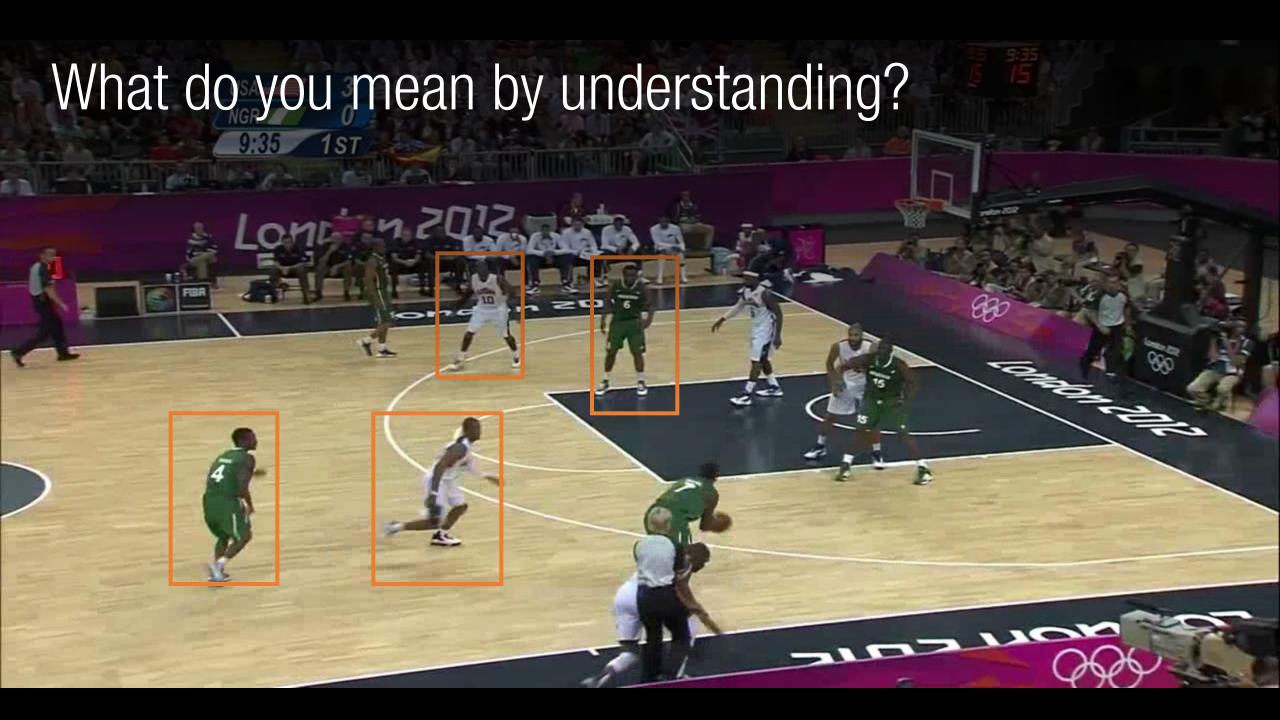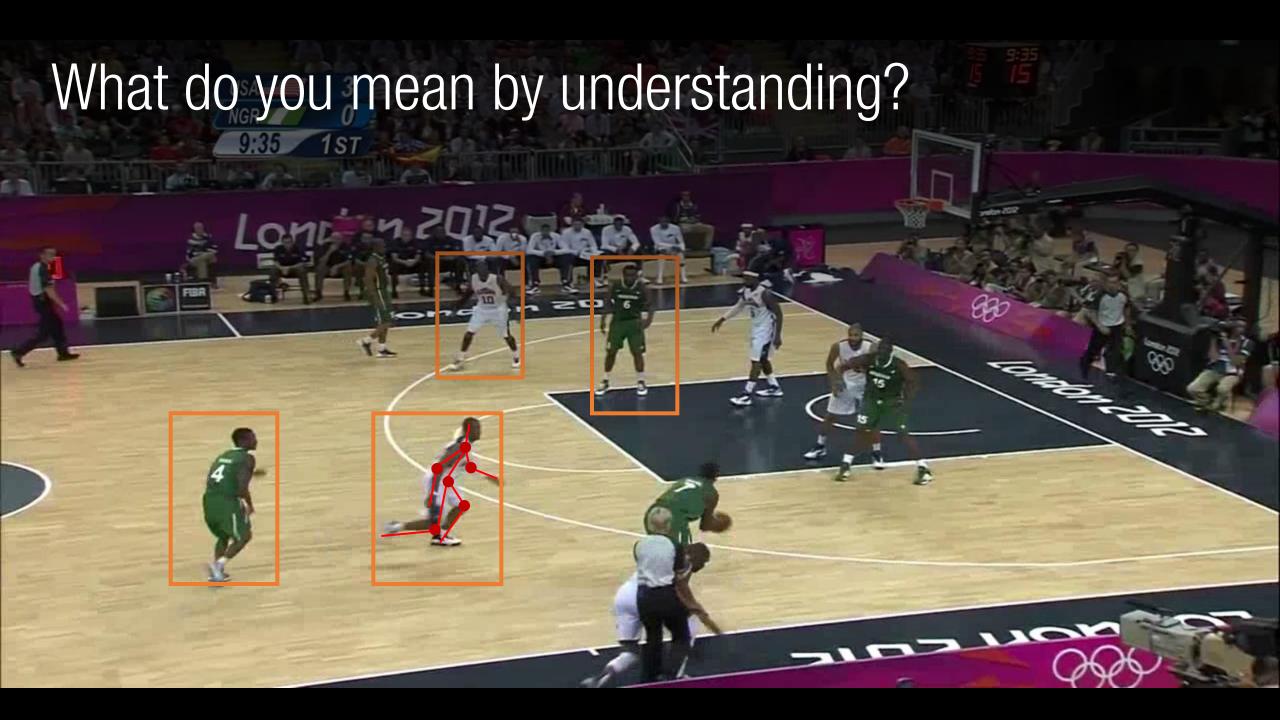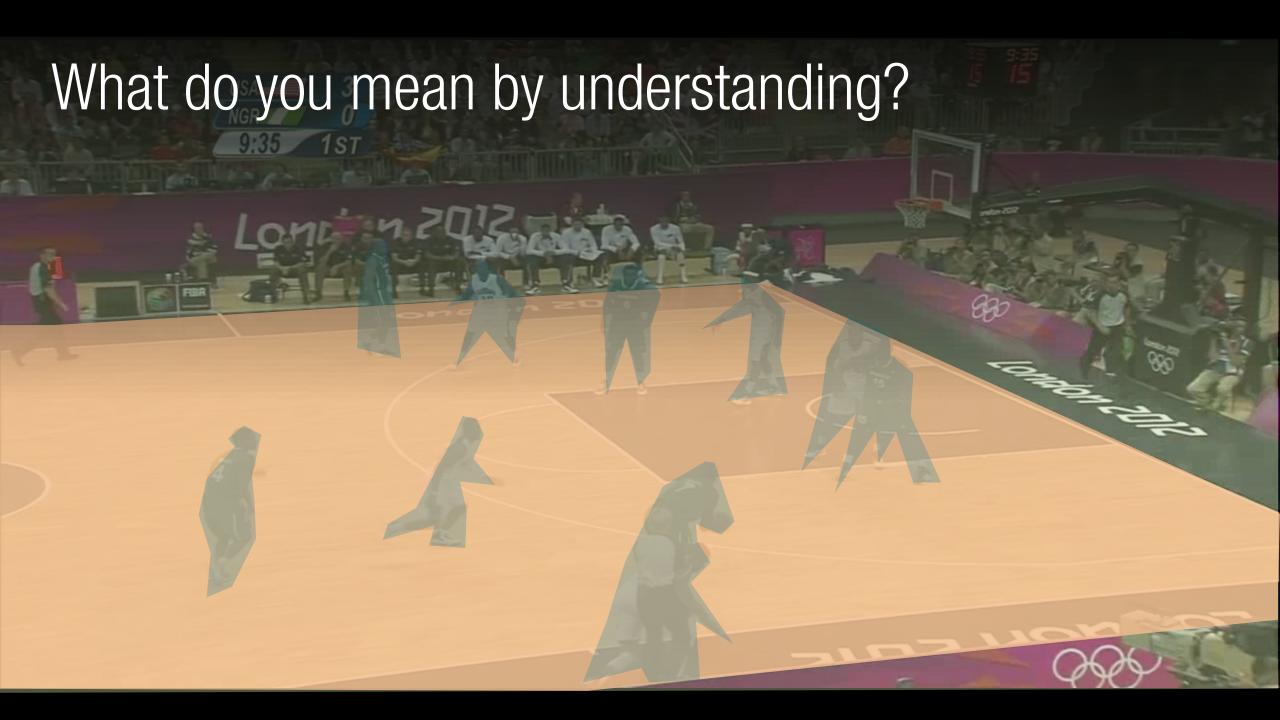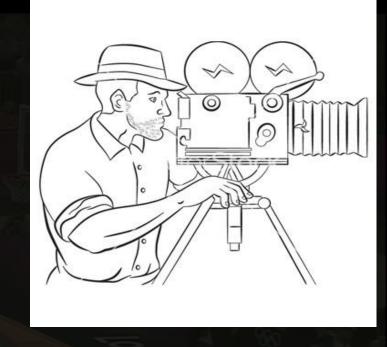
Internal state:
intention, attention, and memory
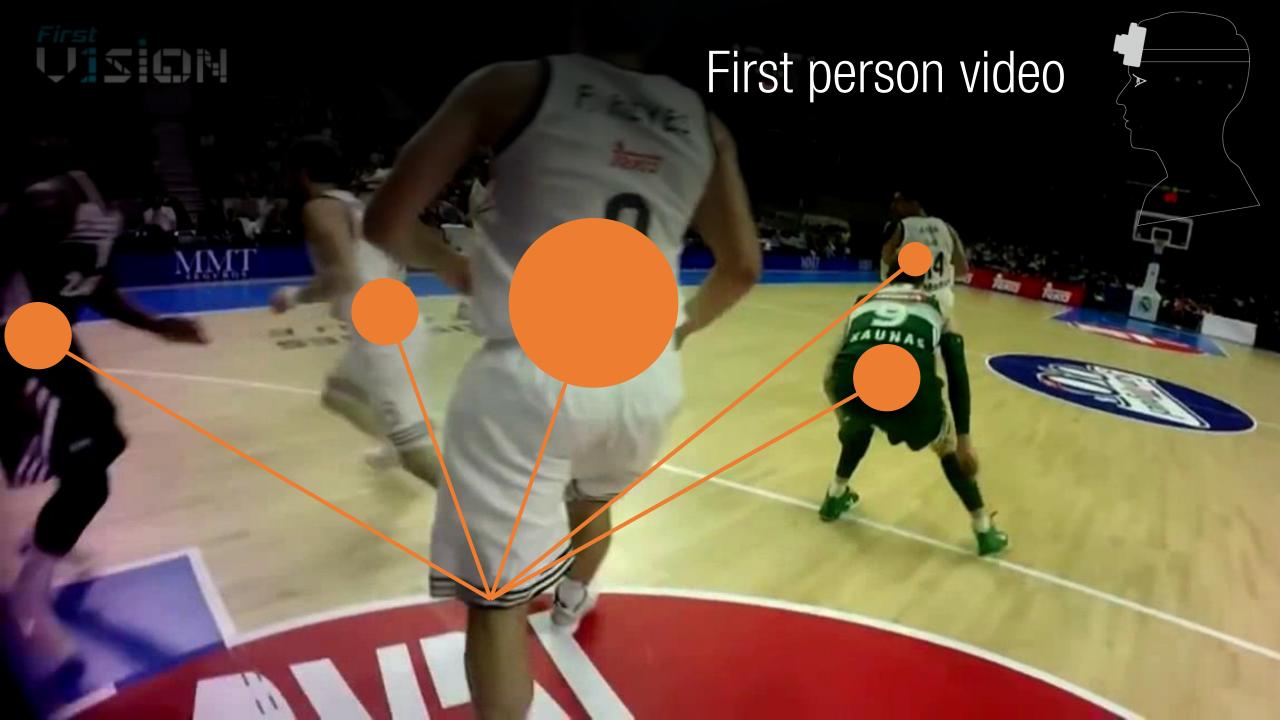
Internal state:
intention, attention, and memory
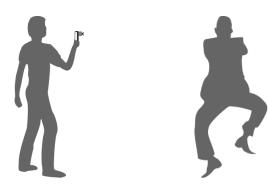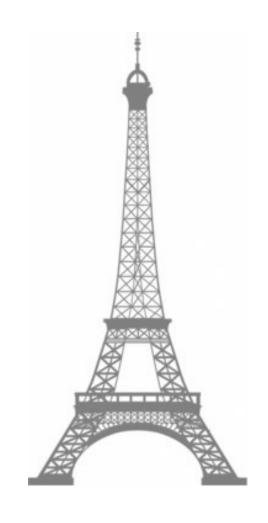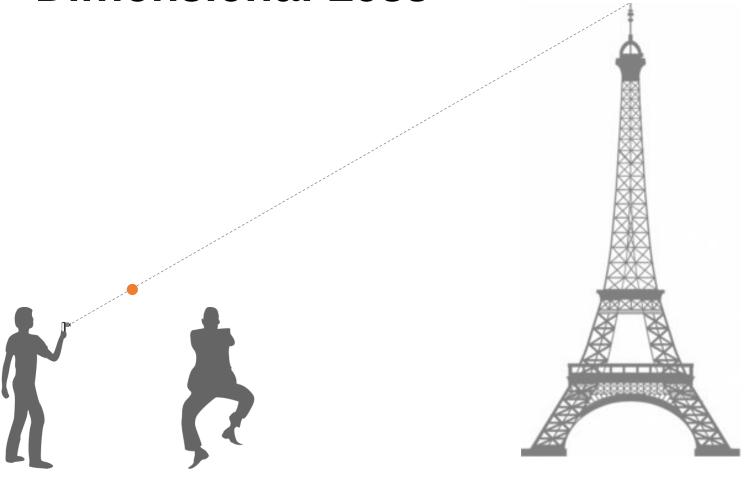
Can we recover the internal states from a video?

First person video

Vanishing line

First person video

First person video

First Vision

First person video

Cliff

3D camera trajectory

3D Computer Vision:
Where am I?

Challenge

Dimensional Loss

3D object
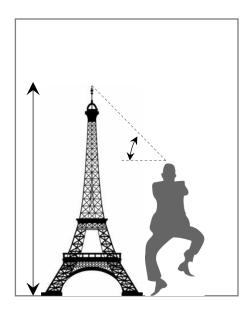
2D image

Dimensional Loss

Information loss:
• No depth

3D object
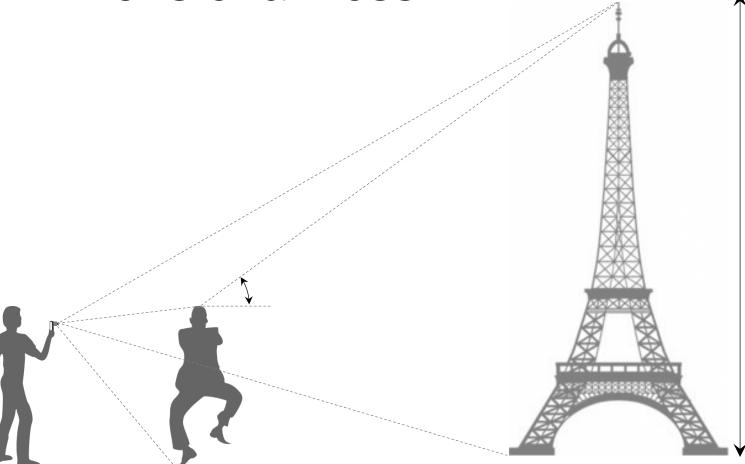
2D image

Dimensional Loss

Information loss:
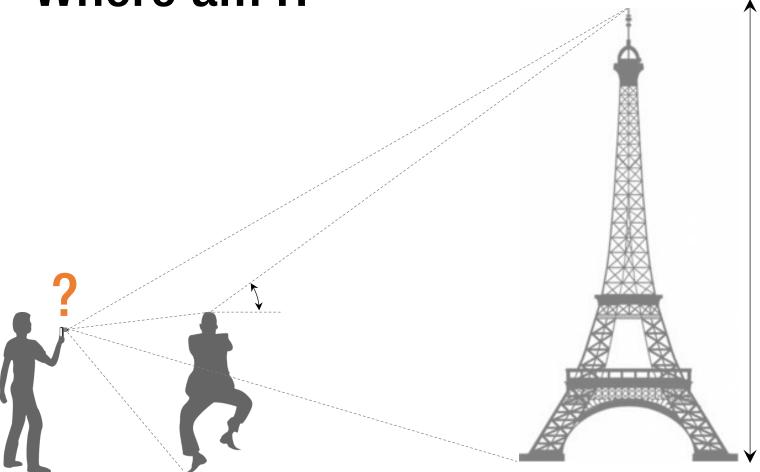- No depth

Information distortion:
- Length/ratio
- Angle

3D object

2D image

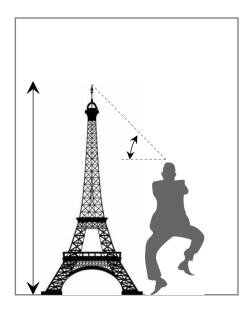# Where am I?
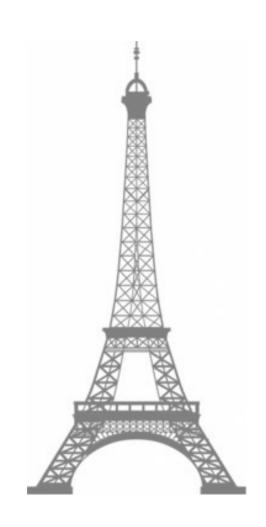
Information loss:
• No depth

Information distortion:
• Length/ratio
• Angle

?

3D object

2D image

Where am I?

3D object

Circa 1984

?

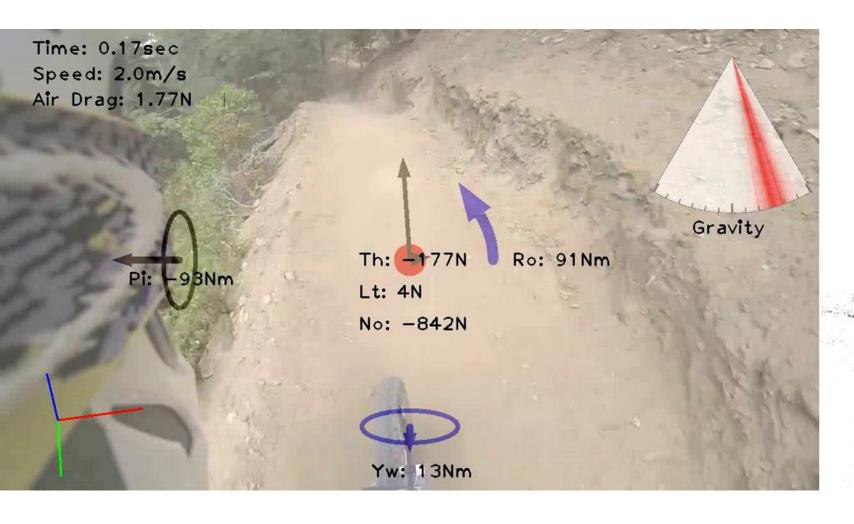**Phototourism (Snavely et al.)**

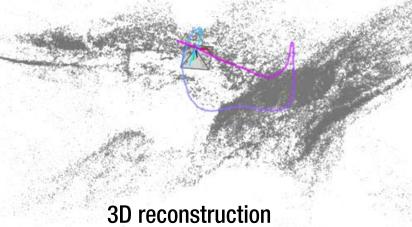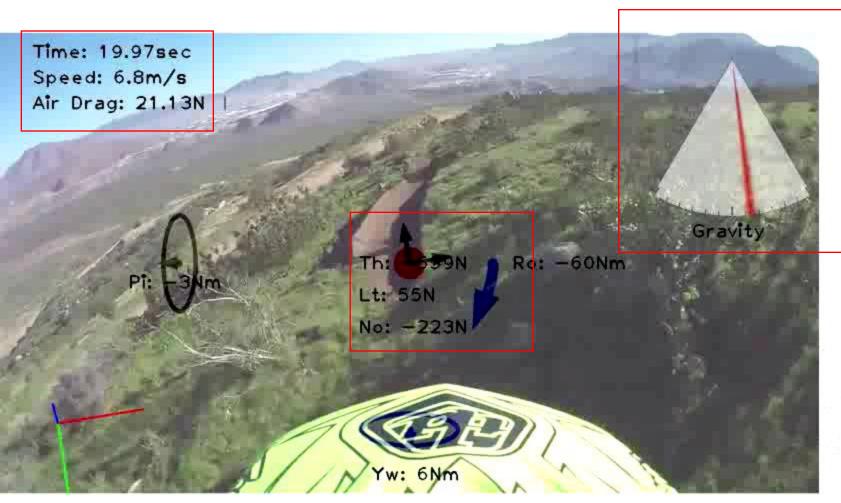Motion Capture from Wearable Cameras

Motion Capture from Wearable Cameras
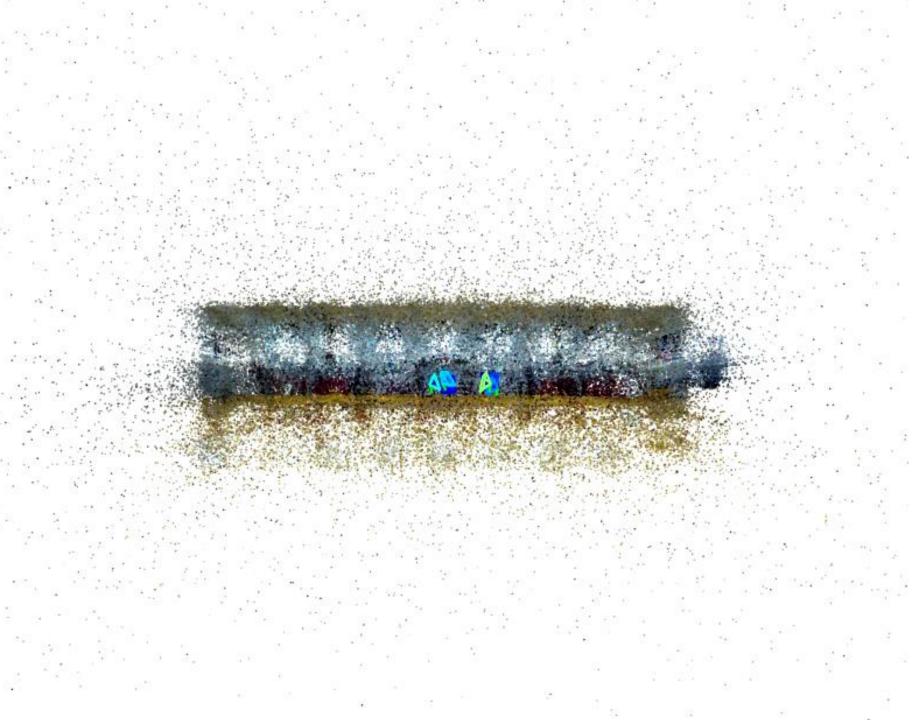
Visual SfM Demo

http://ccwu.me/vsfm/

Time: 0.17sec
Speed: 2.0m/s
Air Drag: 1.77N

Pi: −93Nm

Th: −177N

Lt: 4N

No: −842N

Ro: 91Nm

Gravity

Yw: 13Nm

3D reconstruction

Time: 19.97sec
Speed: 6.8m/s
Air Drag: 21.13N

Gravity

Pi: −3Nm

Th: −899N   Ro: −60Nm
Lt: 55N
No: −223N

Yw: 6Nm
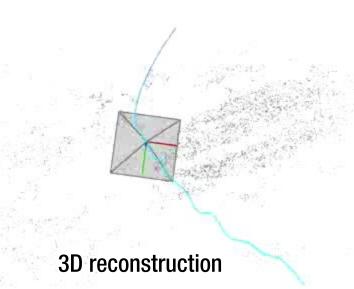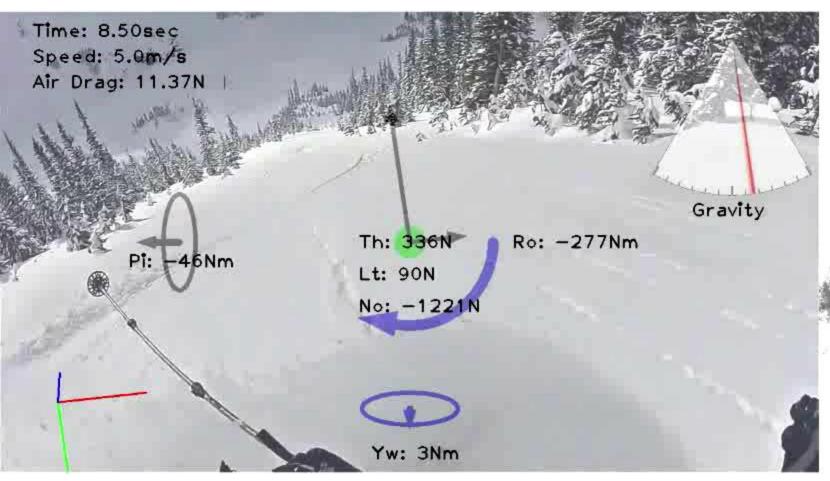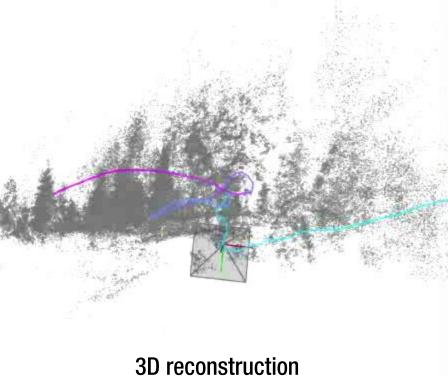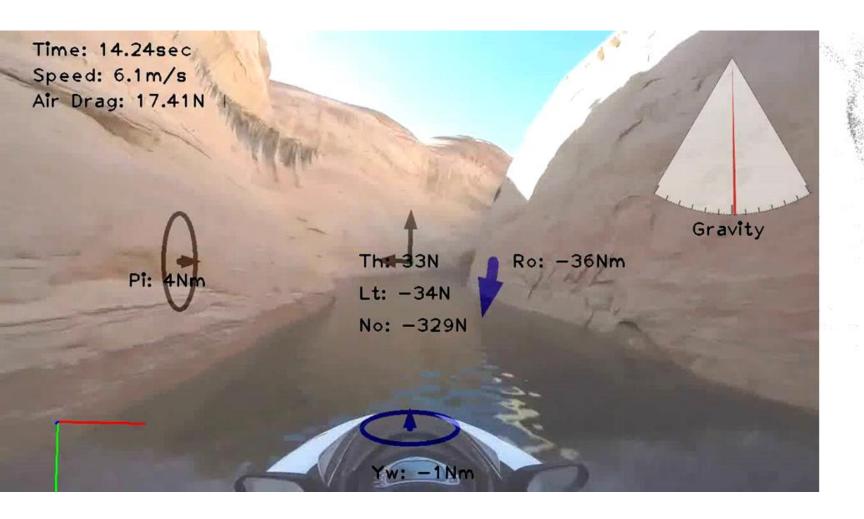
https://www.youtube.com/watch?v=aVJ45wlUE88

3D reconstruction

Time: 8.50sec
Speed: 5.0m/s
Air Drag: 11.37N

Gravity

Pi: −46Nm

Th: 336N   Ro: −277Nm

Lt: 90N

No: −1221N

Yw: 3Nm

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

3D reconstruction

Time: 14.24sec
Speed: 6.1m/s
Air Drag: 17.41N

Pi: 4Nm

Th: 33N
Lt: -34N
No: -329N

Ro: -36Nm

Gravity

Yw: -1Nm

Time: 5.17sec
Speed: 12.6m/s
Air Drag: 73.60N

Gravity

Pi: 2Nm

Th: −699N   Ro: −3Nm
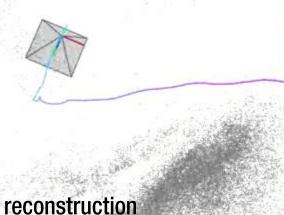Lt: −56N
No: −17N

Yw: 12Nm

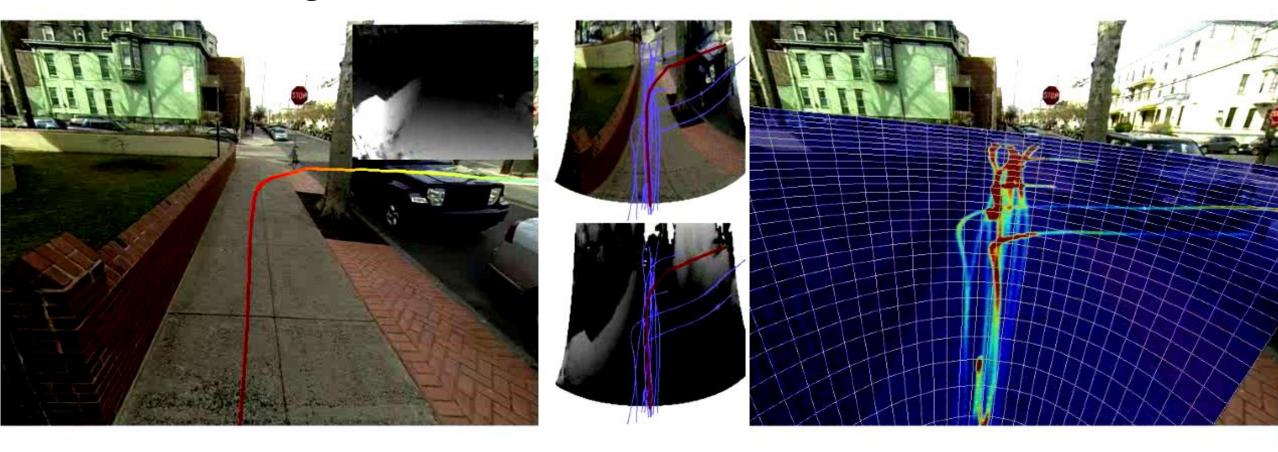https://www.youtube.com/watch?v=rnvvsjstveM

3D reconstruction

Predicting Future
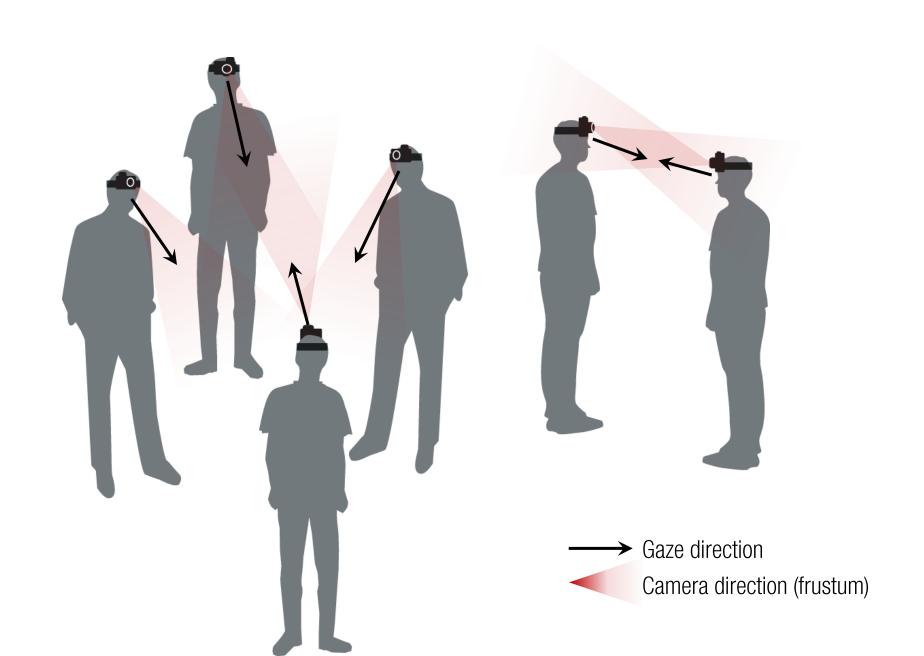
Ground truth   EgoRetinal map   Predicted trajectories
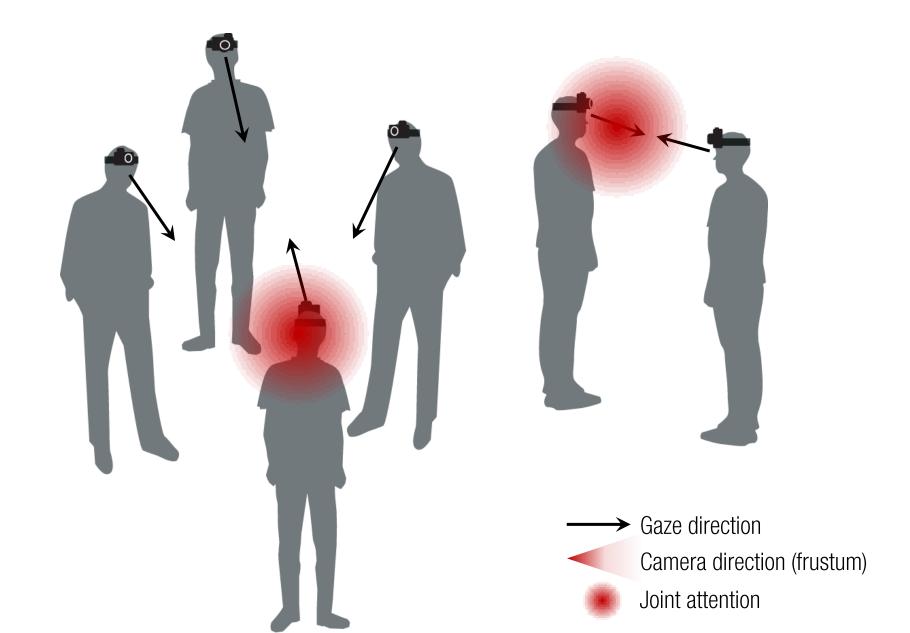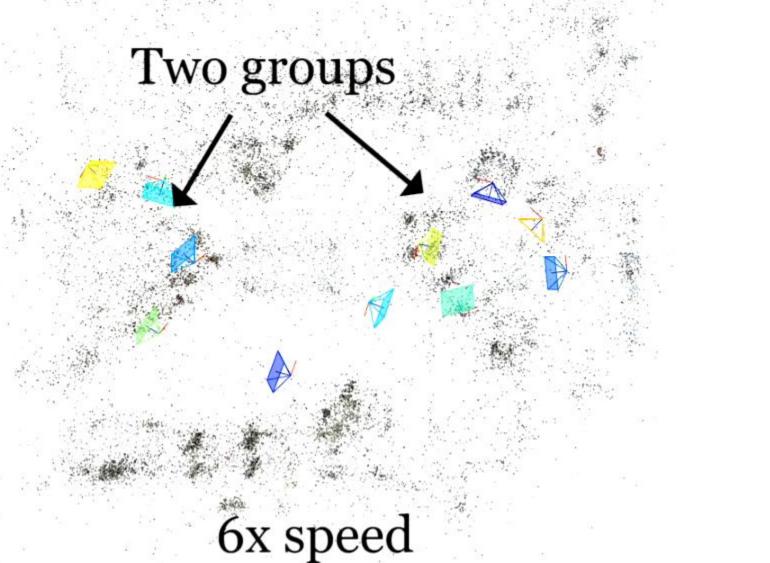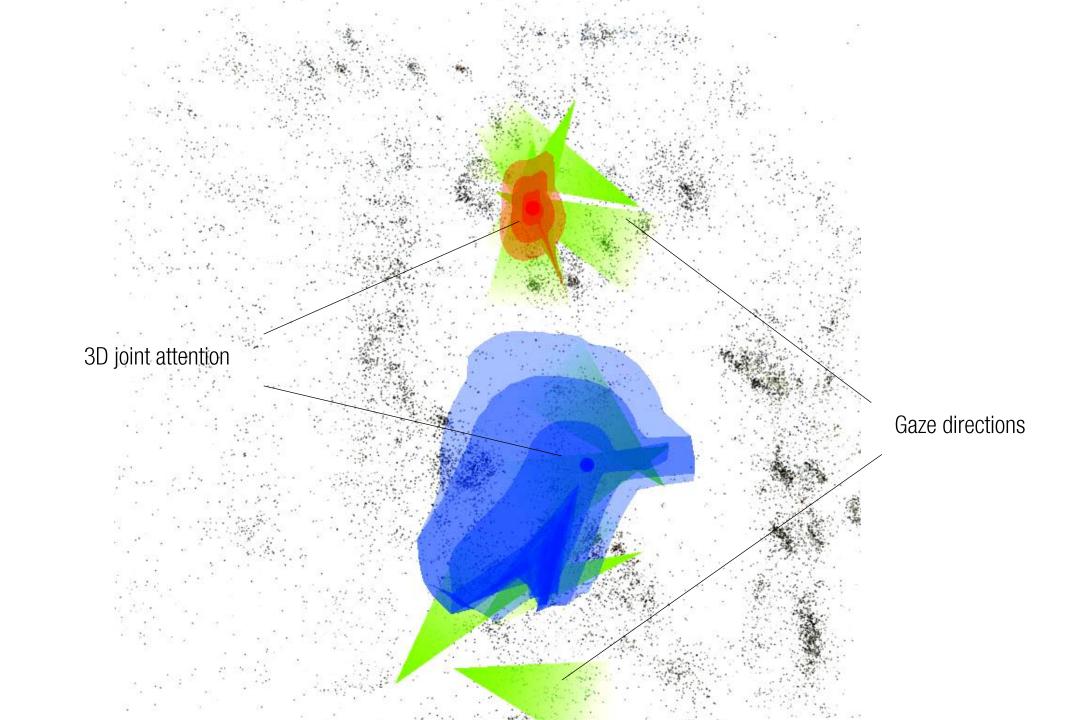
Gaze direction

Camera direction (frustum)

Joint Attention

Gaze direction

Camera direction (frustum)

Joint attention

Input Video: Meeting Scene

1x speed

3D Camera Pose Estimation
(Structure from motion)

Two groups

6x speed

3D joint attention

Gaze directions
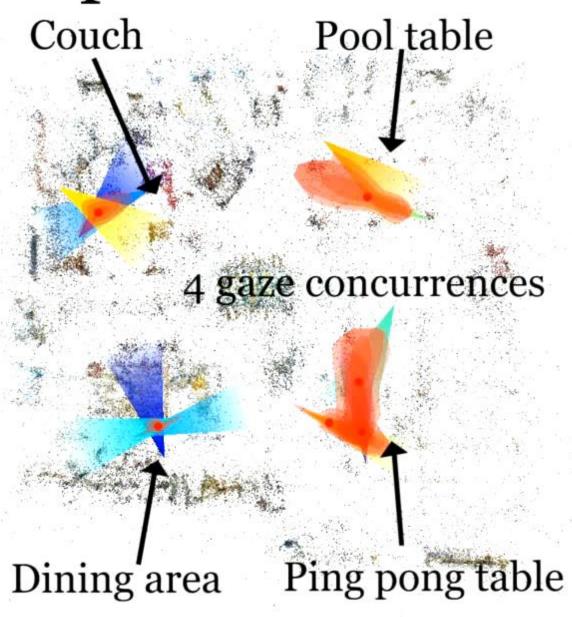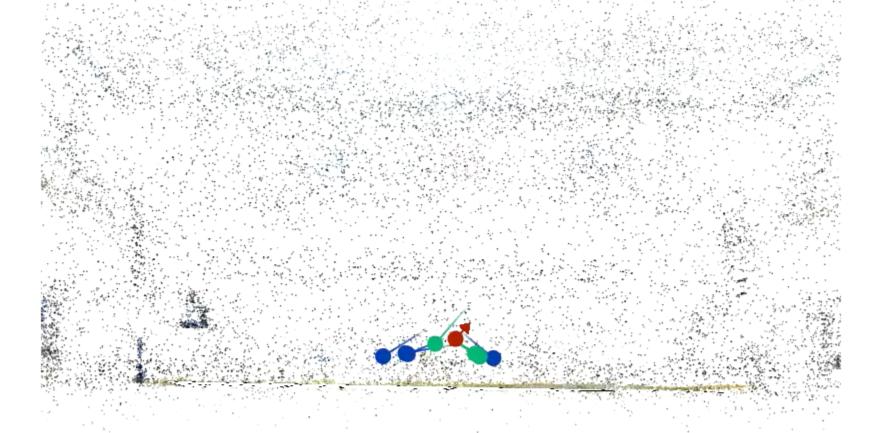
Party Scene: 4 groups in a room

Couch

Pool table
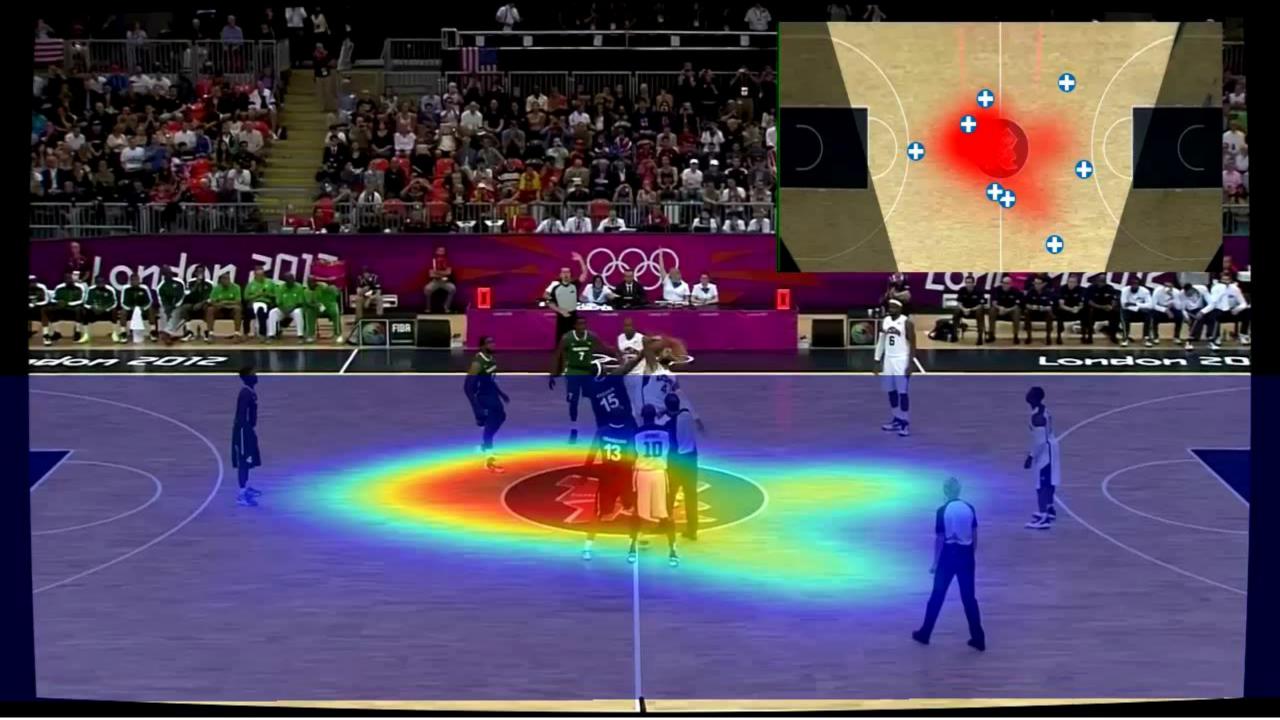
4 gaze concurrences

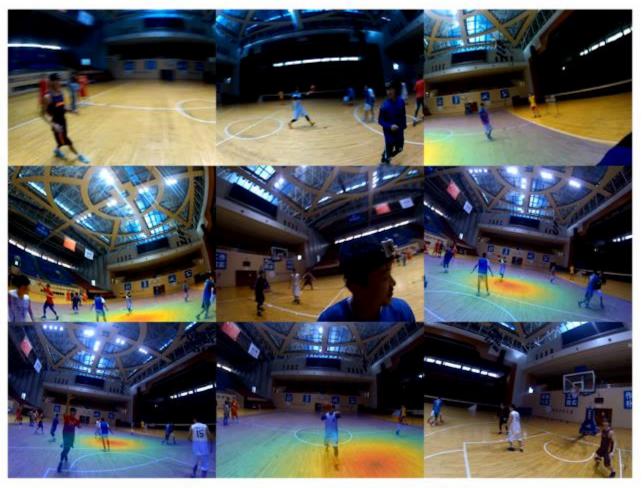1x speed

Dining area

Ping pong table

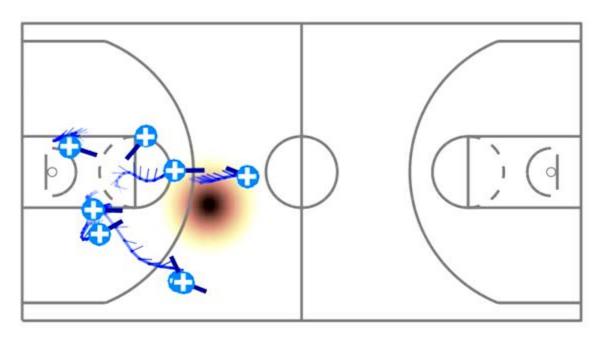First Person Basketball Data
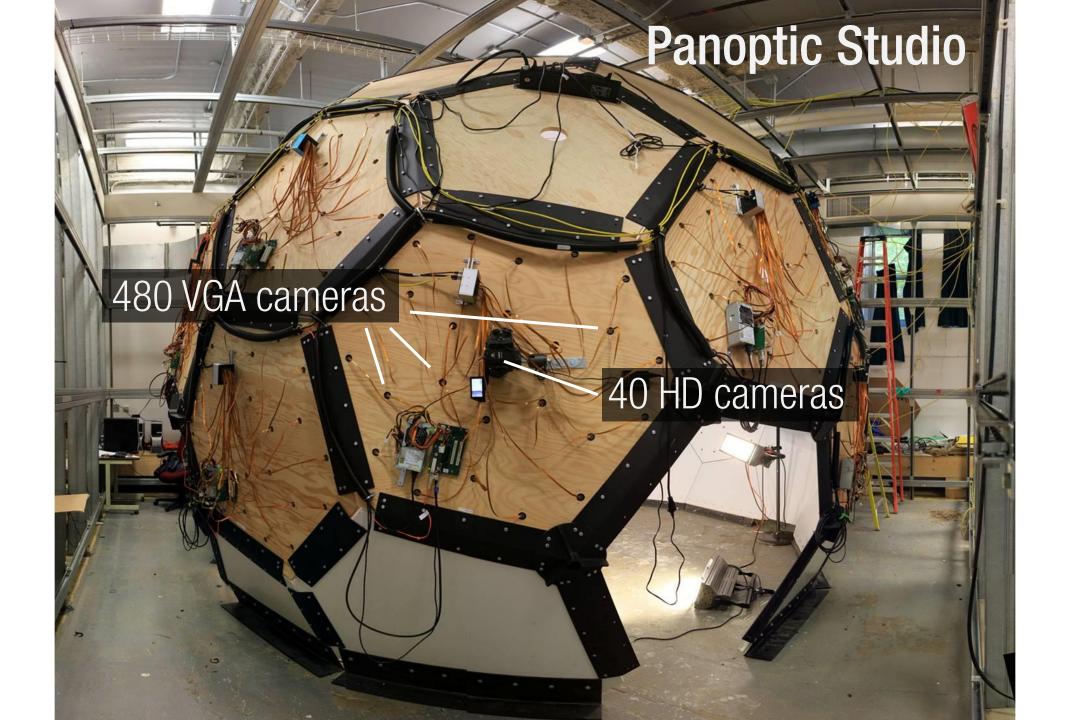
Ground truth location

Predicted gaze direction

Predicted location

First Person Video

Output: Social Prediction
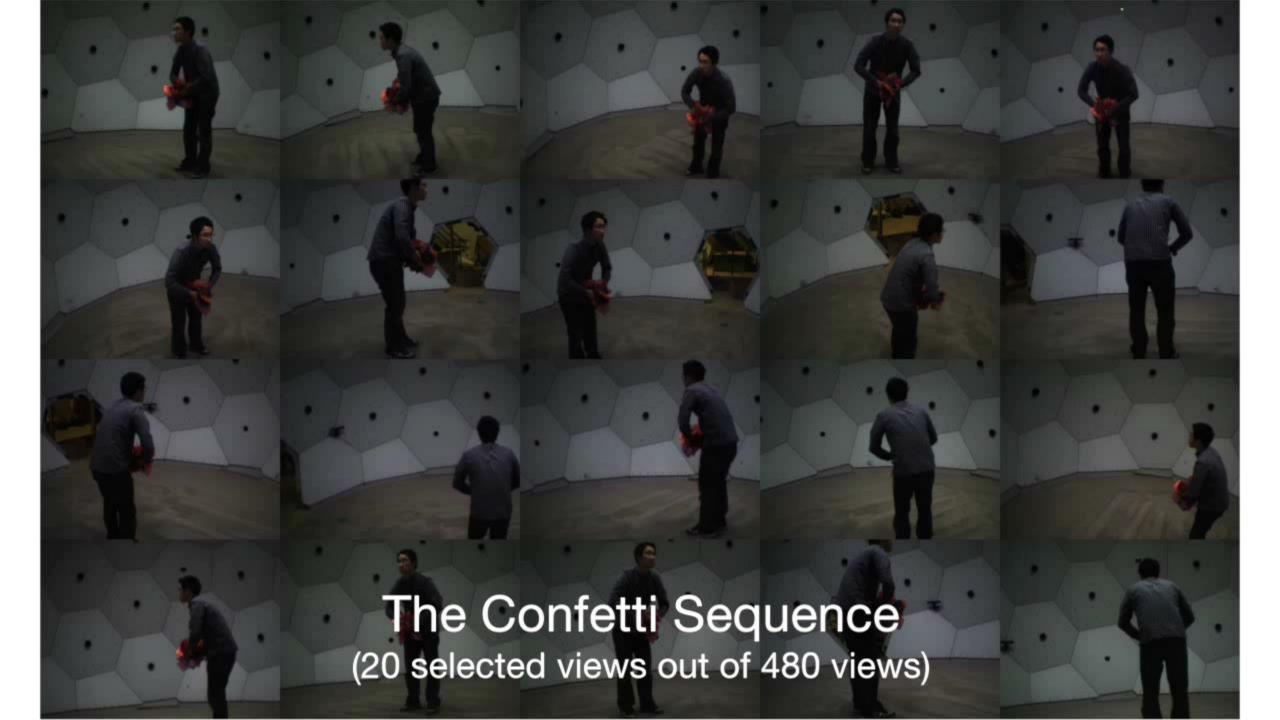
*Images without projection are missing data due to structure from motion failure.

Panoptic Studio

480 VGA cameras

40 HD cameras

3D Trajectory Reconstruction

3D Trajectory Reconstruction

The Confetti Sequence
(20 selected views out of 480 views)
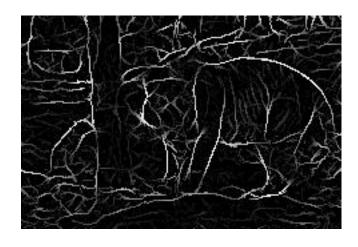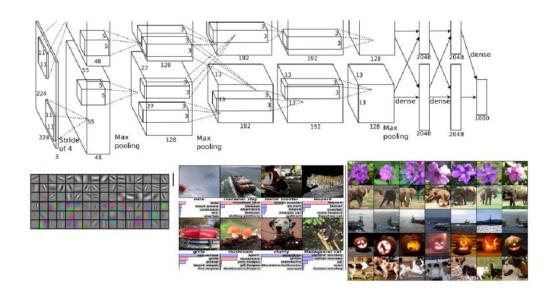
This Course is NOT about …

- Deep learning computer vision course (8980 by Prof. Zhao)

- Image processing (5561 by Prof. Isler)

- Visual SLAM course / Filtering / State Estimation (5552 by Prof. Roumeliotis)

This Course is about …

- Geometry

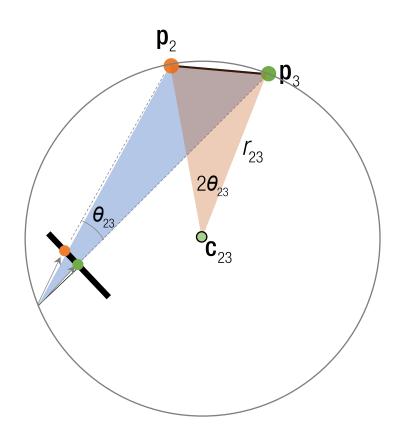- Your cellphone camera
- Your cellphone image

- Programming


```
function ComputeCameraUsingVanishingPoint

im = imread('undistorted.png');

l11 = GetLineFromTwoPoints(m11,m12);
l12 = GetLineFromTwoPoints(m13,m14);
```
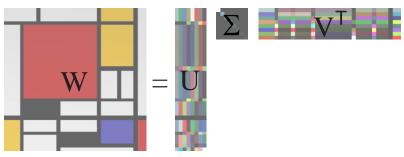
This Course requires …

- Linear Algebra!!!

- A lot of practice with images
  - Always make yourself ready to take a picture.

- Pencil and eraser for drawing

- Creative thinking
  - Where to apply?

- Cool visualization (graduate from MATLAB plot3)!

$$W = U \Sigma V^T$$

Body-mounted cameras

This Cours

- Linear Algebra!!

- A lot of practice
  - Always make

- Pencil and era

- Creative thinking
  - Where to ap

- Cool visualization (graduate from MATLAB plot3)!

$= U$ Σ V^T

nted cameras

After this course, you will …

- Have your own SfM code.

- Understand geometry of scene and camera.

- Be able to read CVPR, ICCV, and ECCV papers (at least geometry papers).

CVPR 2017

ABOUT

CVPR is the premier annual computer vision event comprising the main conference and several co-located workshops and short courses. With its high quality and low cost, it provides an exceptional value for students, academics and industry researchers.

Rubric

- Grading
  - 6 programming assignments (90 % = 15% per hw x 6)
  - 1 paper presentation (10 %)

- Late policy
  - 20% off from each extra late day

- Office hours
  - Tue/Thr 2:00p-4:00p

- For 8980 students
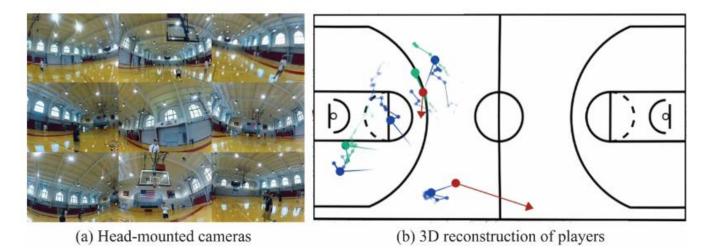 - Scalable SfM code (running with more than 30 images).

Website

- http://www-users.cs.umn.edu/~hspark/CSci5980/csci5980_3dvision.html

Spring 2017 CSCI 5890/8980
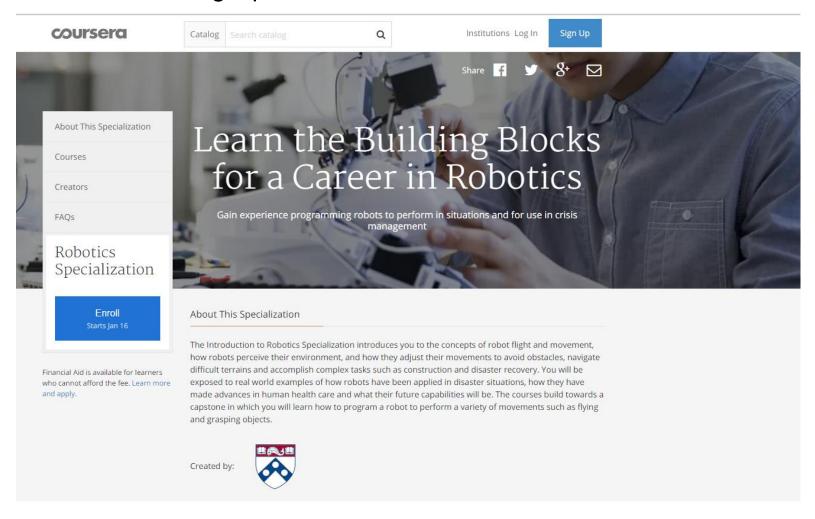**Multiview 3D Geometry in Computer Vision**

Tue/Thr 4:00pm-5:15pm @ Rapson Hall 43

Description

(a) Head-mounted cameras

(b) 3D reconstruction of players

Coursera

- https://www.coursera.org/specializations/robotics

Homework

- HW #1: Take a picture of you appearing the same size with tree and measure the tree height.
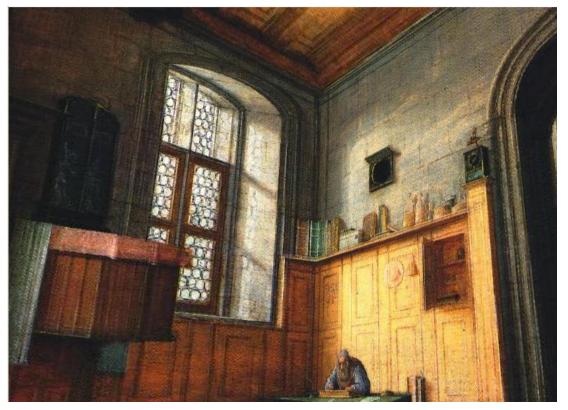

Camera obscura

Image by camera obscura

Image by cellphone camera

Homework

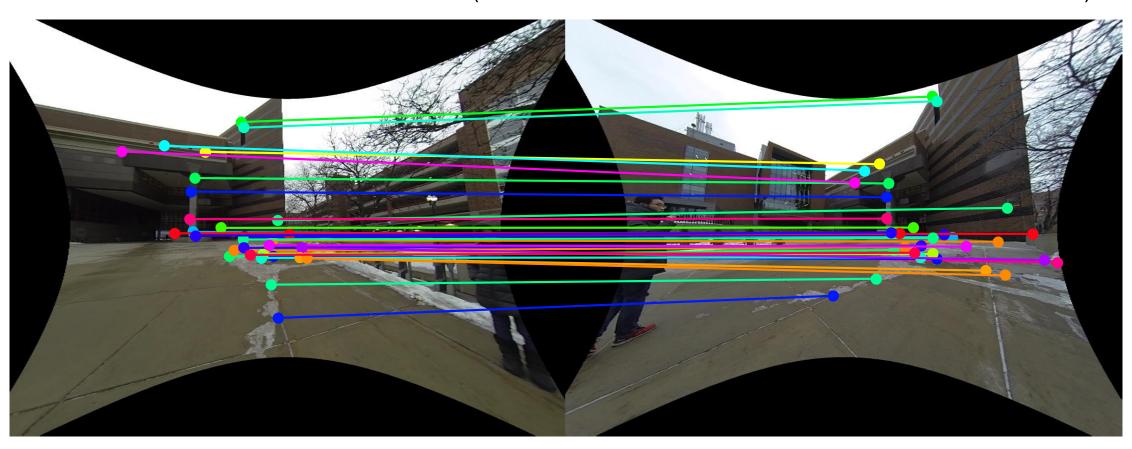- HW #2: Creating a panoramic 360 image and making a visual display

http://bevirtual.ru/sites/default/files/field/image/5_177.jpg

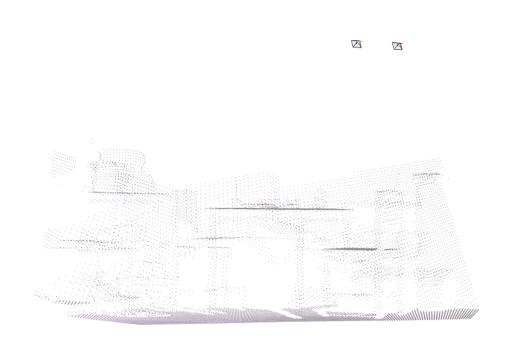# Homework

- HW #3: Virtual tour into your photos

Homework

- HW #4: Structure from Motion I (Fundamental matrix / RANSAC / Camera Pose)
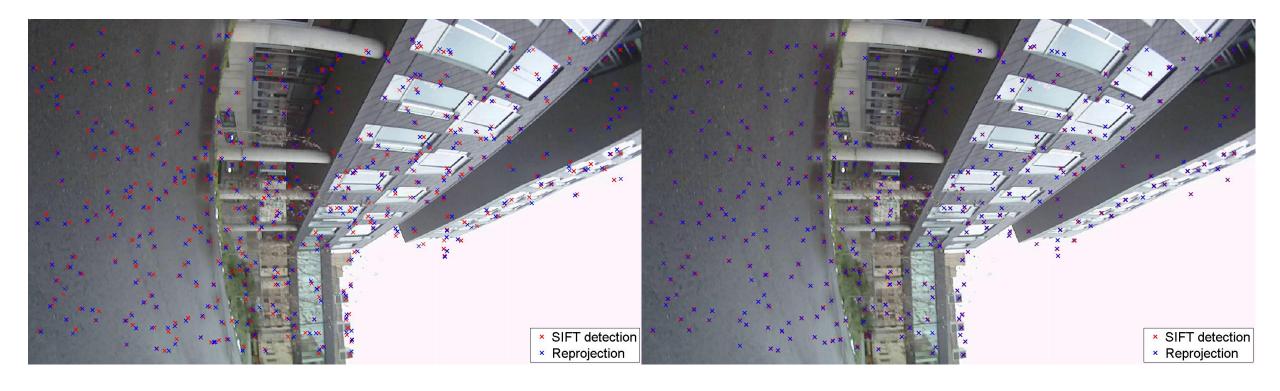
Homework

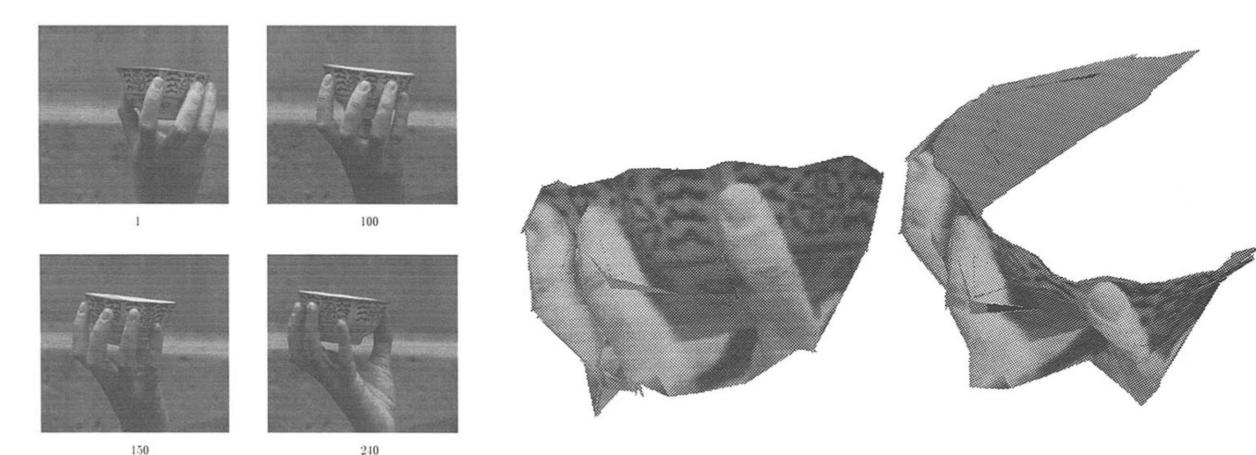- HW #5: Structure from Motion II (Triangulation / PnP)

Homework

- HW #6: Structure from Motion III (Bundle adjustment)

Paper Presentation

- Format
  - 20 min presentation with 15+ min questions
  - One presenter: this person defends the paper.
  - One committee: this person attacks the paper.

- You are free to choose a paper that
  - Is not written by you or your research group
  - Has a strong relevant to 3D vision (theory and application)
  - Is approved by me

- Or, you can choose a paper from my list.

Paper List

- Tomasi and Kanade, Shape and Motion from Image Streams under Orthography: a Factoriaztion Method, IJCV, 1992

Paper List

- Reid and Zisserman, Goal-directed Video Metrology, ECCV, 1996

Paper List

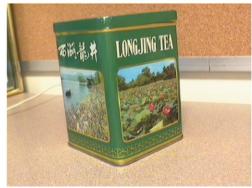- Zhang, A Flexible New Technique for Camera Calibration, PAMI, 2000
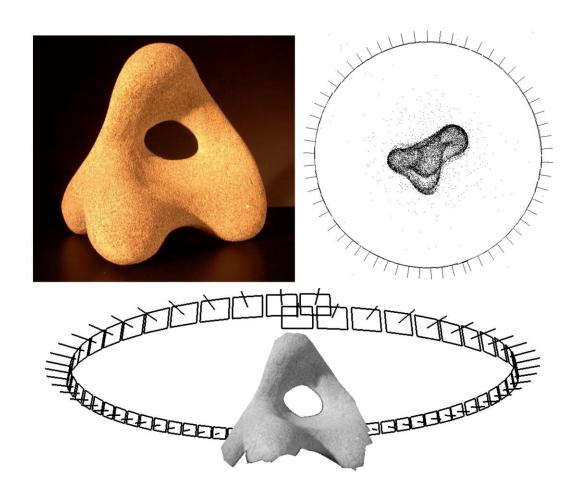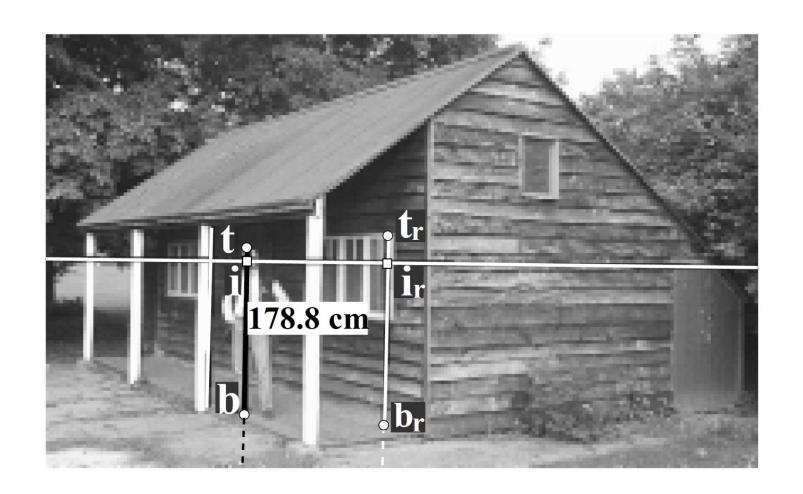

Figure 6: Two images of a tea tin

Figure 7: Three rendered views of the reconstructed tea tin

Paper List

- Nister, An Efficient Solution to the Five-Point Relative Pose Problem, PAMI, 2004

Paper List

- Criminisi, Reid, and Zisserman, Single View Metrology, IJCV, 2000

Paper List

- Xiao and Furukawa, Reconstructing the World's Museum, ECCV, 2012

Paper List

- Izadi et al., KinectFusion, UIST, 2011

Reference

Questions?