# Today

**Areas in computer vision**

**Perspective Camera Models**

**Reading Assignments:**

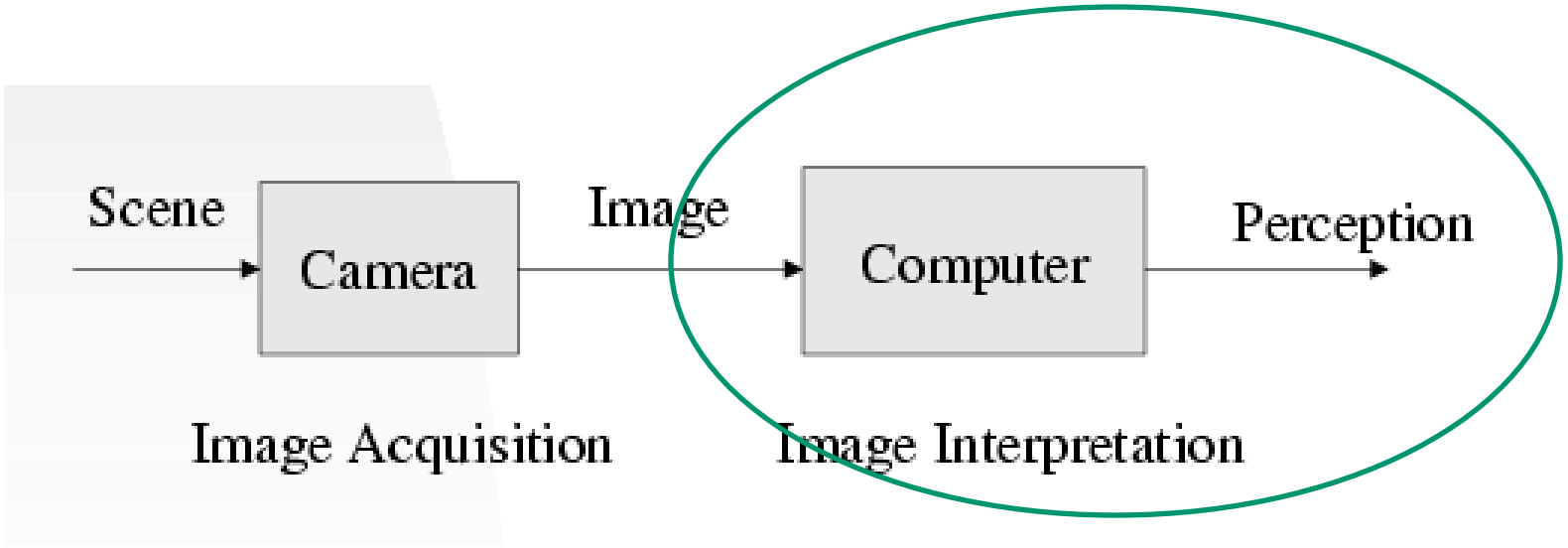
- Chapter 1, David A. Forsyth and Jean Ponce, "Computer Vision: A Modern Approach",

**Related Reference**

- Chapter 3, Olivier Faugeras, "Three Dimensional Computer Vision", MIT Press, 1993

# Computer Vision

**Computer Vision is the study of analysis of pictures and videos (using computers) in order to achieve results similar to those as by human.**

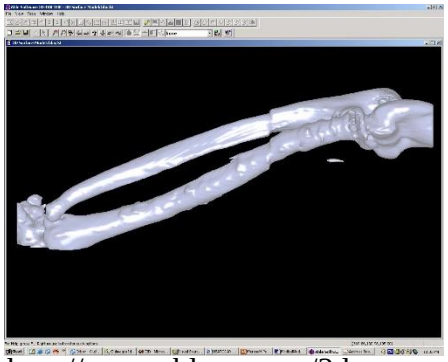


# Why Computer-Vision

**We are using computer vision techniques every day in our daily life.**

**Numerous applications**

- 3D/4D Medical image
- Surveillance
- Image retrieval from database
  - –Google image
  - –Amazon go
- Self-driving
- Robotics
- and more …

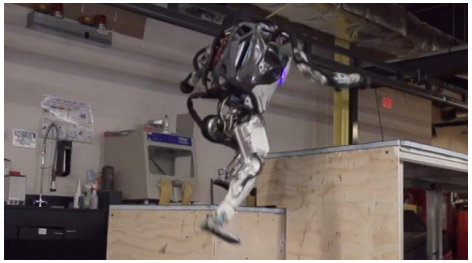


http://www.ablesw.com/3d-doctor/surgmod.html



https://cars.usnews.com/cars-trucks/autonomous-vehicle-levels

https://www.castlewallsecurity.com/home-security-cameras/



https://www.extremetech.com/tag/boston-dynamics

# Why Computer-Vision

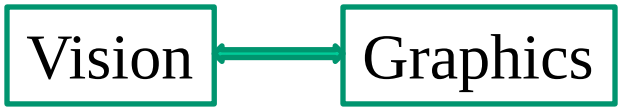
The total size of the worldwide computer vision industry was estimated at $10.6 billion in 2019 (Computer Vision Market Size & Share Report, 2020-2027 (grandviewresearch.com)), and will increase to $18.24 billion by 2025 (Machine Vision Market Size Worth $18.24 Billion By 2025 (grandviewresearch.com))

# Vision vs Graphics

***Vision***: **from image to model/perception (analyzing image)**

***Graphics***: **from model/perception to image (constructing image)**

**So they are inverse and correlated processes**




**Human vision always see the world with prior model (knowledge) in the mind**

**Models are usually important in vision**

**Problem is how to incorporate the model into the image understanding process**

# Related Areas

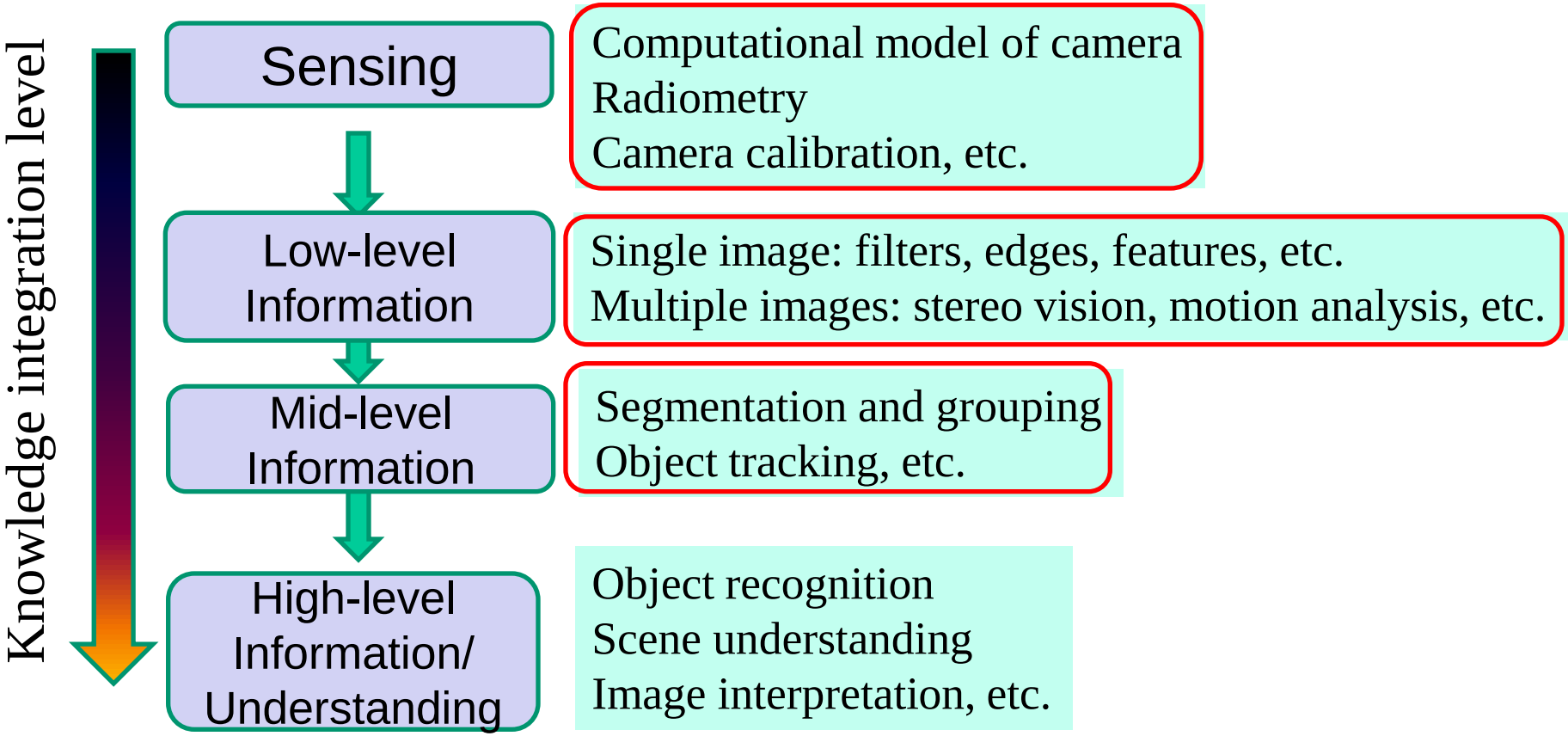
*Computer vision* overlaps with *image processing,* and *machine learning* significantly.

- *Image processing*: operations are usually performed from image to image including compression, restoration, and enhancement

- *Machine learning*: development of computer algorithms to automatically learn models from data (experience) and improve prediction/decision making

*Image processing* and *machine learning* are important tools used in computer vision.

# Hierarchy of Computer Vision Problems



# Some Problems in Computer Vision: Imaging Process

**Imaging process**

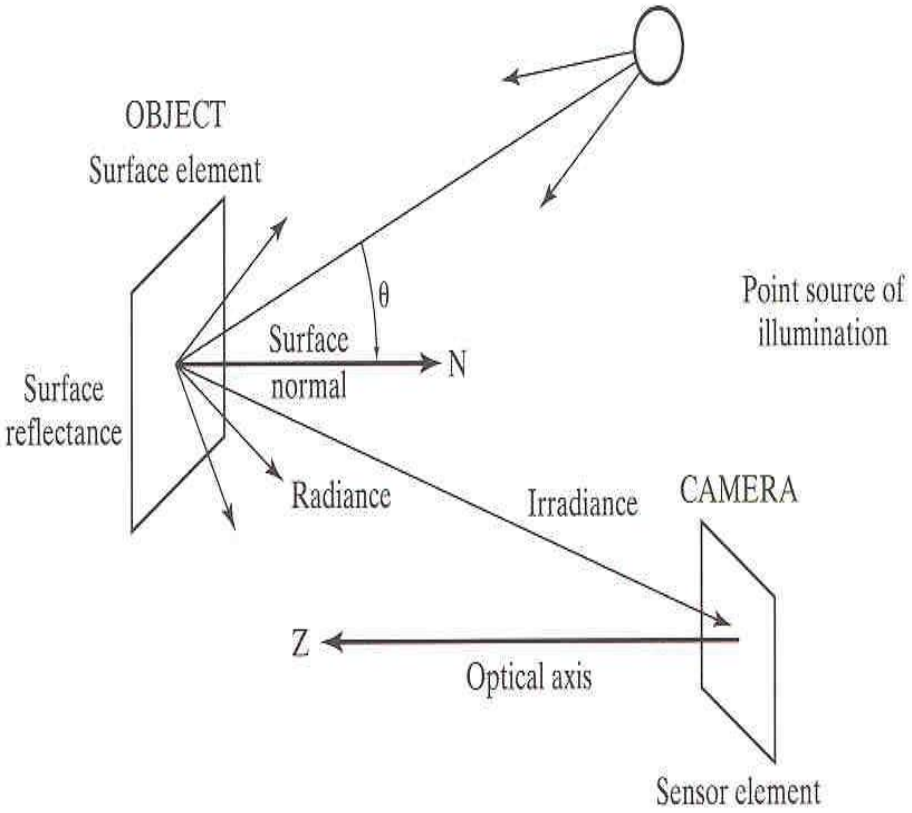
- Light reaches surfaces in 3D
- Surfaces reflect light
- Sensor element receives light energy

**Factors**

- Intensity of energy
- Surface roughness
- Surface material

**Issues**

Shadow and occlusions



# Some Problems in Computer Vision: Perspective Projection

**Camera model -- Perspective Projection**

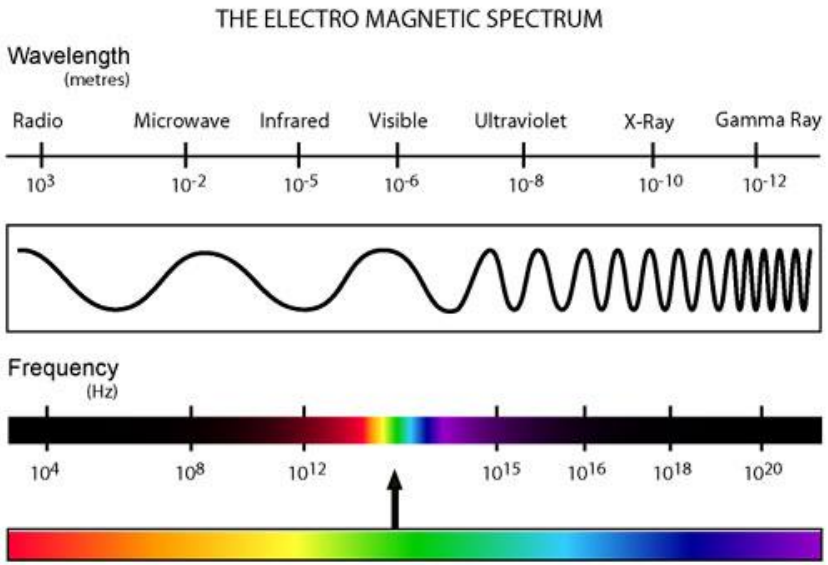
**3D←→2D**

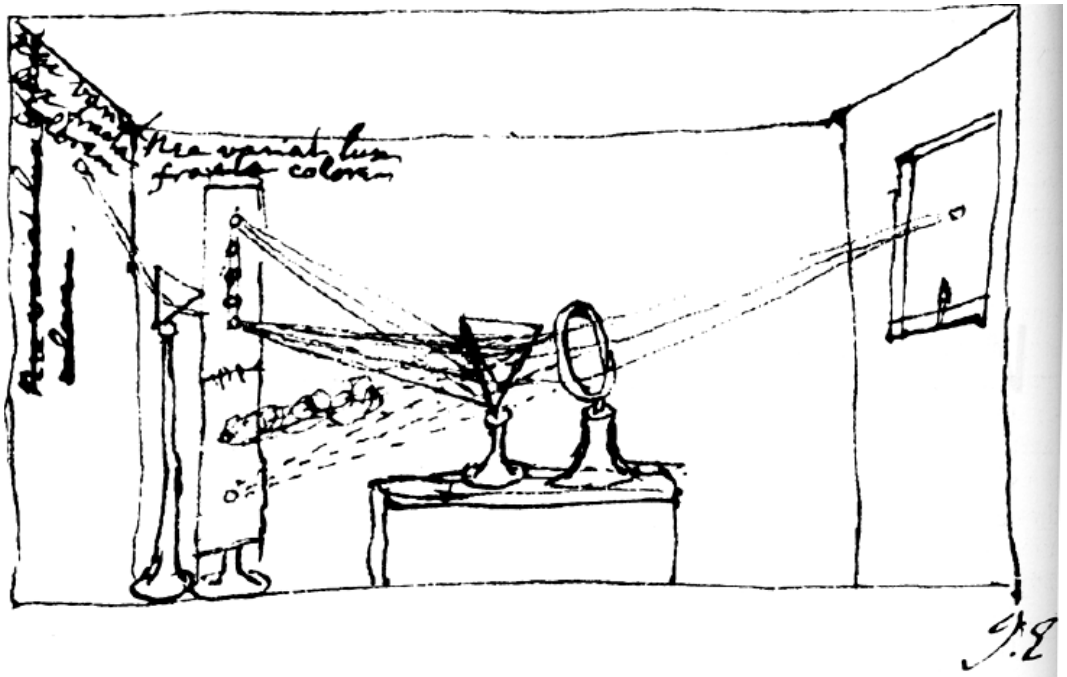
The right figure is a picture of a cubic prism taken by a camera, isn't it?

**Yes. How do you know this?**

This involves camera model and projection transform. The developed method can be used to decide whether a building picture is a faked one

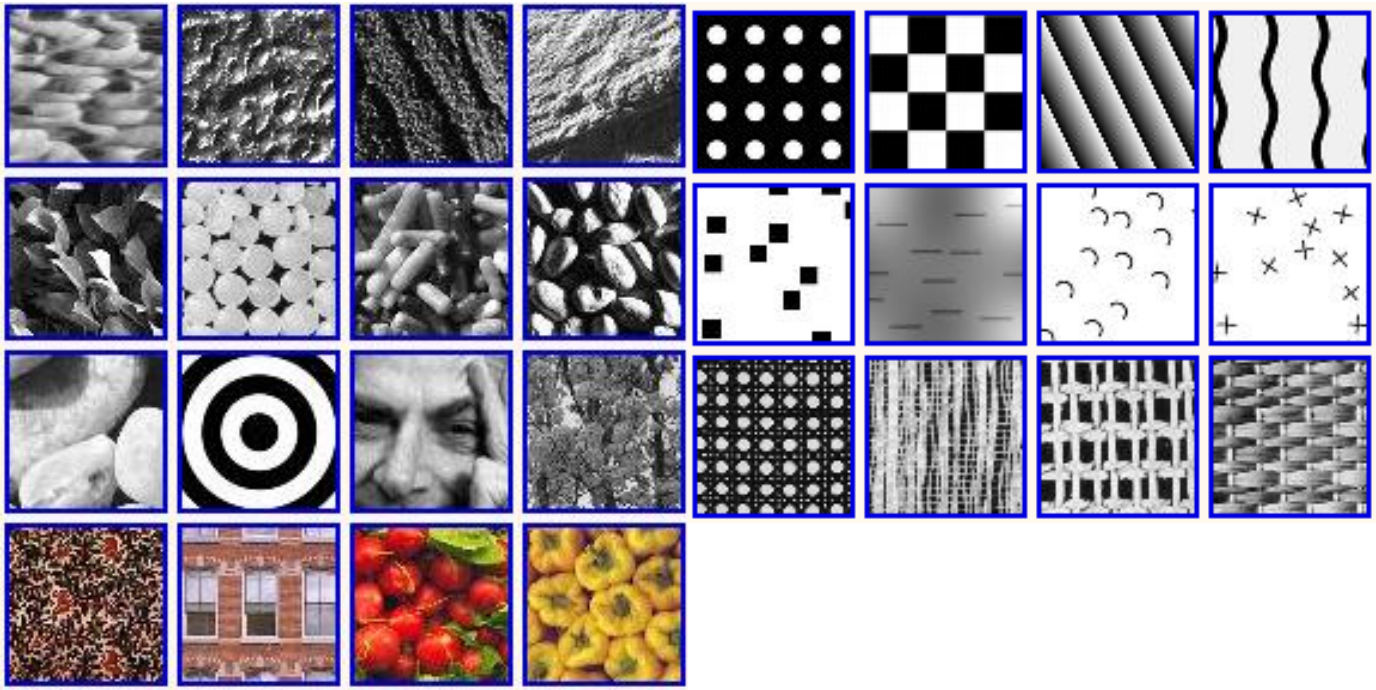
# Some Problems in Computer Vision: Color



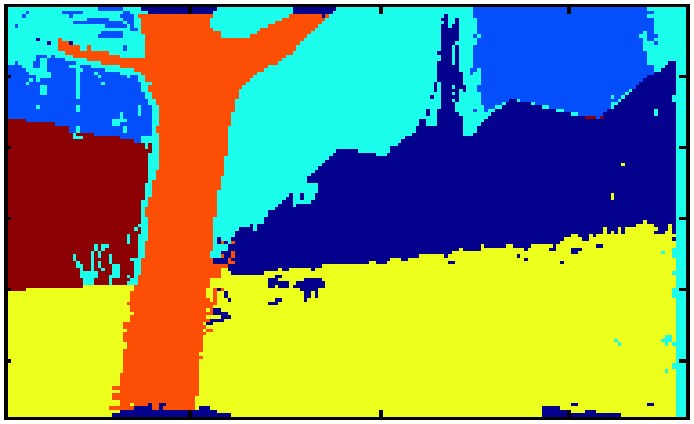



4.1 **NEWTON'S SUMMARY DRAWING** of his experiments with light. Using a point source of light and a prism, Newton separated sunlight into its fundamental components. By reconverging the rays, he also showed that the decomposition is reversible.

# Texture



# Some Problems in Computer Vision: Grouping and Segmentation



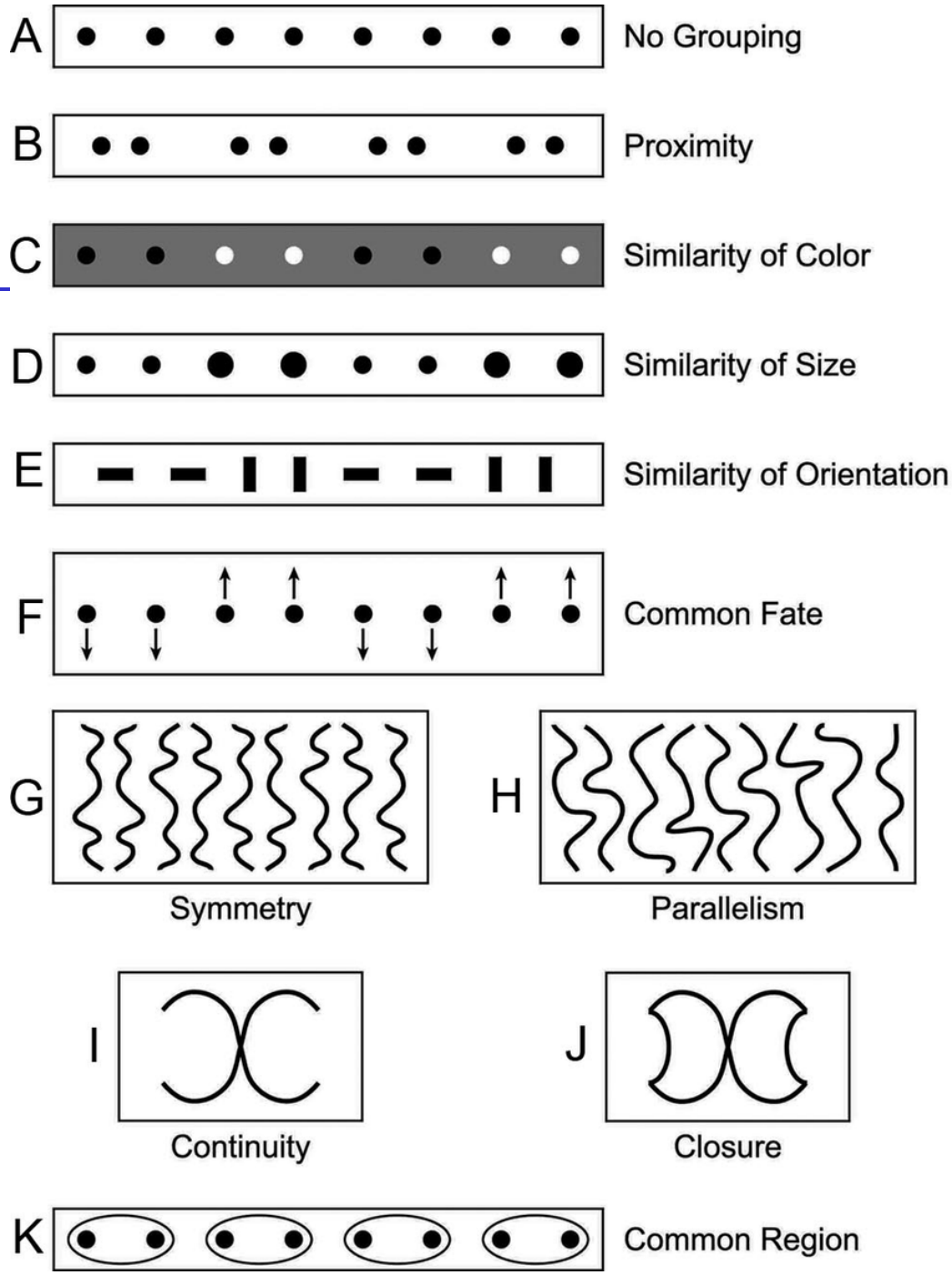
What can you do after segmentation?

Manipulate by PhotoShop

Movie generating- Greenscreen

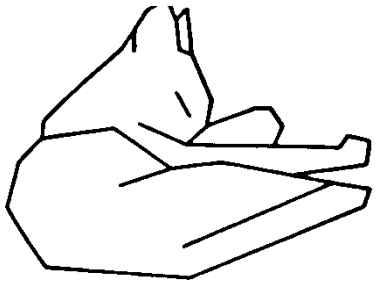

https://www.youtube.com/watch?v=2lLAc03DaeI

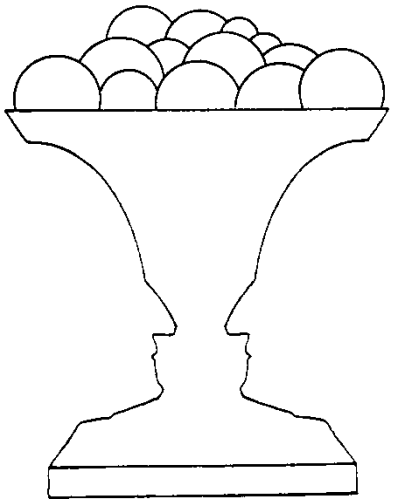
# Perceptual Organization



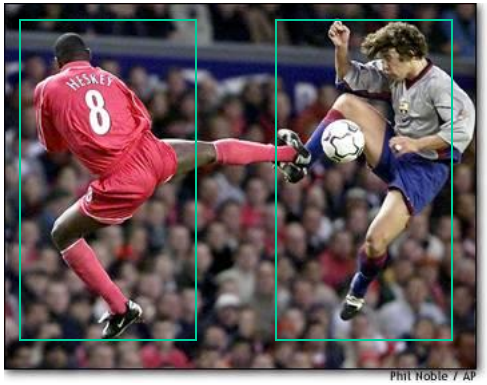

Wagemans, Johan & Elder, James & Kubovy, Michael & Palmer, Stephen & Peterson, Mary & Singh, Manish & Heydt, Rüdiger. (2012). A Century of Gestalt Psychology in Visual Perception: I. Perceptual Grouping and Figure-Ground Organization. Psychological bulletin. 138. 1172-217. 10.1037/a0029333.

# Object Recognition from Shape Analysis





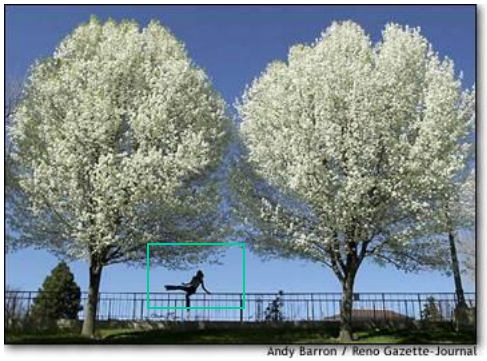
# Human Detection/ Localization



Phil Noble / AP

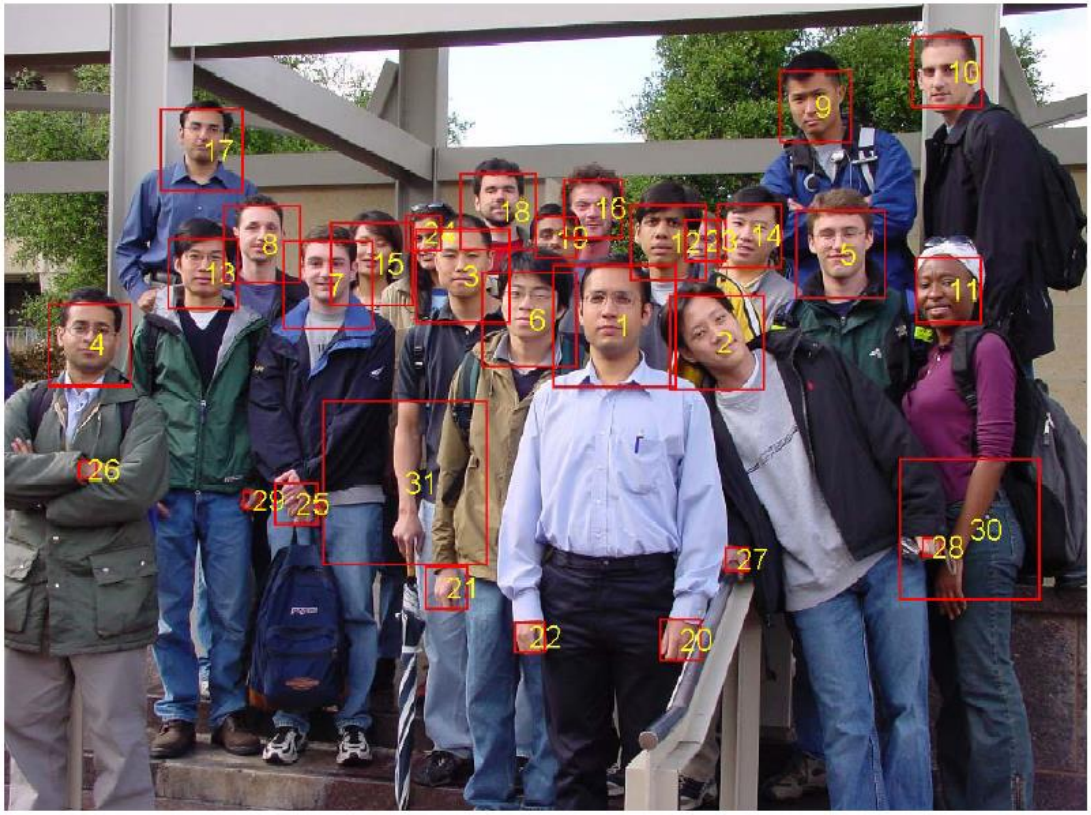

Mike Hewitt / Allsport


Patrick Gardin / AP

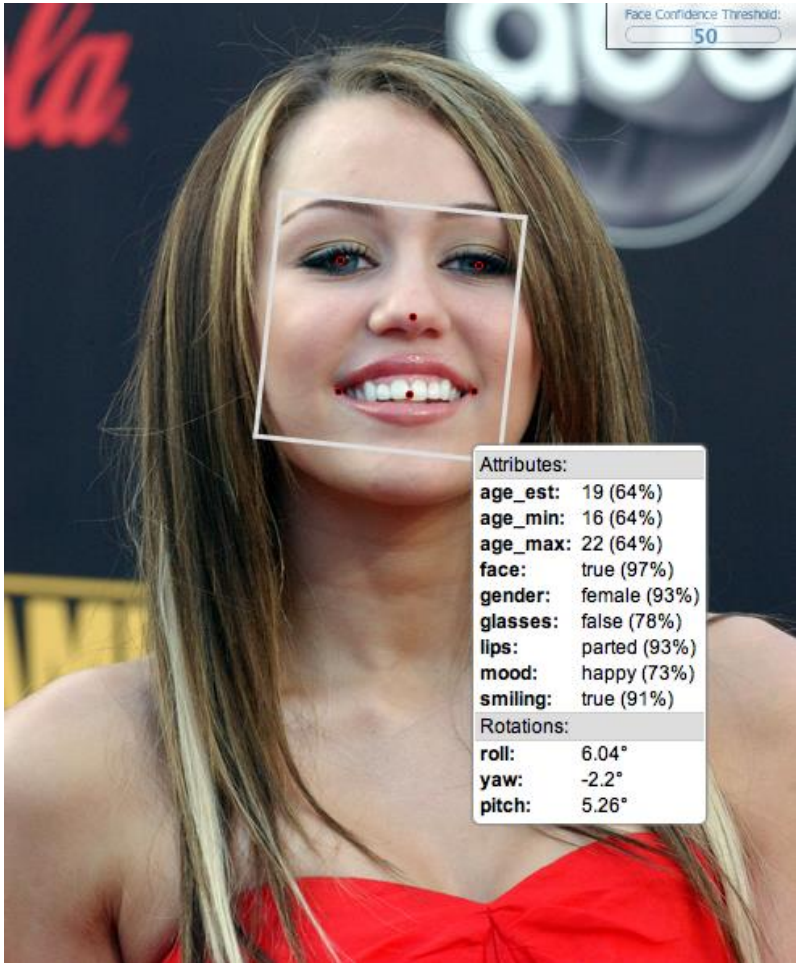

Andy Barron / Reno Gazette-Journal


Sydney Morning Herald

# Face Detection/Recognition

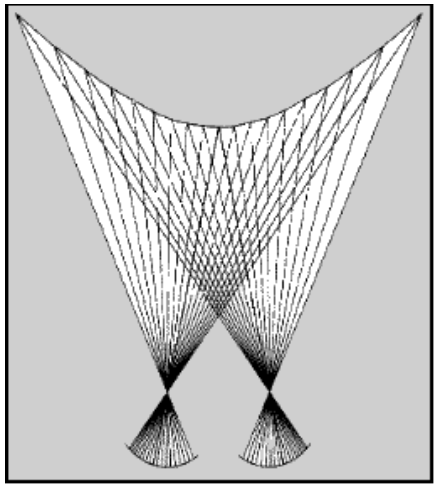


# More from a Face

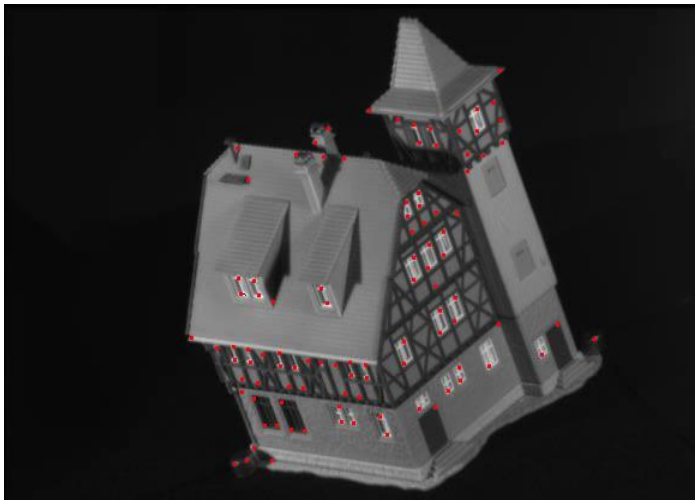


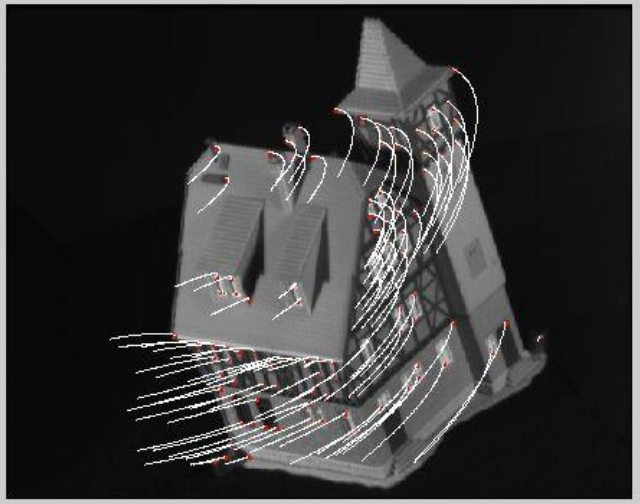
# Stereopsis

From 2D to 3D: Our world is 3D, but images are 2D projection from a specific view point, what can we do



# Motion and Optical Flow





# Tracking People

Human activity recognition: surveillance, behavior analysis, gait, etc.

# Computer-Vision Resources

http://resources.visionbib.com/

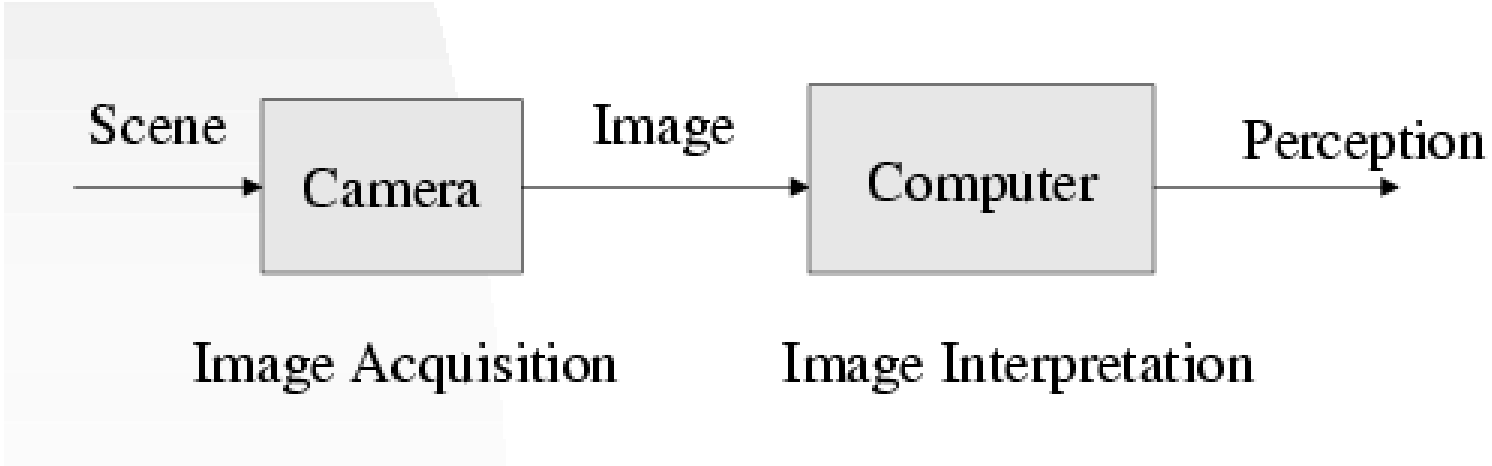
**OpenCV Library**

Home – OpenCV

**PyTorch Library**

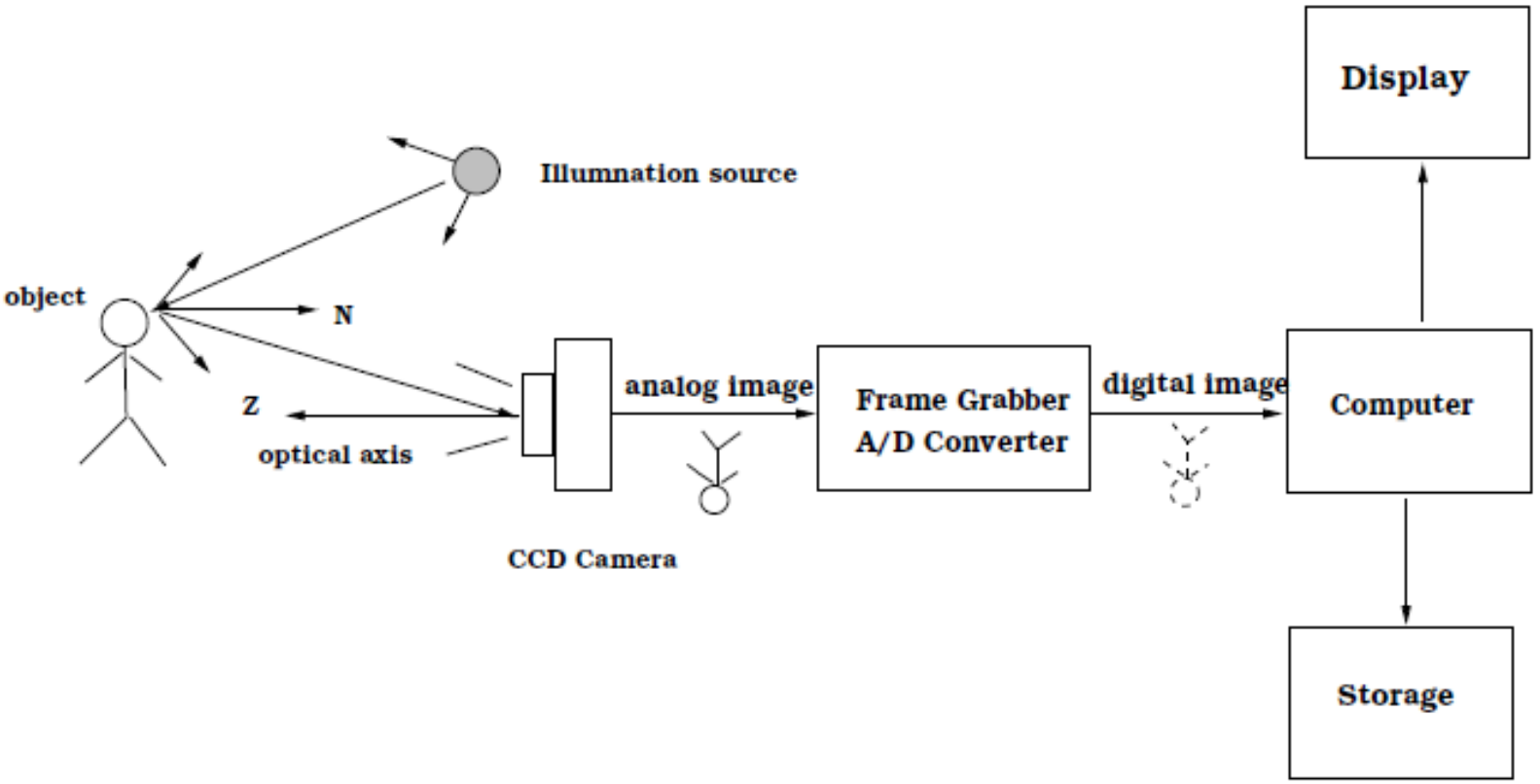
PyTorch

# Next




**How to get image --- Camera**

# Digital Image Acquisition

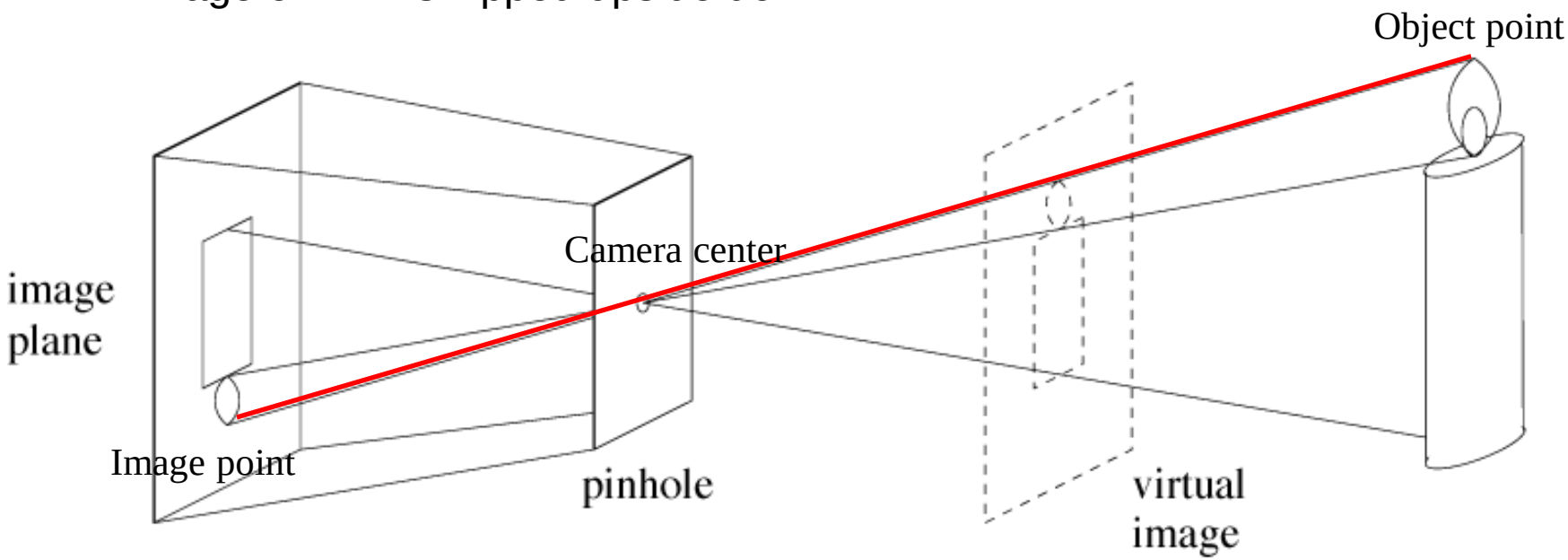


# Basic Optics: Pinhole Cameras

**Mount a piece of film in a lightproof box with a single pinhole in it**

**Pinhole focuses light on the film**

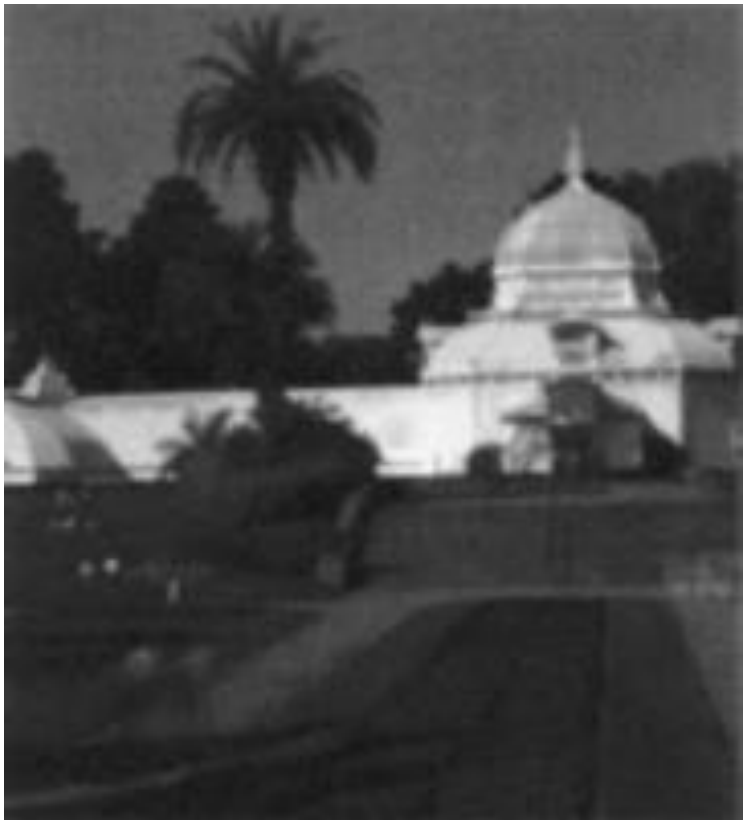
- Lens degenerates to a point
- One-to-one correspondence between 3D object point and 2D image point
- Only select light ray can go through the hole (the hole is reduced to a point)
- Image on film is flipped upside down



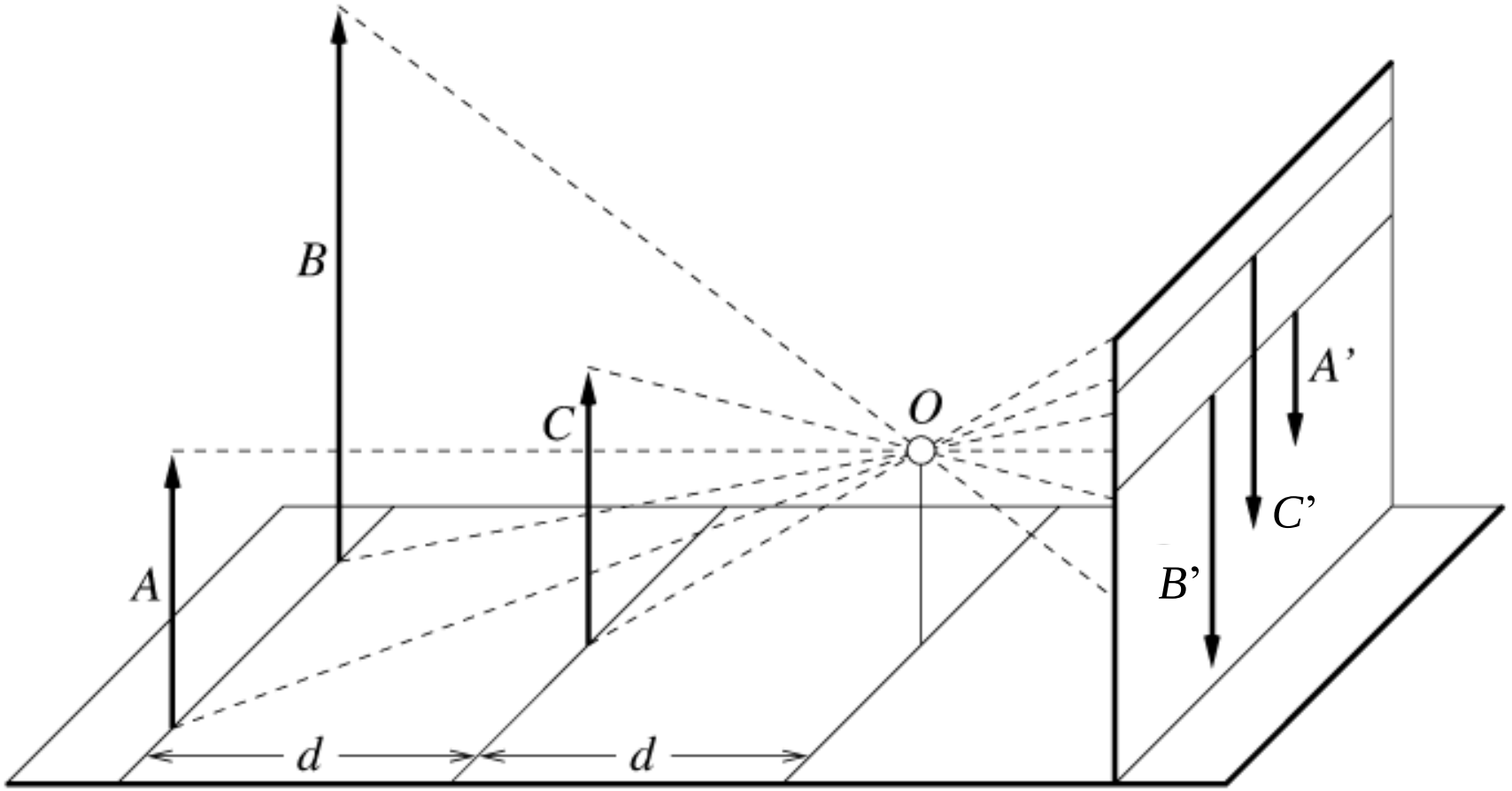
# Picture Taken by Pinhole Camera

**How to make pinhole camera?**

- http://www.exploratorium.edu/light_walk/camera_todo.html



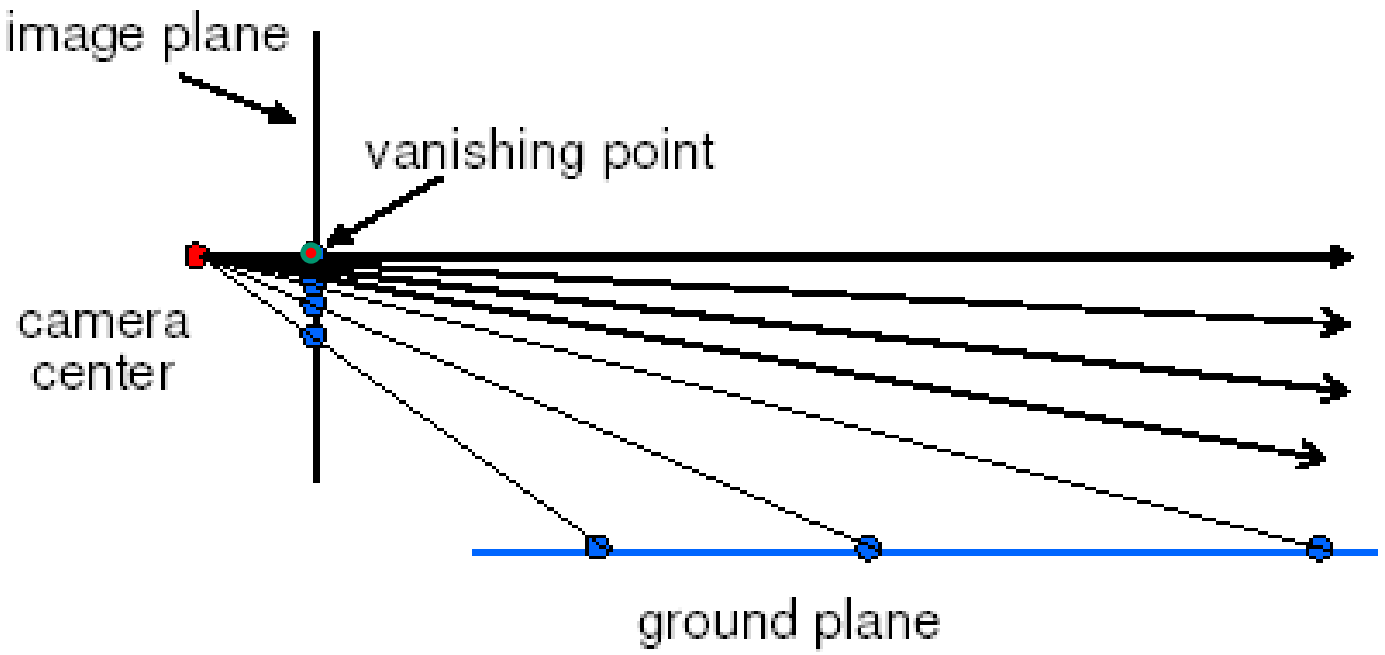
# Distant Objects Are Smaller




- Comparing A and C → with a fixed size, distant objects are smaller
- Comparing A and B → with a fixed distance, larger objects are larger

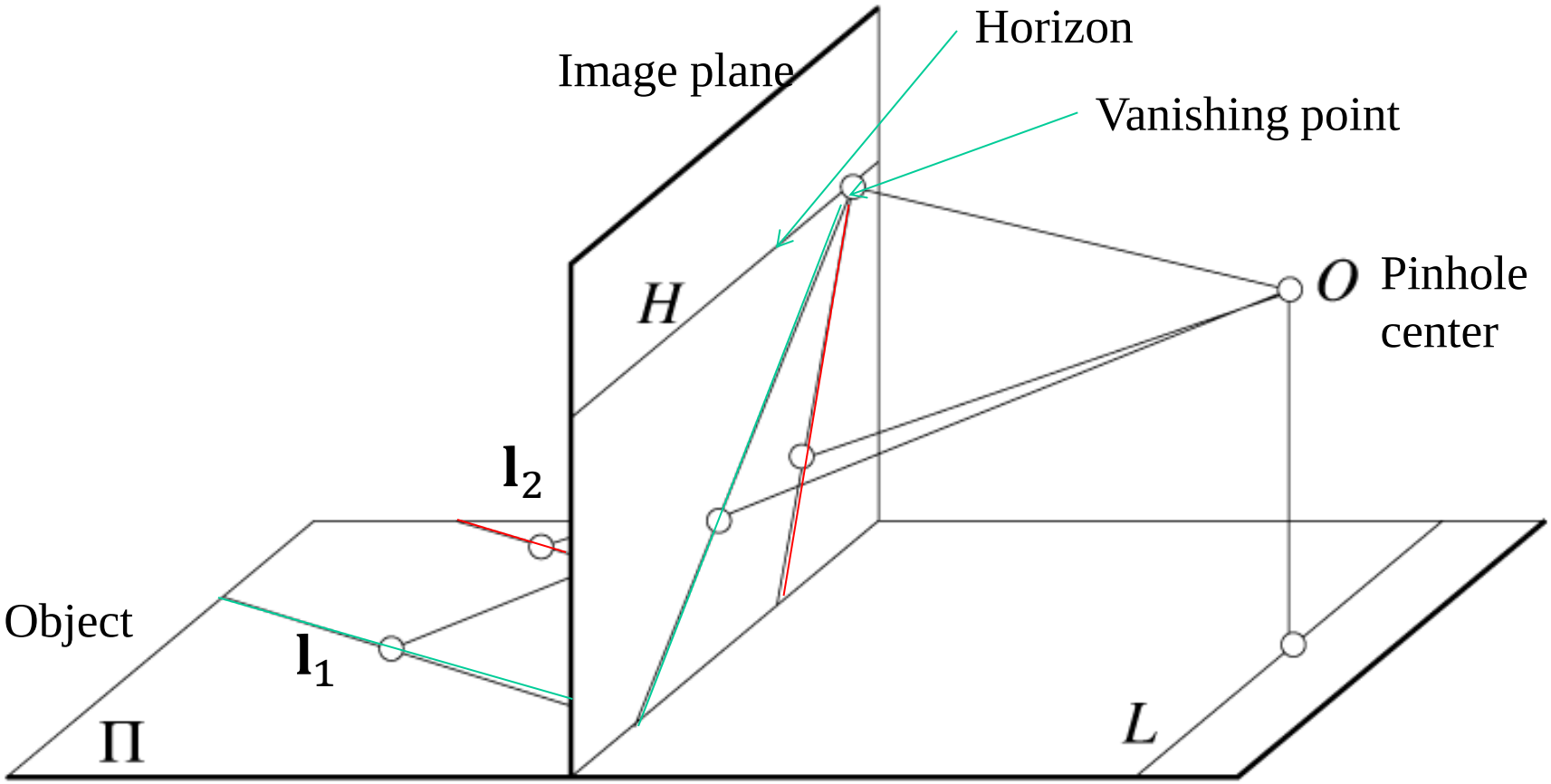
# Vanishing Points

**Projection of a point at infinity**



# Parallel Lines Meet at Vanishing Points

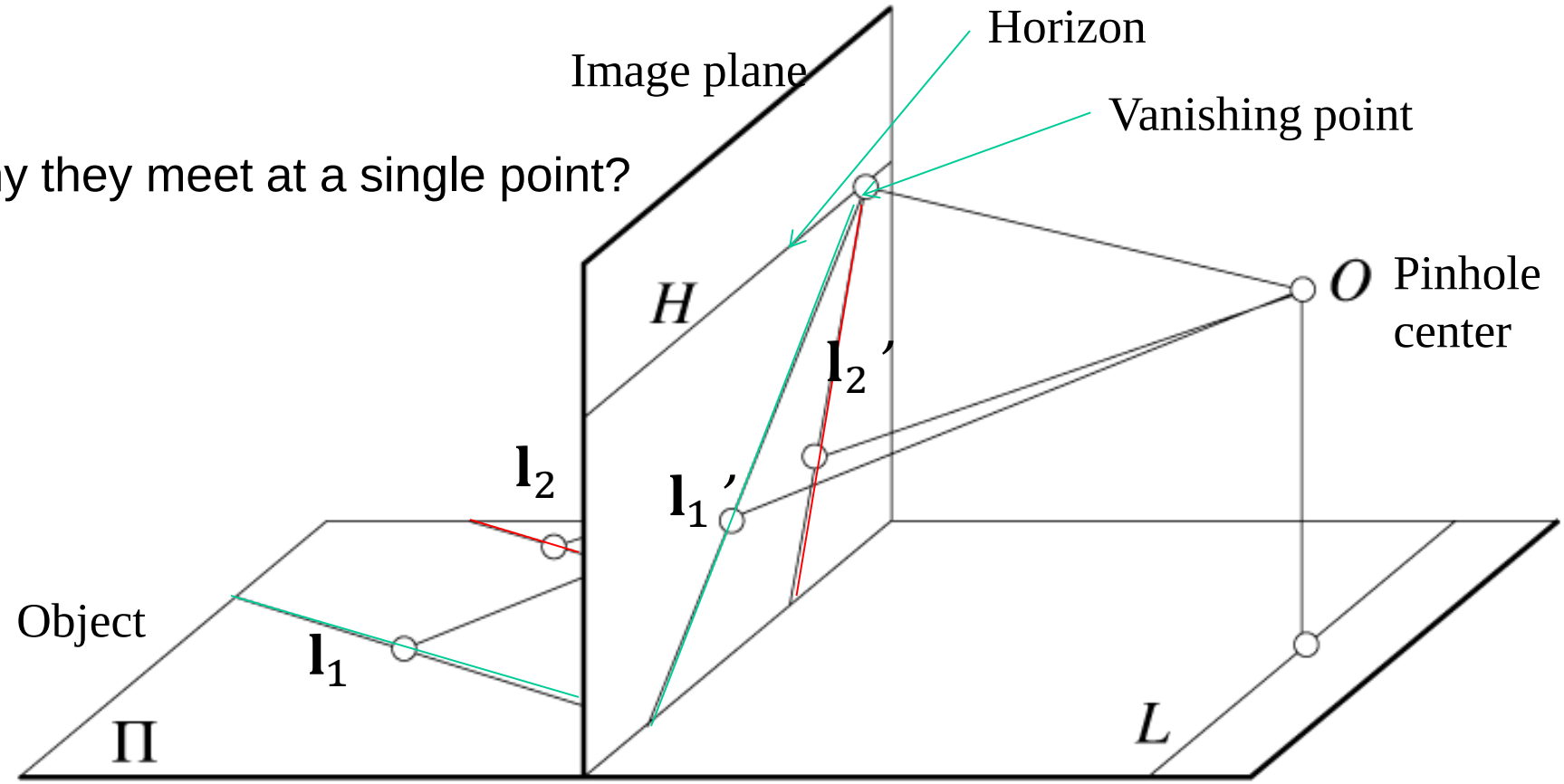
- Horizon H is the intersection of a plane, which is parallel to Π and passes through the pinhole center O, and the image plane



# Parallel Lines Meet at Vanishing Points

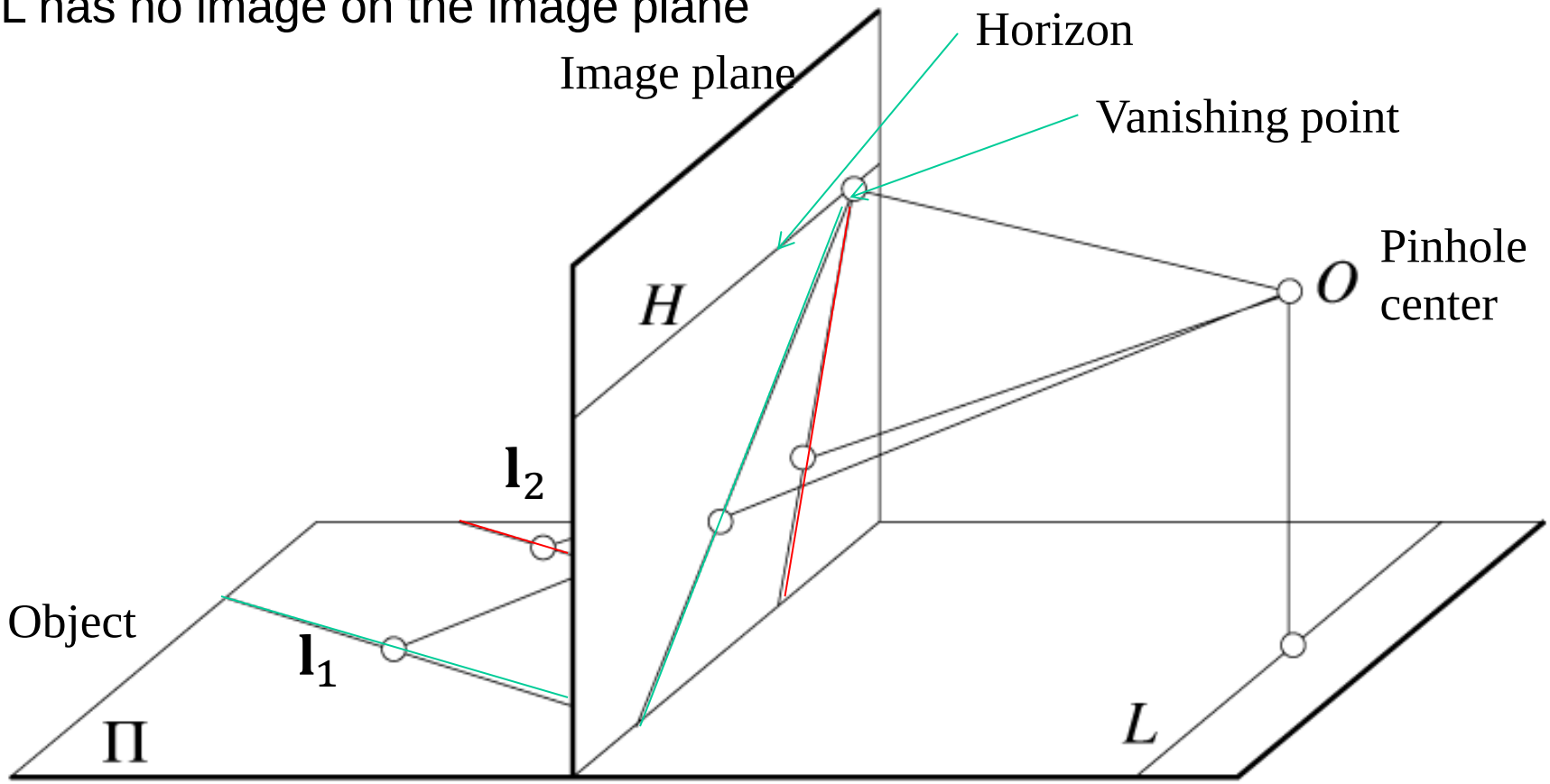
- The images of parallel lines on the plane Π intersects at a point on the horizon H

Why they meet at a single point?



# Parallel Lines Meet at Vanishing Points

- L is the intersection of $\Pi$ and a plane, which is parallel to the image plane and passing through the pinhole center
- L has no image on the image plane



# Vanishing Points (cont.)

**Each set of parallel lines (=direction) meets at a different point**

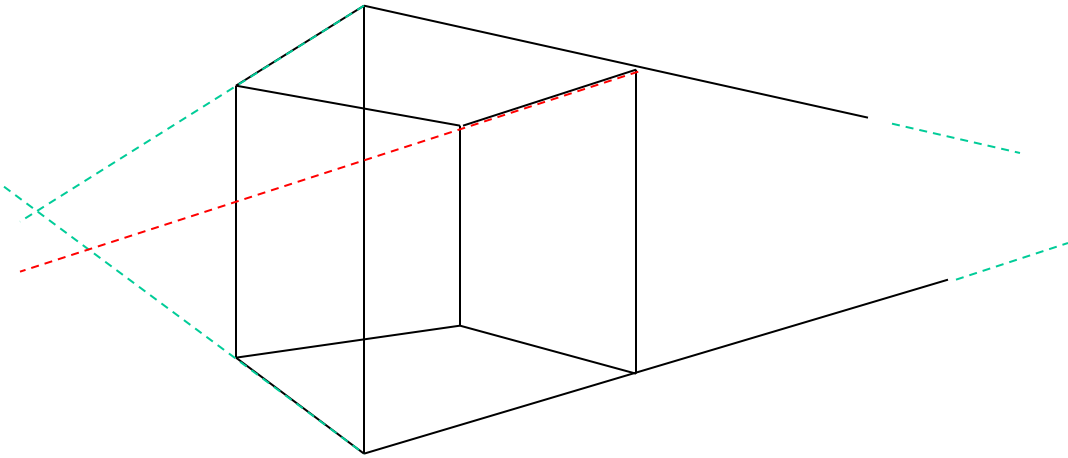
- The *vanishing point* for this direction

**Good ways to spot faked images**

- scale and perspective don't work
- vanishing points behave badly

**Sets of parallel lines on the same plane led to *collinear* vanishing points.**

- The line is called the *horizon* for that plane



# Vanishing Points (cont.)

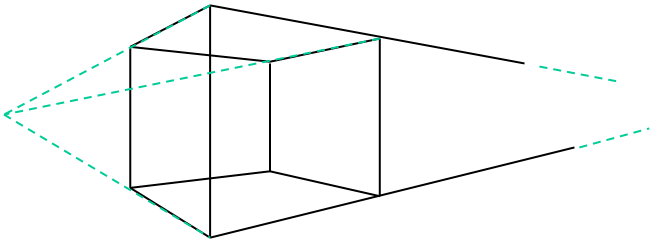
## One-point perspective:

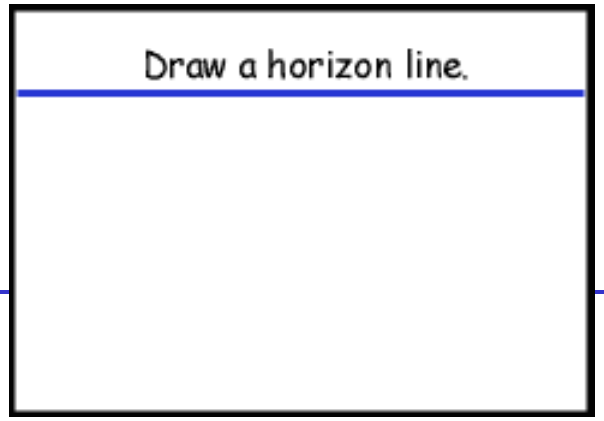
- The image plane is parallel to two axes of a 3D scene
- the lines are parallel to the image plane are still parallel in the image
- the lines are perpendicular to the image plane are intersected at the vanishing point in the image

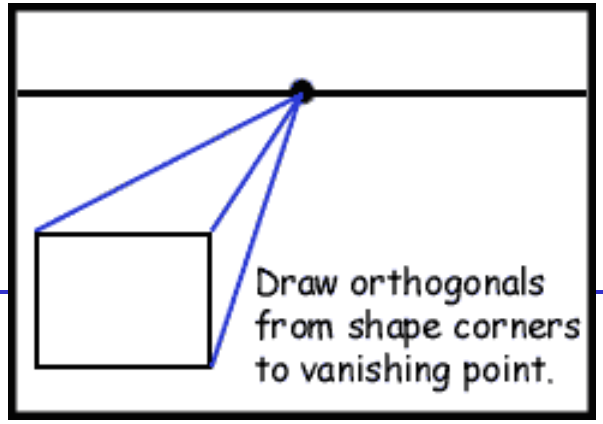


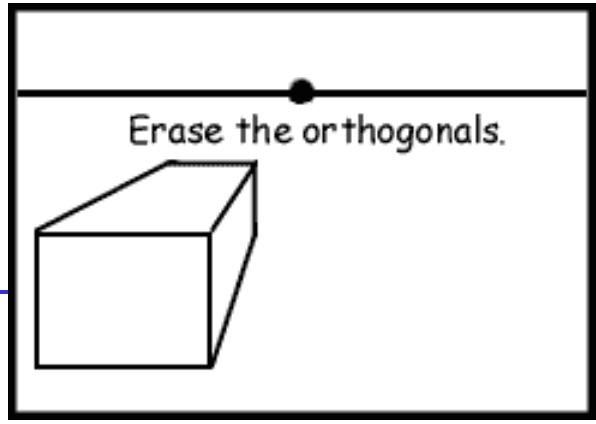
## Two-point perspective:

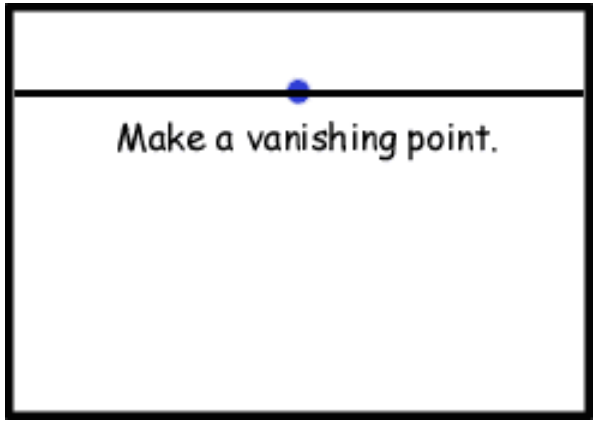
- The image plane is parallel to one axis in the world

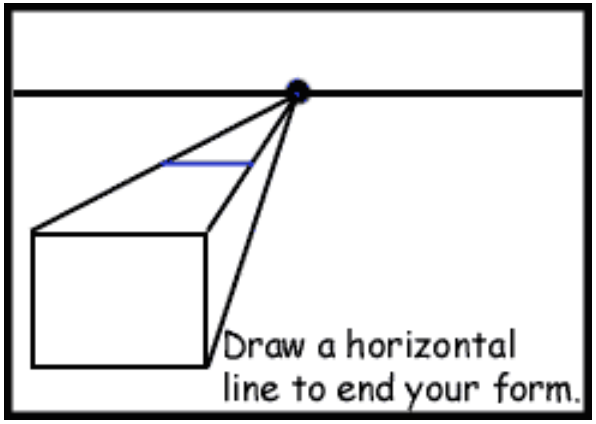


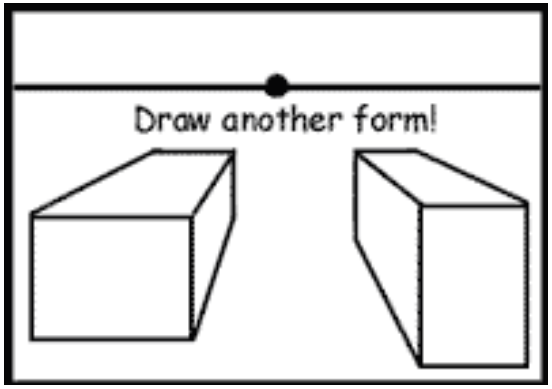


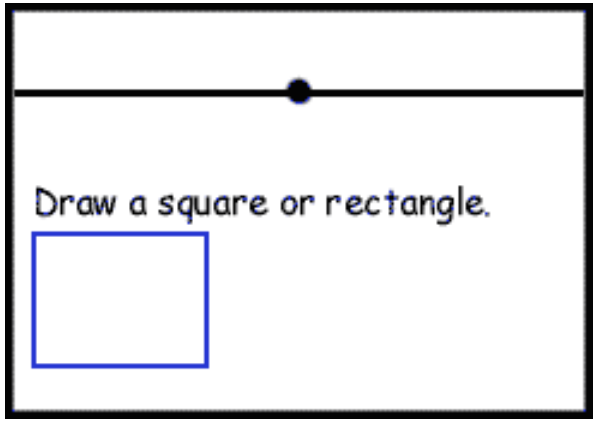



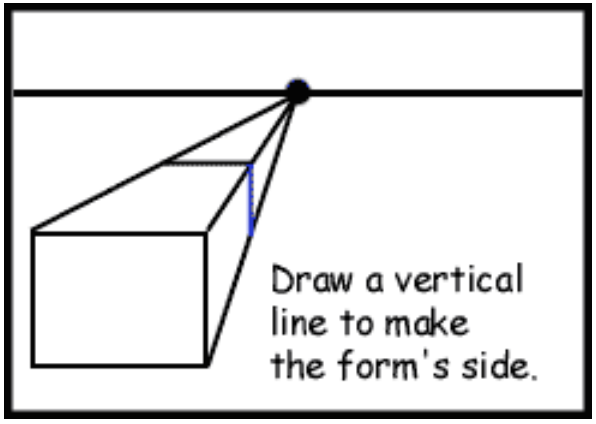



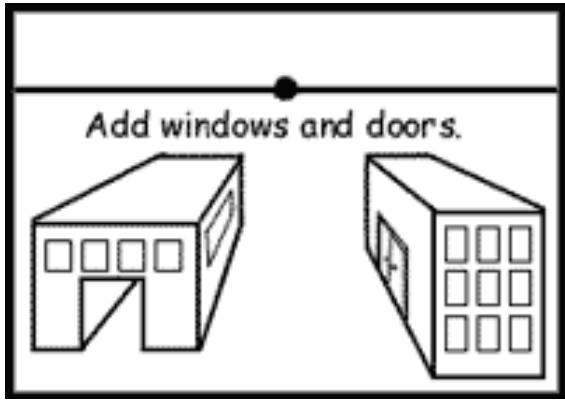




Slide credit: David Jacobs

# Points, Lines, and Planes

**Point: represented as a vector $\mathbf{p} = [p_1, p_2, \cdots, p_N]$ in Euclidean space $\mathbb{R}^N$**

**Line:**

- **Lines in 2D**
  - Slope-intercept form: $y = ax + b$
  - $\mathbf{l} \cdot \mathbf{p} = 0$, where $\mathbf{l}=[a, b, c]$, and $\mathbf{p}=[x, y, 1]$

# Points, Lines, and Planes

**Line:**

- **Lines in 2D**
- **Lines in general**
  - Parametric form: $\mathbf{p}(t) = \mathbf{p}_0 + t\,\mathbf{d}$, where $\mathbf{p}_0$ is any point on the line and $\mathbf{d}=[d_1, d_2, \cdots, d_N]$ is a unit vector - the direction of the line
    - Parallel lines have the same $\mathbf{d}$ with different $\mathbf{p}_0$
  - Point-normal: $\mathbf{m} \cdot (\mathbf{p} - \mathbf{p}_0) = 0$, where $\mathbf{p}_0$ is any point on the line and **m** is normal to the line

# Points, Lines, and Planes

**Plane:**

$$\mathbf{n} \cdot (\mathbf{p} - \mathbf{p_0}) = \mathbf{0}$$

**$\mathbf{n}$ is the normal vector – perpendicular to the plane**

**$\mathbf{p}_0$ is any point on the plane**