

Computer Vision - Lecture 1

Introduction

14.10.2013

Bastian Leibe

RWTH Aachen

<http://www.vision.rwth-aachen.de>

leibe@vision.rwth-aachen.de

Organization

- **Lecturer**
 - Prof. Bastian Leibe (leibe@vision.rwth-aachen.de)
- **Teaching Assistants**
 - Aljosa Osep (osep@vision.rwth-aachen.de)
 - Theodora Kontogianni (kontogianni@vision.rwth-aachen.de)
- **Course webpage**
 - <http://www.vision.rwth-aachen.de/teaching/>
→ Computer Vision
 - Slides will be made available on the webpage
 - There is also an L2P electronic repository
- **Please subscribe to the lecture on the Campus system!**
 - Important to get email announcements and L2P access!

Language

- **Official course language will be English**
 - If at least one English-speaking student is present.
 - If not... you can choose.

- **However...**
 - Please tell me when I'm talking too fast or when I should repeat something in German for better understanding!
 - You may at any time ask questions in German!
 - You may turn in your exercises in German.
 - You may answer exam questions in German.

Organization

- **Structure: 3V (lecture) + 1Ü (exercises)**
 - 6 EECS credits
 - Part of the area “Applied Computer Science”
- **Place & Time**
 - **Lecture:** Tue 14:15 - 15:45 UMIC 025
 - **Lecture/Exercises:** Thu 09:15 - 10:45 UMIC 025
- **Exam**
 - Planned as written exam
 - We’ll soon fix the date

Course Webpage

Tentative Schedule

Date	Topic	Content	Slides	Related Material
14.10.14	Introduction	Why vision? Applications, Challenges, Image Formation	pdf, fullpage	
16.10.14	Image Processing I	Binary Images, Thresholding, Morphology, Connected Components, Region Descriptors		Tuesday: Matlab tutorial
21.10.14	<i>Exercise 1</i>	<i>Intro Matlab</i>		Matlab resources
23.10.14	Image Processing II	Linear Filters, Gaussian Smoothing, Median Filter		F&P Chapter 7
28.10.14	Edge Detection	Multi-scale Representations, Image Derivatives, Edge Detection		F&P Chapter 8
30.10.14	Structure Extraction	Chamfer Matching, Line Fitting, Hough Transform, Gen. Hough Transform		B&B on the Generalized HT, Hough Transform demo (Java)
04.11.14	<i>no class (DIES Fachschaftsvollvers.)</i>	-		
06.11.14	<i>Exercise 2</i>	<i>Thresholding, Morphology, Derivatives, Edges</i>		
11.11.14	Segmentation I	Segmentation as Clustering, k-means, EM, Mean-Shift		F&P chapter 14, Max Wertheimer's Gestalt Laws

<http://www.vision.rwth-aachen.de/teaching/>

Exercises and Demos

- Exercises

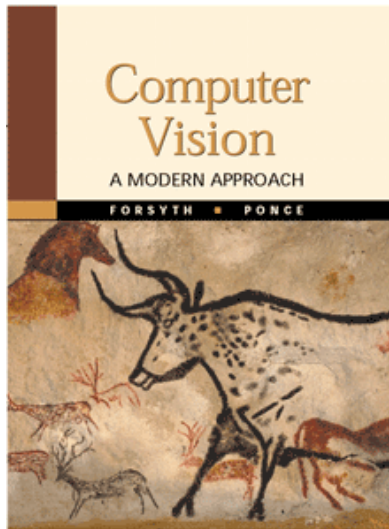
- Typically 1 exercise sheet every 2 weeks (Matlab based)
- Hands-on experience with the algorithms from the lecture.
- Send in your solutions the night before the exercise class.
- **Need to reach $\geq 50\%$ of the points to qualify for the exam!**

- Teams are encouraged!

- You can form teams of up to 3 people for the exercises.
- Each team should only turn in one solution.
- But list the names of all team members in the submission.

Textbooks

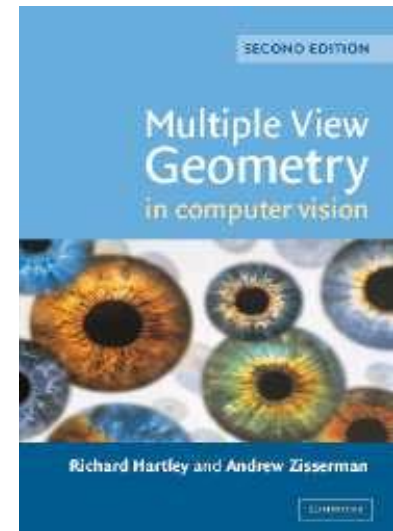
- No single textbook for the class.
- Basic material is covered in the following two books.



D. Forsyth, J. Ponce
Computer Vision - A Modern Approach
Prentice Hall, 2002

(available in the library's "Handapparat")

R. Hartley, A. Zisserman
Multiple View Geometry in Computer Vision
2nd Ed., Cambridge Univ. Press, 2004



- Additional material will be given out for some topics.
 - Tutorials and deeper introductions.
 - Application papers

How to Find Us

- **Office:**

- UMIC Research Centre
- Mies-van-der-Rohe-Strasse 15, room 124



- **Office hours**

- If you have questions to the lecture, come to us.
- My regular office hours will be announced (additional slots are available upon request)
- Send us an email before to confirm a time slot.

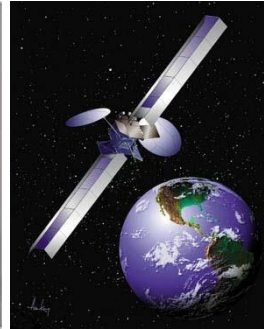
Questions are welcome!

Topics of Today's Lecture

- What is computer vision?
- What does it mean to see and how do we do it?
- How can we make this computational?

- First Topic: Image Formation
 - Details in Forsyth & Ponce, chapter 1.

Why Computer Vision?



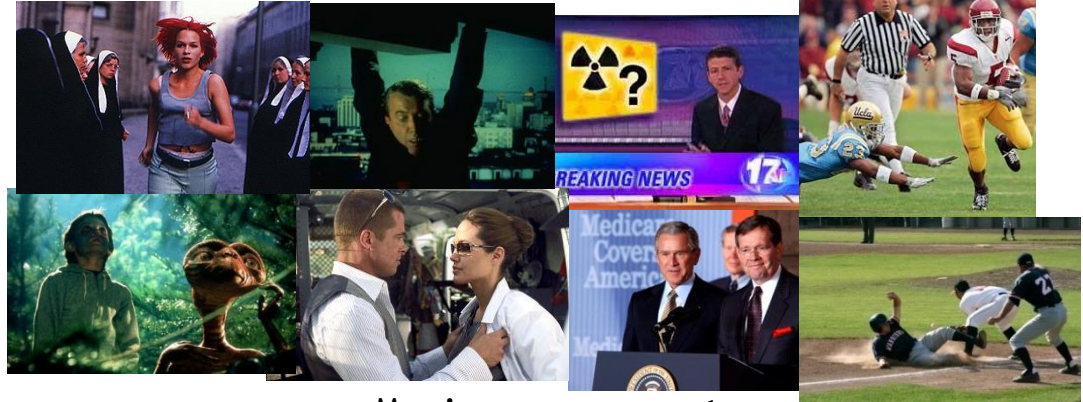
**Cameras are
all around us...**



Images and video are everywhere...



Personal photo albums



Movies, news, sports



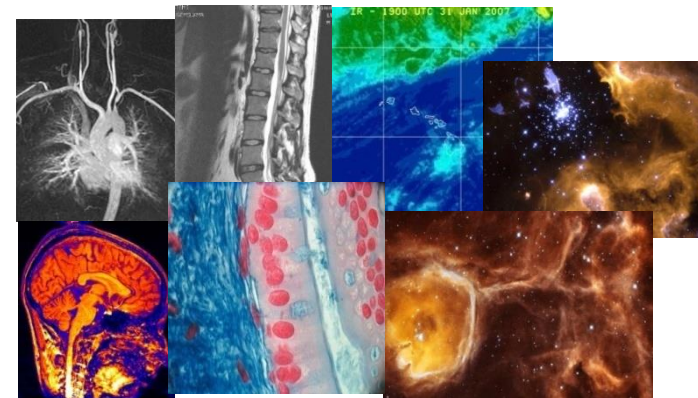
Internet services



Surveillance and security



Mobile and consumer applications



Medical and scientific images

What is Computer Vision?

- **Goal of Computer Vision**
 - *Enable a machine to “**understand**” images and videos*
- **Automatic understanding**
 - **Computing properties of the 3D world from visual data** (*measurement*)
 - **Algorithms and representations to allow a machine to recognize objects, people, scenes, and activities.** (*perception and interpretation*)

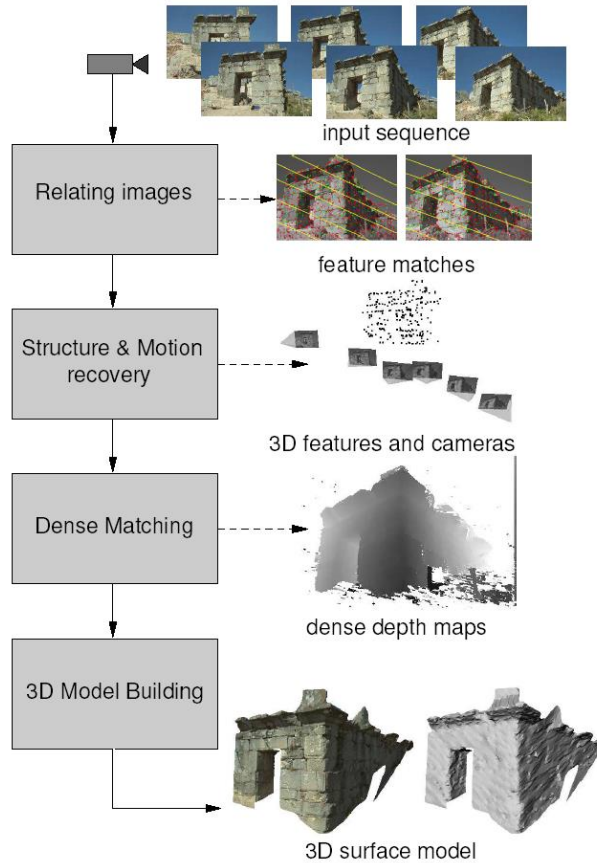
Vision for Measurement

Real-time stereo

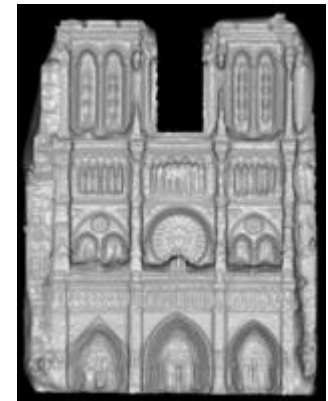


Pollefeys et al.

Structure from motion



Multi-view stereo for community photo collections



Goesele et al.

Vision for Perception, Interpretation



sky

amusement park

- Objects
- Activities
- Scenes
- Locations
- Text / writing
- Faces
- Gestures
- Motions
- Emotions...

The Wicked Twister

Cedar Point

ride

Ferris wheel

ride

Lake Erie

water

12 E

12 E

ride

tree

tree

people waiting in line

people sitting on ride

tree

umbrellas

maxair

deck

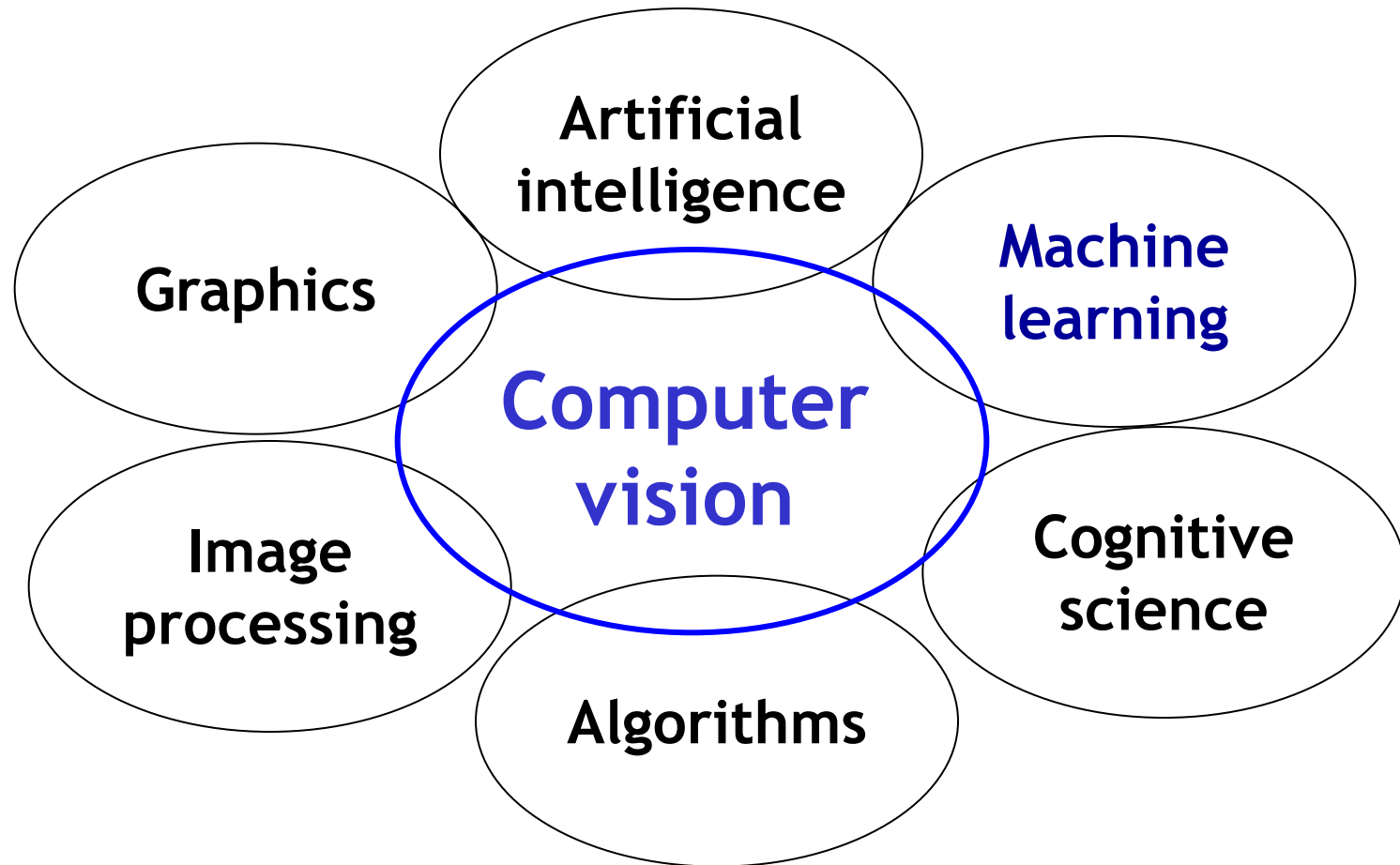
bench

carousel

tree

pedestrians

Related Disciplines



Directions to Computer Vision

- **Science**
 - Foundations of perception. How do WE see?
- **Engineering**
 - How do we build systems that perceive the world?
- **Many applications**
 - Medical imaging, surveillance, entertainment, graphics, ...

Applications: Faces and Digital Cameras



Setting camera focus
via face detection



Camera waits for everyone to
smile to take a photo [Canon]

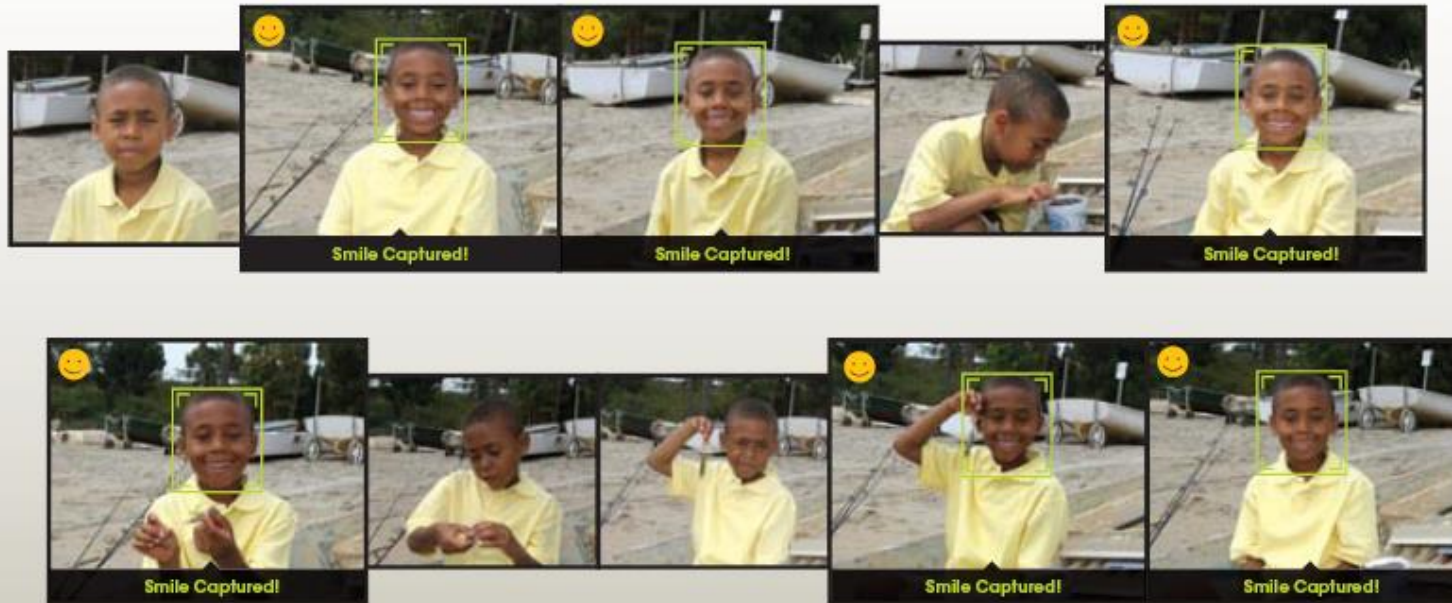
Automatic lighting
correction based
on face detection



Smile detection

The Smile Shutter flow

Imagine a camera smart enough to catch every smile! In Smile Shutter Mode, your Cyber-shot® camera can automatically trip the shutter at just the right instant to catch the perfect expression.



[Sony Cyber-shot® T70 Digital Still Camera](#)

Segmentation



- **Automatic background removal from images**
 - **Functionality is included in Microsoft Office 2010...**



Matching



- Stitch your photos together to create panoramas

AUTOSTITCH



Available on the iPhone
App Store

Applications: Vision for Mobile Phones

Google Goggles in Action

Click the icons below to see the different ways Google Goggles can be used.



- Take photos of objects as queries for visual search

Applications: Vision-based Interfaces



**Games
(Microsoft Kinect)**

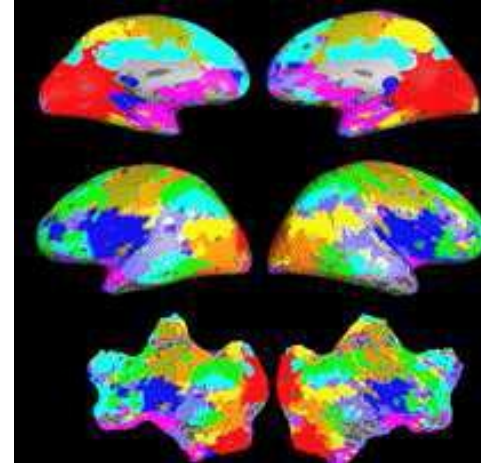


**Assistive technology systems
Camera Mouse
Boston College**

Applications: Medical & Neuroimaging



**Image guided surgery
MIT AI Vision Group**



**fMRI data
Golland et al.**



Applications: Visual Special Effects



The Matrix



MoCap for *Pirates of the Caribbean*, Industrial Light and Magic

(Source: S. Seitz)

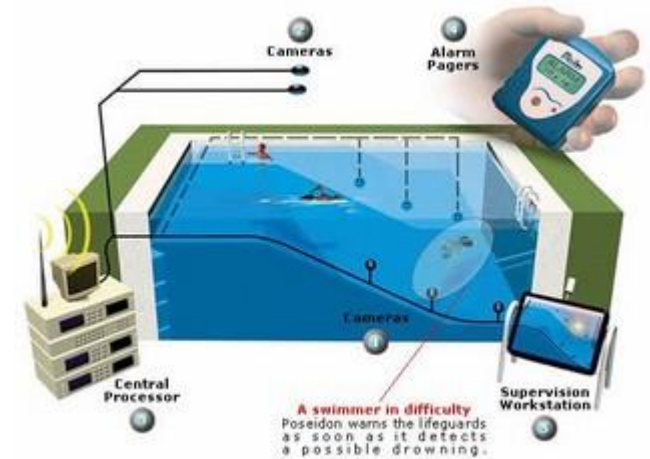
Applications: Safety & Security



Autonomous robots



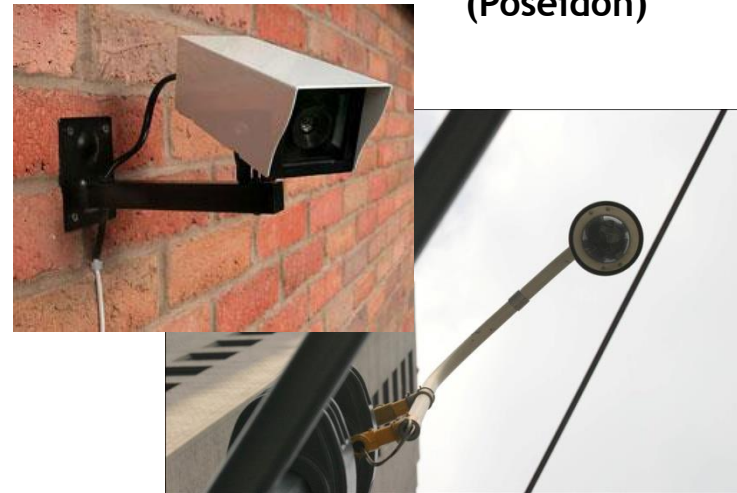
Driver assistance



Monitoring pools (Poseidon)



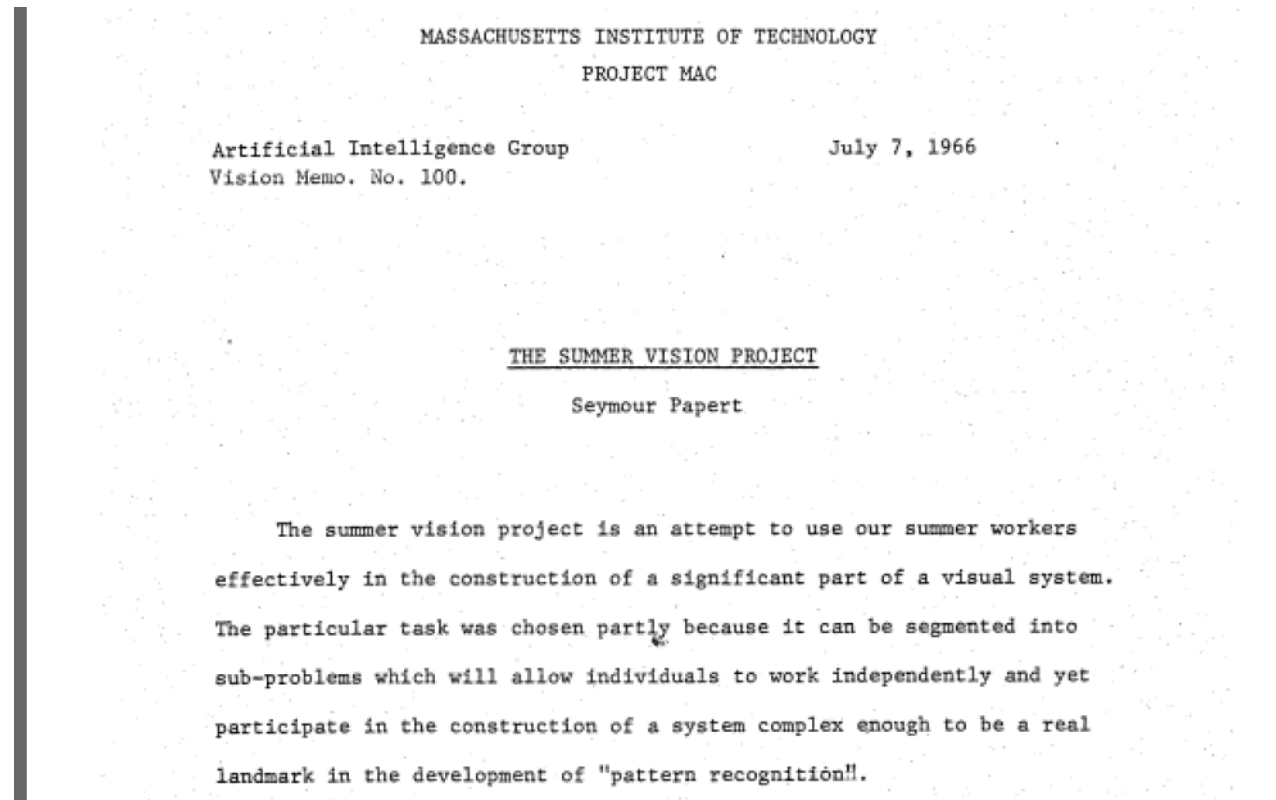
Pedestrian detection
[MERL, Viola et al.]



Surveillance

Ok, Let's Do It - Any Obstacles?

- 1966: Seymour Papert directs an undergraduate student to solve "the problem of computer vision" as a summer project.



- Obviously, computer vision was too difficult for that...

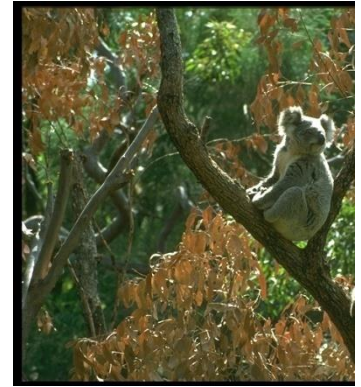
Challenges: Many Nuisance Parameters



Illumination



Object pose



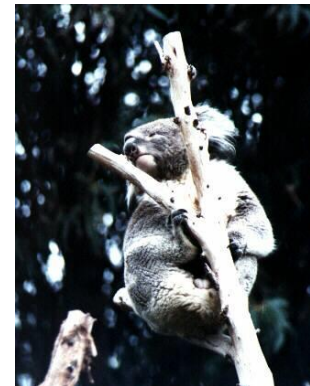
Clutter



Occlusions

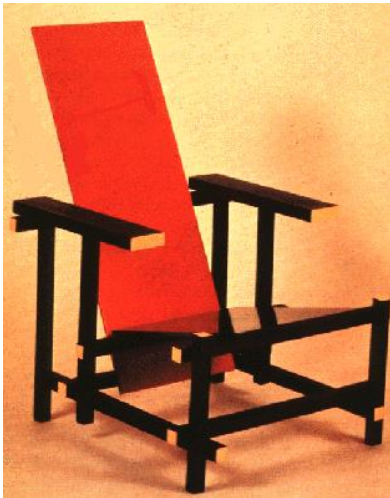


**Intra-class
appearance**



Viewpoint

Challenges: Intra-Category Variation



Slide credit: Fergus, FeiFei, Torralba

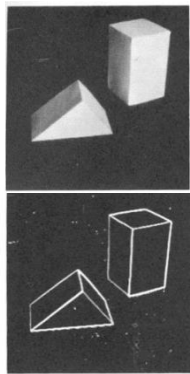
B. Leibe

Challenges: Complexity

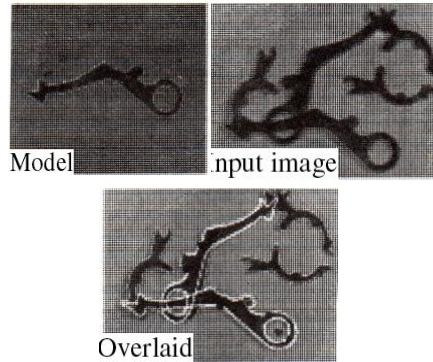
- Thousands to millions of pixels in an image
- 3,000-30,000 human recognizable object categories
- 30+ degrees of freedom in the pose of articulated objects (humans)
- Billions of images indexed by Google Image Search
- 18 billion+ prints produced from digital camera images in 2004
- 295.5 million camera phones sold in 2005
- **About half of the cerebral cortex in primates is devoted to processing visual information [Felleman and van Essen 1991].**

So, Should We Give Up?

- NO! Very active research area with exciting progress!



.....



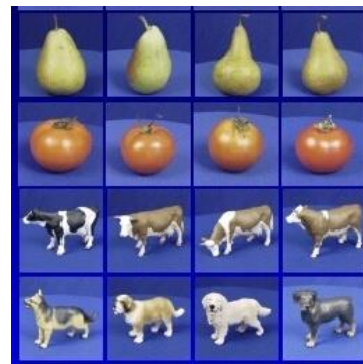
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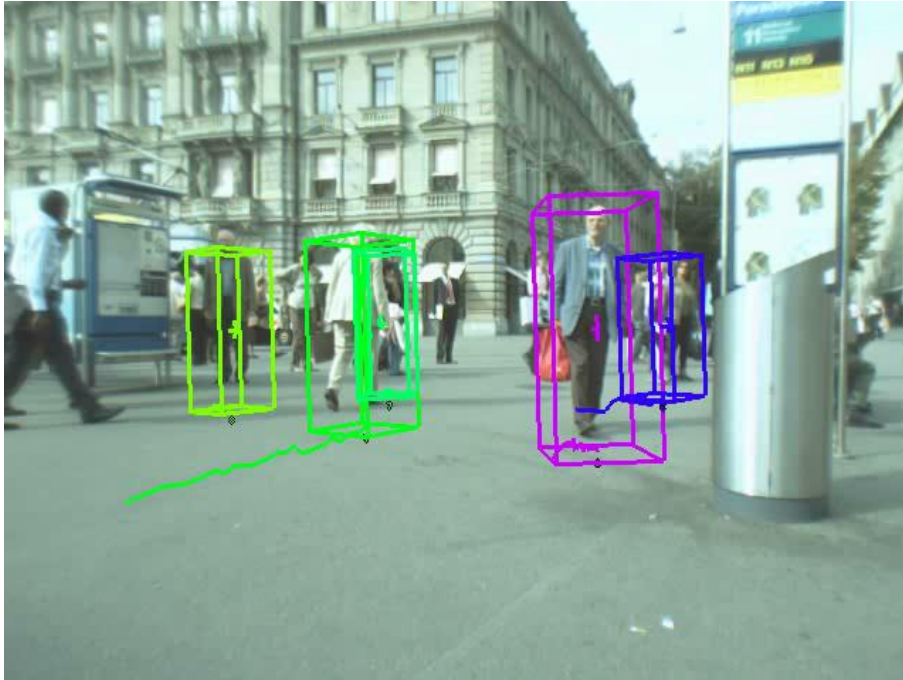


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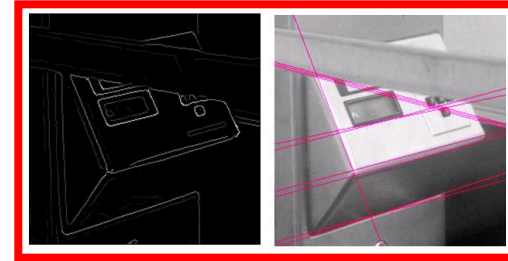
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Things Are Starting to Work...



- **Computer Vision in realistic scenarios is becoming feasible!**

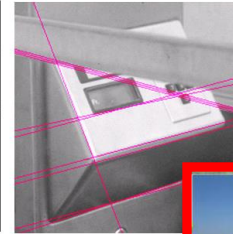
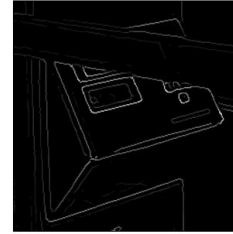
Course Outline



- **Image Processing Basics**
- Segmentation
- Local Features & Matching
- Object Recognition and Categorization
- 3D Reconstruction
- Motion and Optical Flow

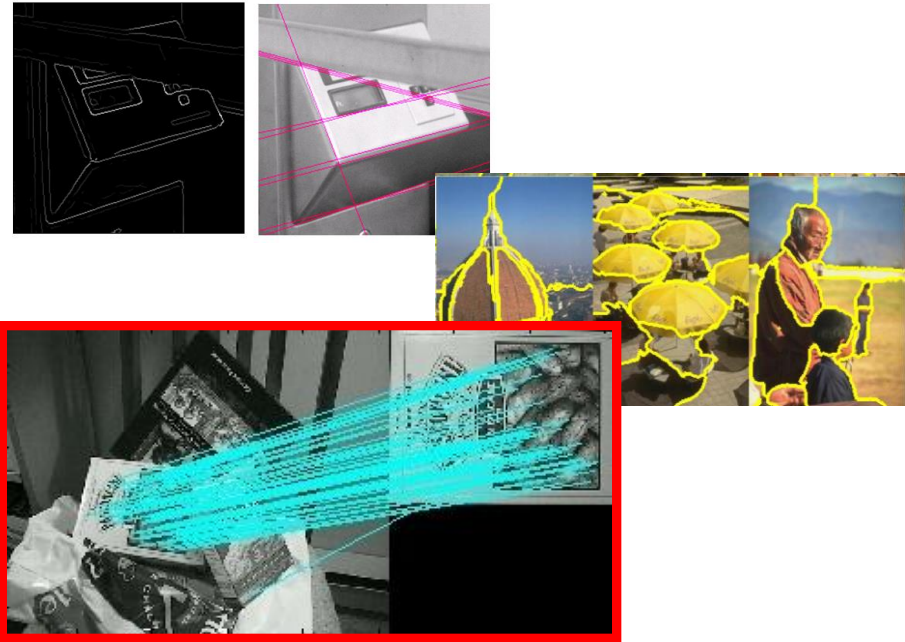
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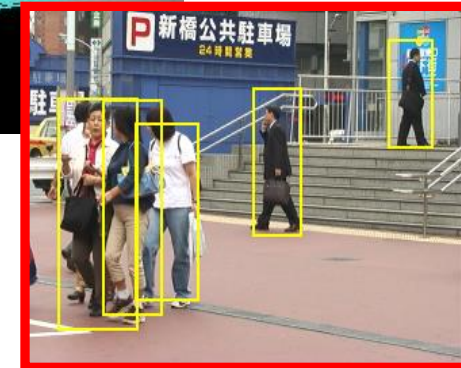
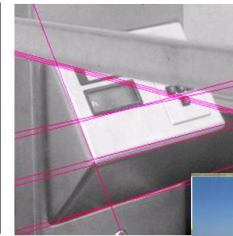
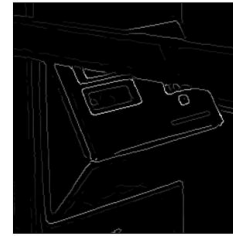
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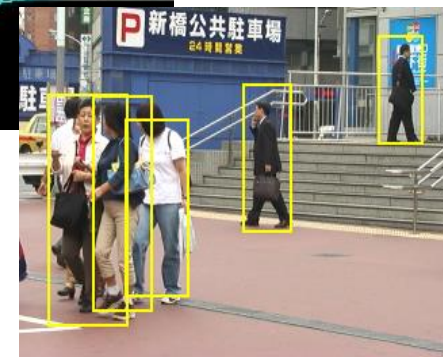
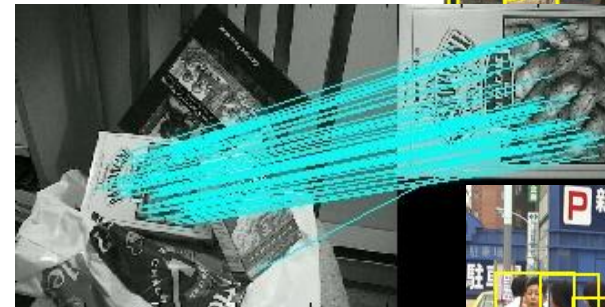
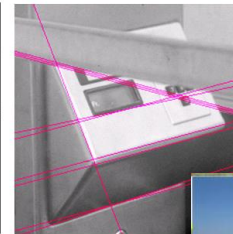
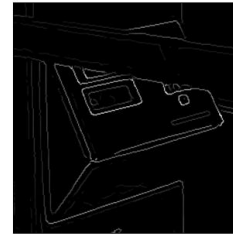
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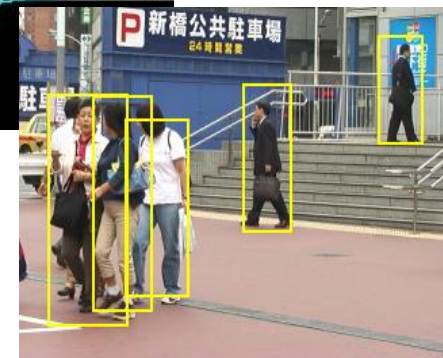
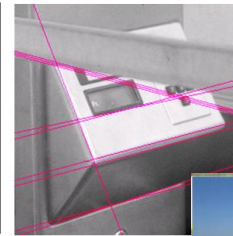
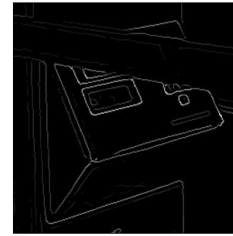
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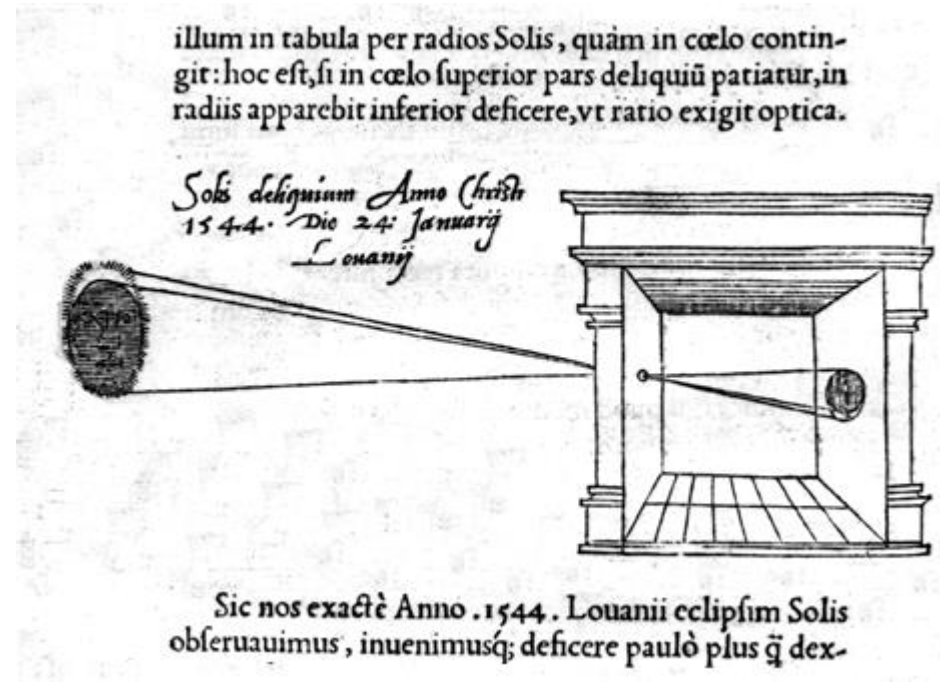
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- How can we make this computational?

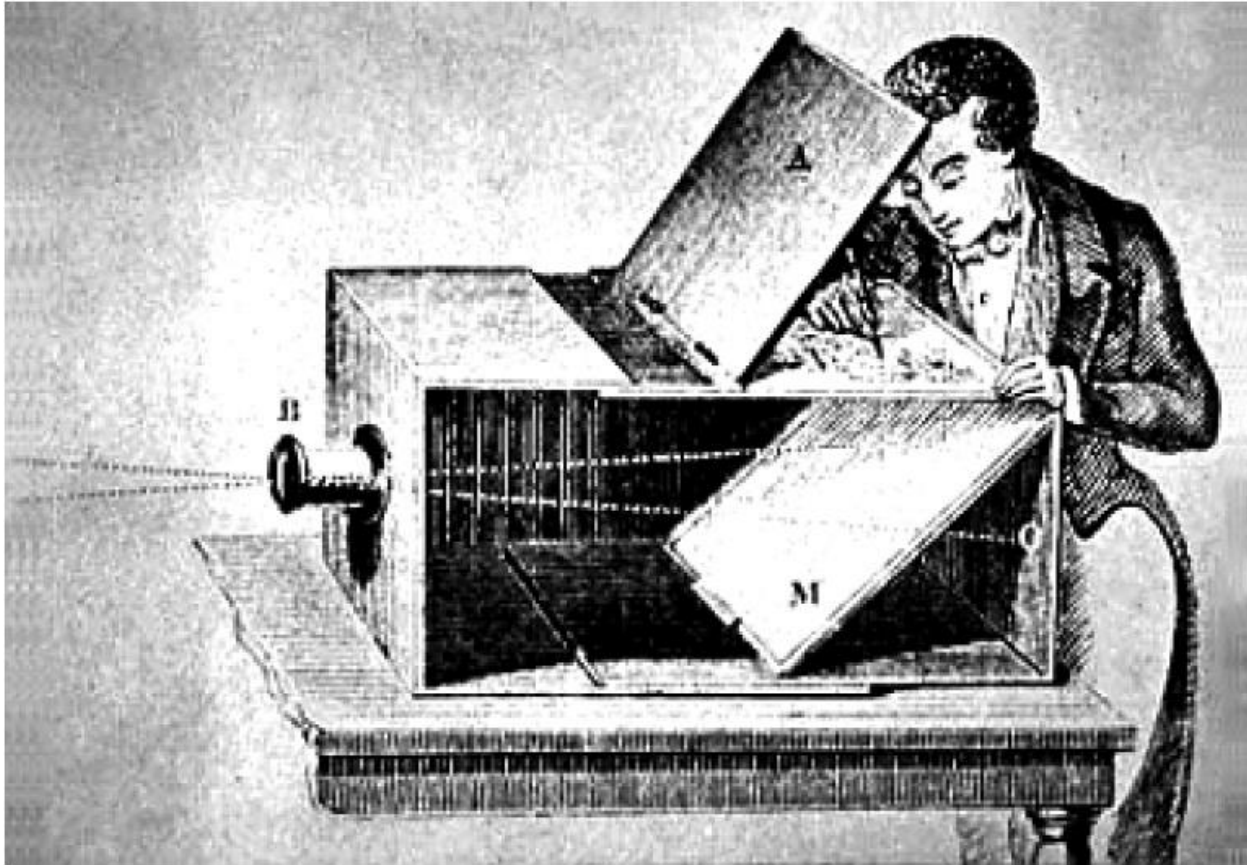
- **First Topic: Image Formation**
 - **Details in Forsyth & Ponce, chapter 1.**

Camera Obscura

- Around 1519, Leonardo da Vinci (1452 - 1519)
 - “When images of illuminated objects ... penetrate through a small hole into a very dark room ... you will see [on the opposite wall] these objects in their proper form and color, reduced in size ... in a reversed position owing to the intersection of the rays”

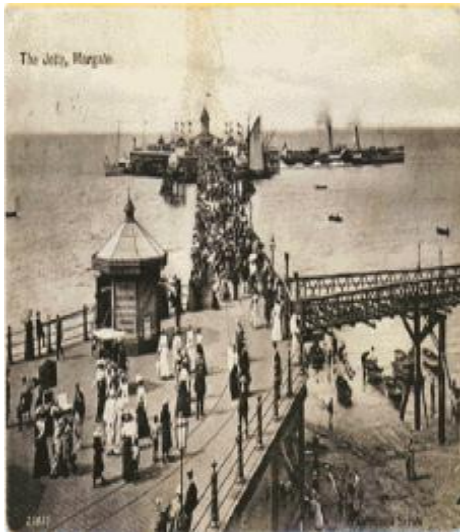


Camera Obscura



- **Used by artists (e.g. Vermeer 17th century) and scientists**

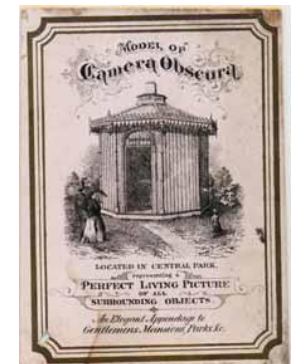
Camera Obscura



LOCATED IN CENTRAL PARK,
representing a
PERFECT LIVING PICTURE
OF ALL
SURROUNDING OBJECTS.
*An Elegant Appendage to
Gentlemen's Mansions, Parks &c.*

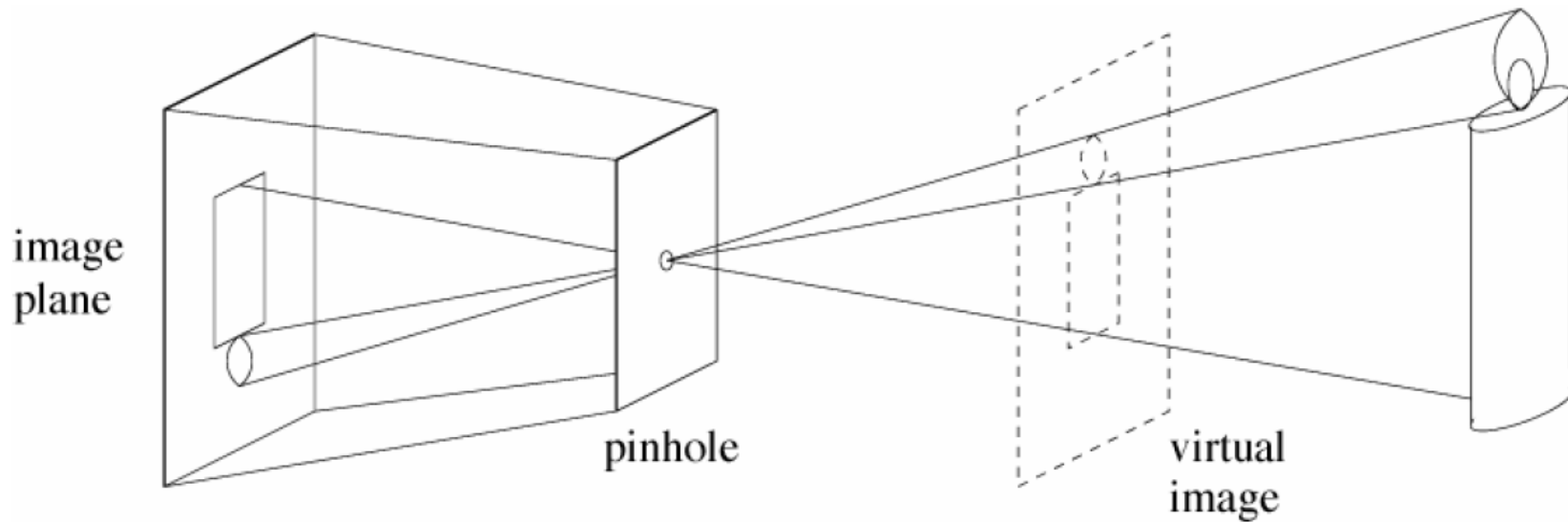
Jetty at Margate England, 1898.

An attraction in the late 19th century



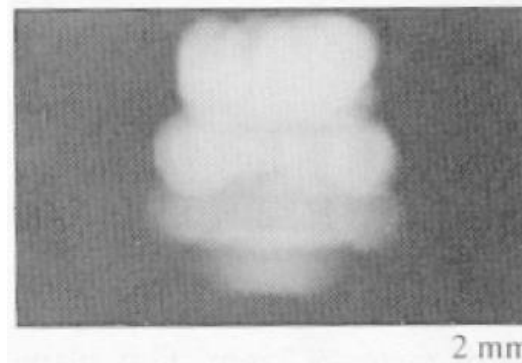
Pinhole Camera

- (Simple) standard and abstract model today
 - Box with a small hole in it
 - Works in practice



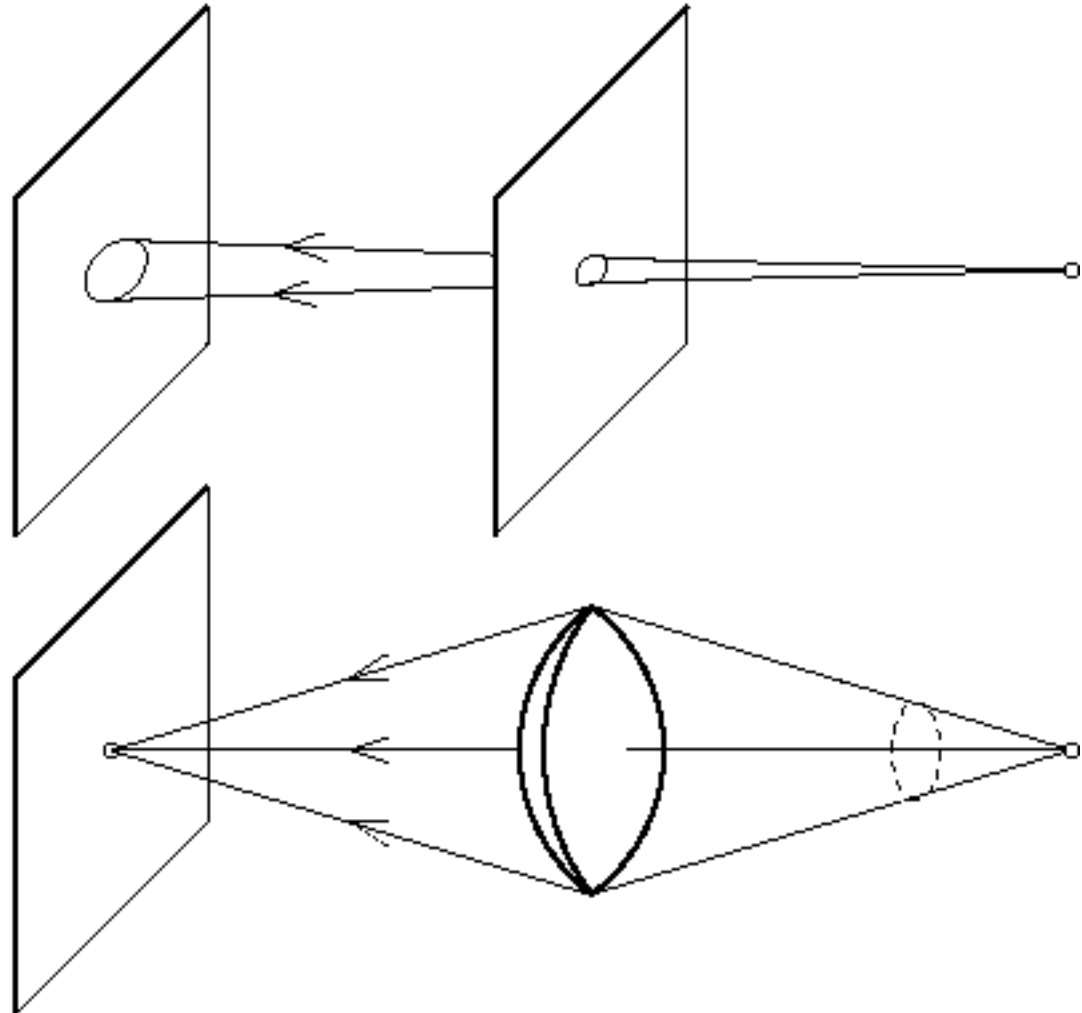
Pinhole Size / Aperture

- Pinhole too big - many directions are averaged, blurring the image
- Pinhole too small - diffraction effects blur the image
- Generally, pinhole cameras are *dark*, because a very small set of rays from a particular point hits the screen.

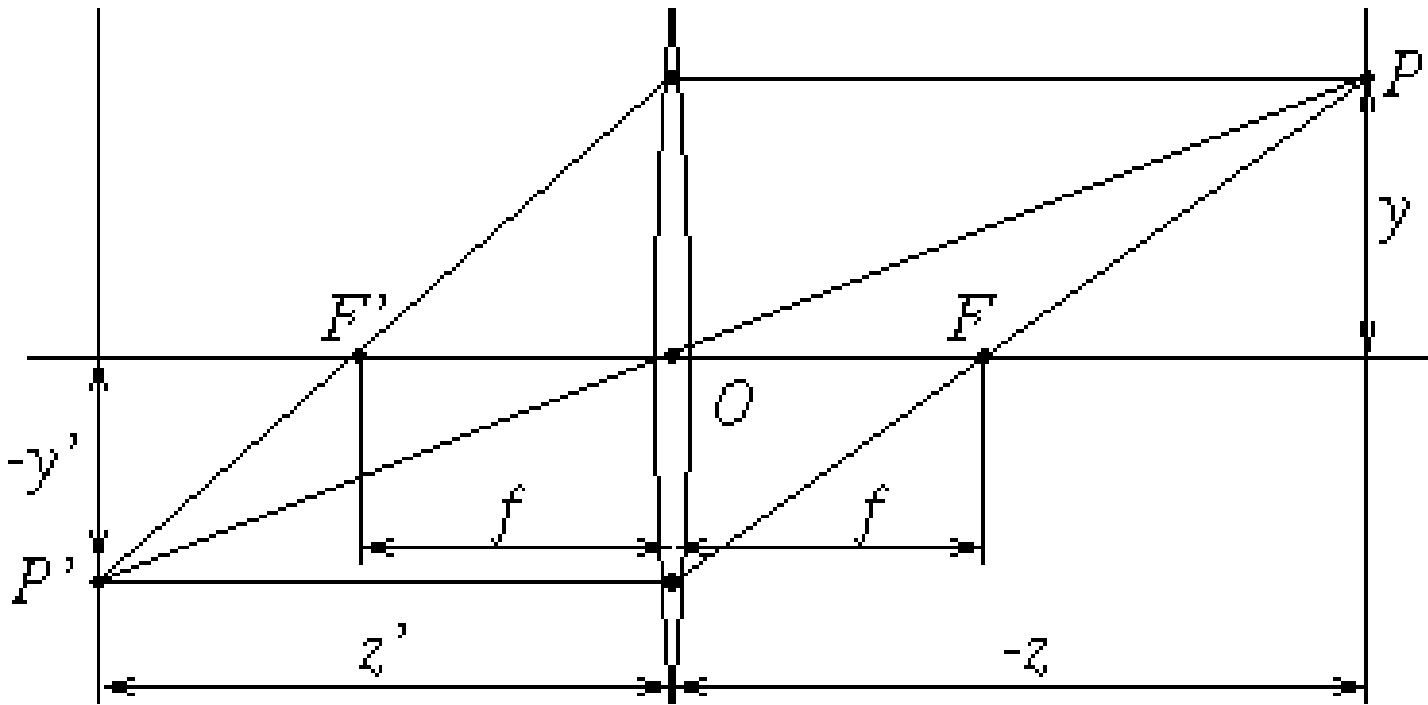


The Reason for Lenses

- Keep the image in sharp focus while gathering light from a large area

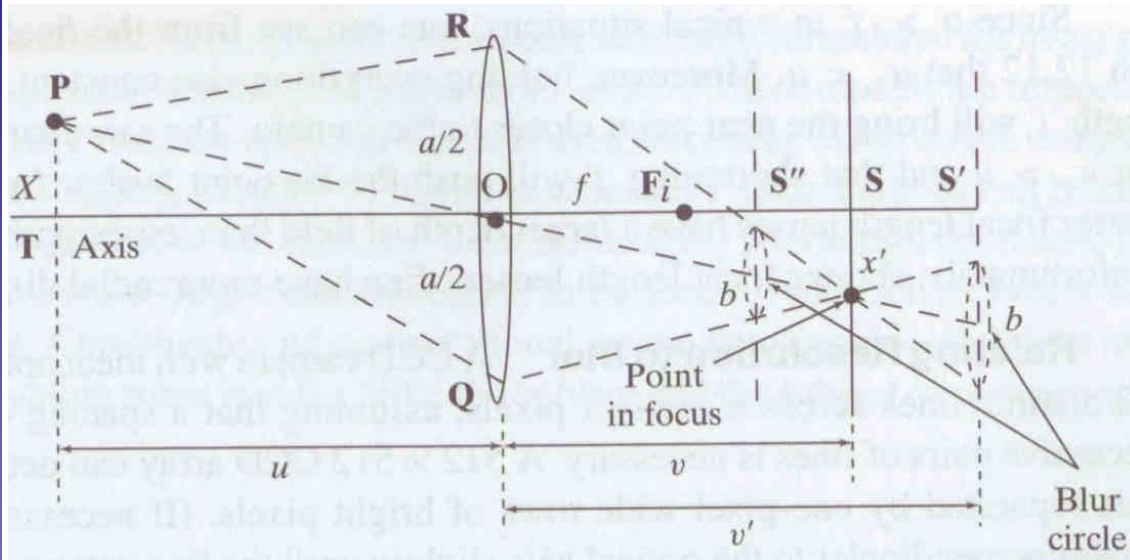


The Thin Lens



$$\frac{1}{z'} - \frac{1}{z} = \frac{1}{f}$$

Focus and Depth of Field



“circles of confusion”

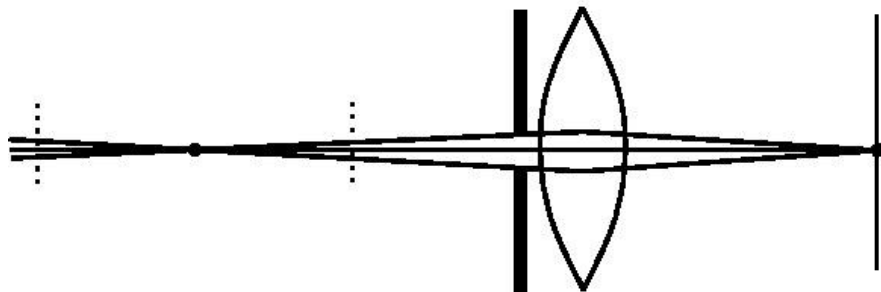
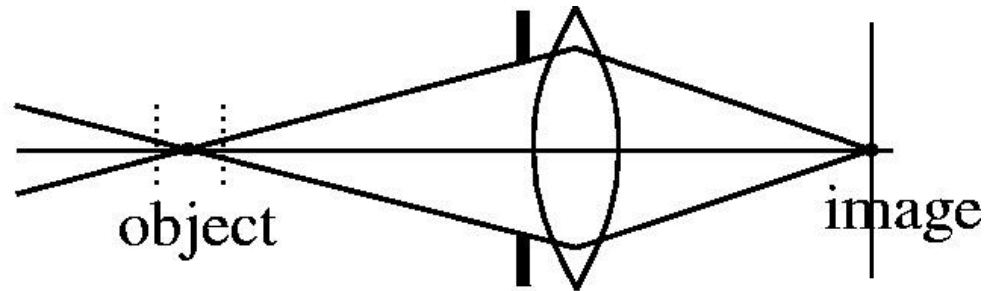
Thin lens: scene points at distinct depths come in focus at different image planes.

(Real camera lens systems have greater depth of field.)

- **Depth of field: distance between image planes where blur is tolerable**

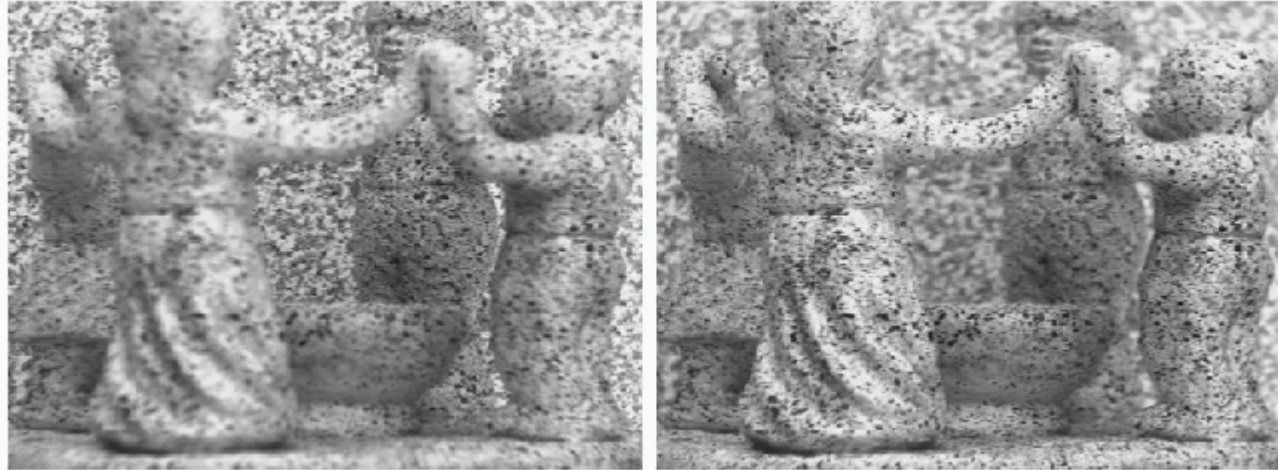
Focus and Depth of Field

- How does the aperture affect the depth of field?

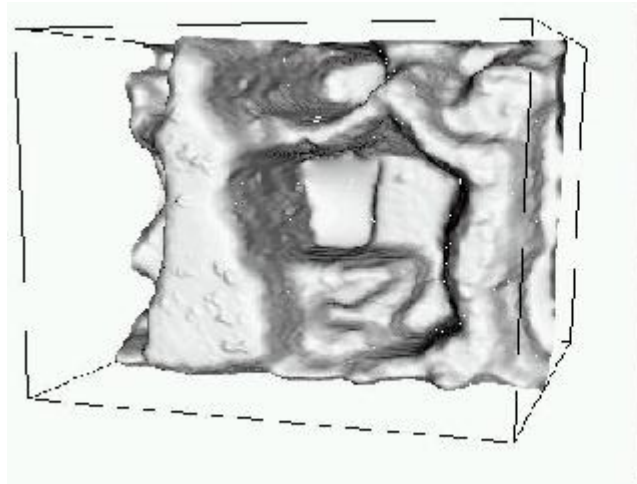


- A smaller aperture increases the range in which the object is approximately in focus

Application: Depth from (De-)Focus



Images from
same point of view,
different
camera
parameters



3D Shape /
depth
estimates

Field of View



28 mm lens, $65.5^\circ \times 46.4^\circ$



50 mm lens, $39.6^\circ \times 27.0^\circ$



70 mm lens, $28.9^\circ \times 19.5^\circ$

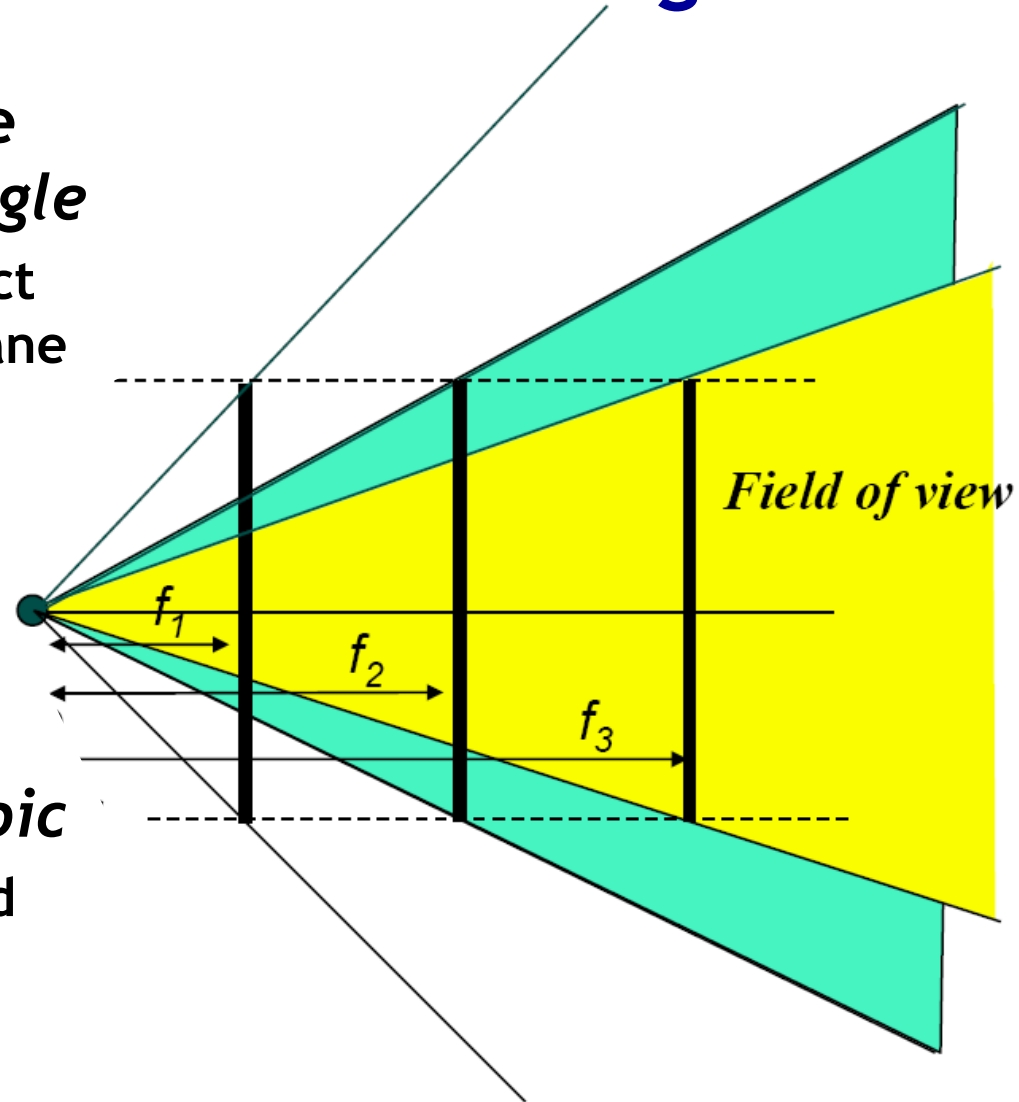


210 mm lens, $9.8^\circ \times 6.5^\circ$

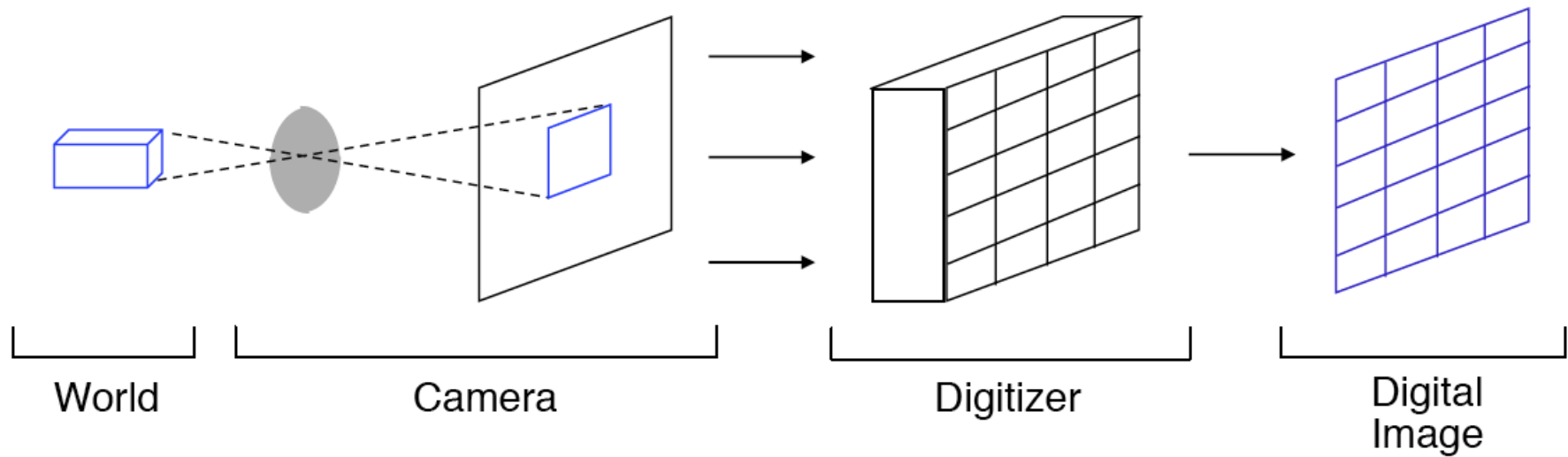
- Angular measure of the portion of 3D space seen by the camera

Field of View Depends on Focal Length

- As f gets smaller, image becomes more *wide angle*
 - More world points project onto the finite image plane
- As f gets larger, image becomes more *telescopic*
 - Smaller part of the world projects onto the finite image plane



Digital Images



- Film is replaced by a sensor array
- Current technology: arrays of *charge coupled devices* (CCD)
- *Discretize* the image into pixels
- *Quantize* light intensities into pixel values.

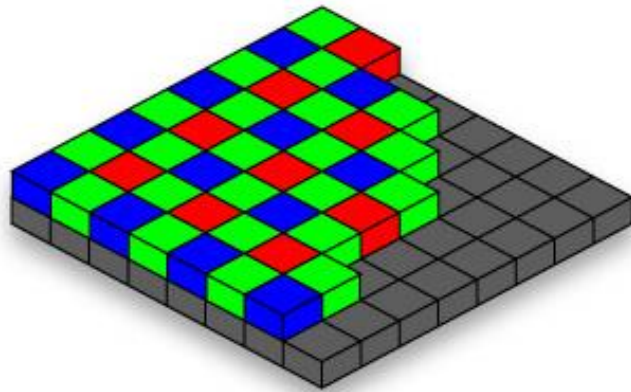
Resolution

- **Sensor:** size of real world scene element that images to a single pixel
- **Image:** number of pixels
- Influences what analysis is feasible, affects best representation choice

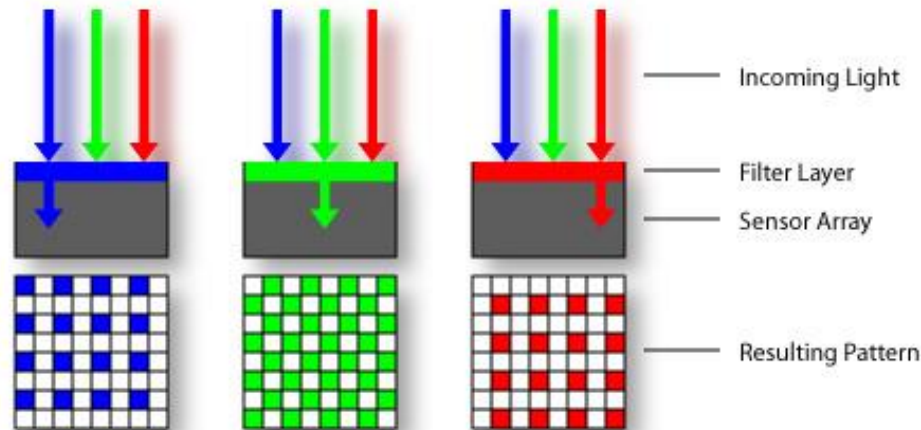


Color Sensing in Digital Cameras

Bayer grid



Estimate missing components from neighboring values (demaosaicing)



Grayscale Image

- Problem of Computer Vision

- How can we recognize fruits from an array of (gray-scale) numbers?
- How can we perceive depth from an array of (gray-scale) numbers?
- ...

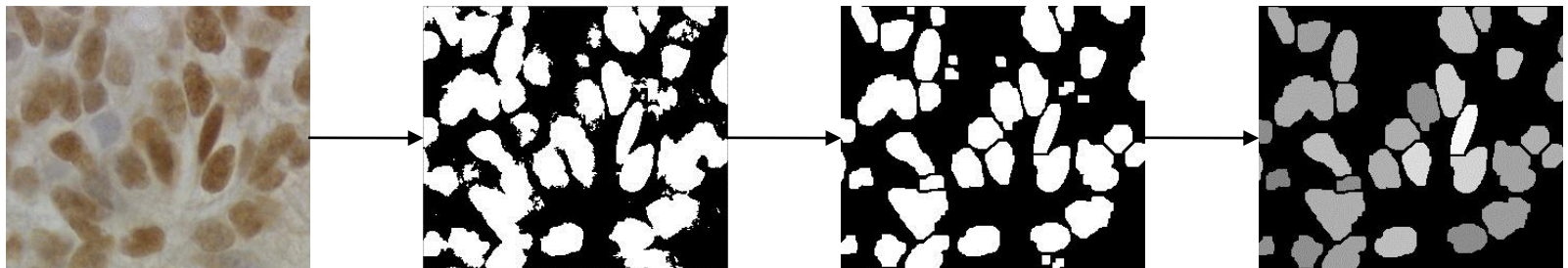


	x =														
	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
y = 41	210	209	204	202	197	247	143	71	64	80	84	54	54	57	58
42	206	196	203	197	195	210	207	56	63	58	53	53	61	62	51
43	201	207	192	201	198	213	156	69	65	57	55	52	53	60	59
44	216	206	211	193	202	207	208	57	69	60	55	77	49	62	61
45	221	206	211	194	196	197	220	56	63	60	55	46	97	58	106
46	209	214	224	199	194	193	204	173	64	60	59	51	62	56	48
47	204	212	213	208	191	190	191	214	60	62	66	76	51	49	55
48	214	215	215	207	208	180	172	188	69	72	55	49	56	52	56
49	209	205	214	205	204	196	187	196	86	62	66	87	57	60	48
50	208	209	205	203	202	186	174	185	149	71	63	55	55	45	56
51	207	210	211	199	217	194	183	177	209	90	62	64	52	93	52
52	208	205	209	209	197	194	183	187	187	239	58	68	61	51	56
53	204	206	203	209	195	203	188	185	183	221	75	61	58	60	60
54	200	203	199	236	188	197	183	190	183	196	122	63	58	64	66
55	205	210	202	203	199	197	196	181	173	186	105	62	57	64	63

- How do we humans do it? How can we make a computer do it?

Next Lectures

- **First few lectures: low-level vision**
 - Binary image processing
 - Filtering operations
 - Edge and structure extraction
 - Color
 - Segmentation and grouping
- **Next week: Binary image processing**



- **Tuesday 21.10.: *Exercise 1***
 - Intro Matlab, basic image operations

Questions ?