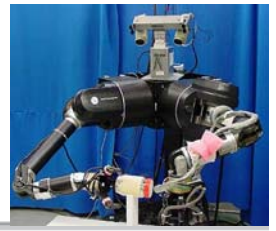
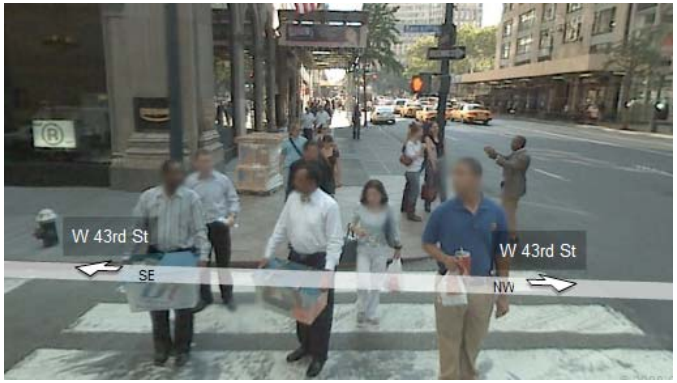
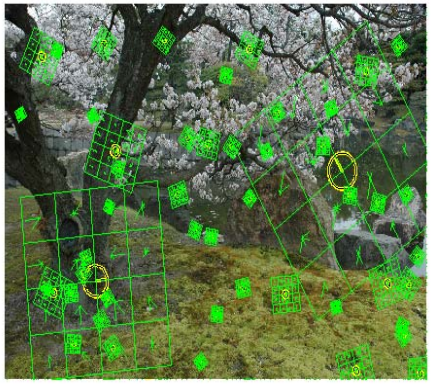
Einführung in Visual Computing (EVC)
Image Processing & Computer Vision

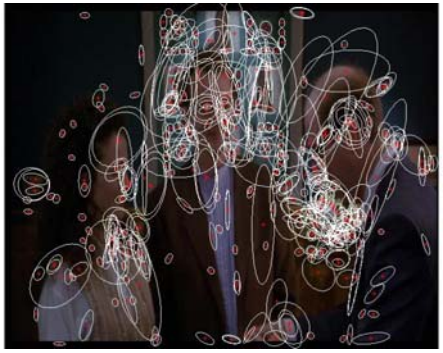


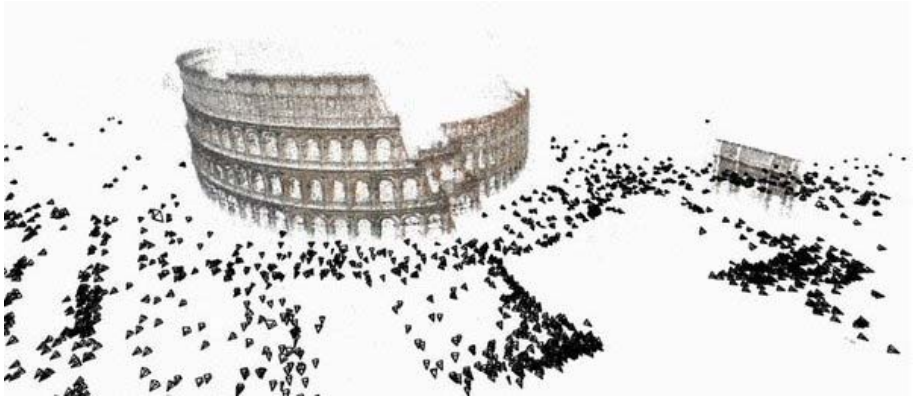
186.822 VU 5.0 6 ECTS

Robert Sablatnig

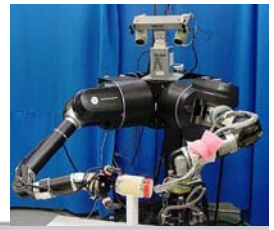








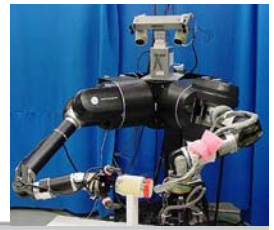
EVC: Image Processing & Computer Vision



http://www.caa.tuwien.ac.at/cvl/teaching/sommersemester/evc

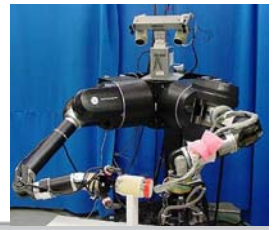
- Content:
  - What are the **basic concepts** of Image Processing and Computer Vision and how are they used in **applications**? The course answers these questions by describing the **creation** of **digital images** using digital cameras and the subsequent steps in order to derive **information kept in digital images automatically**.
  - A closer look is taken into **classical image processing** techniques like image **enhancement** and **compression**.
  - The next step consists in the development of **digital filters** and **segmentation** techniques in order to be able to extract specific information.
  - **Interest Points** Computational Photography, 3D and motion are further topics.
  - Application of **Algebra and Analysis** in reality

Logistics



- Lectures: 13:00 - 15:00
- Instructors: Robert Sablatnig (VO) and
  Sebastian Zambanini (UE)
- Textbook: 4 A4 pages/lesson available in pdf at website
- Further Reading:
  - Richard Szeliski, Computer Vision: A Modern Approach
    http://szeliski.org/Book/
  - Sonka, Hlavac, Boyle: Image Processing, Analysis, and Machine Vision, 2nd Edition
- Webpage:
  http://www.caa.tuwien.ac.at/cvl/teaching/sommersemester/evc

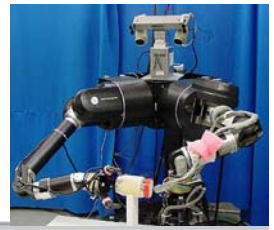
Readings



- Alfred Nischwitz, Max Fischer, Peter Haberäcker, Gudrun Socher, „*Computergrafik und Bildverarbeitung*“, Vieweg+Teubner Verlag, Springer Fachmedien Wiesbaden GmbH, 2011.
- Downloadbar (nur im TU Netz):

  http://link.springer.com/book/10.1007/978-3-8348-8300-1

Readings



Springer Link

Search

Home • Contact Us

TU WIEN UB Universitätsbibliothek

» Download Book (52,007 KB)

Search within this book

2011

Computergrafik und Bildverarbeitung

Band II: Bildverarbeitung

Authors: Alfred Nischwitz, Max Fischer, Peter Haberäcker, Gudrun Socher

ISBN: 978-3-8348-1712-9 (Print) 978-3-8348-8[illegible]00-1 (Online)

» Download Book (52,007 KB)

Table of contents (28 chapters)

Page 1 of 2

Front Matter

» Download PDF (117KB) Pages I-XVI

Book Chapter

Einleitung

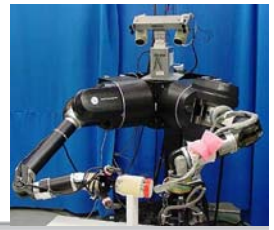
Alfred Nischwitz, Max Fischer, Peter Haberäcker, Gudrun Socher

Other actions

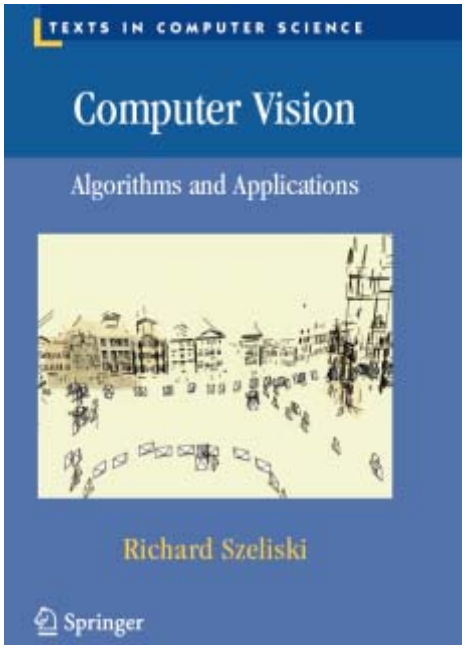
» About this Book

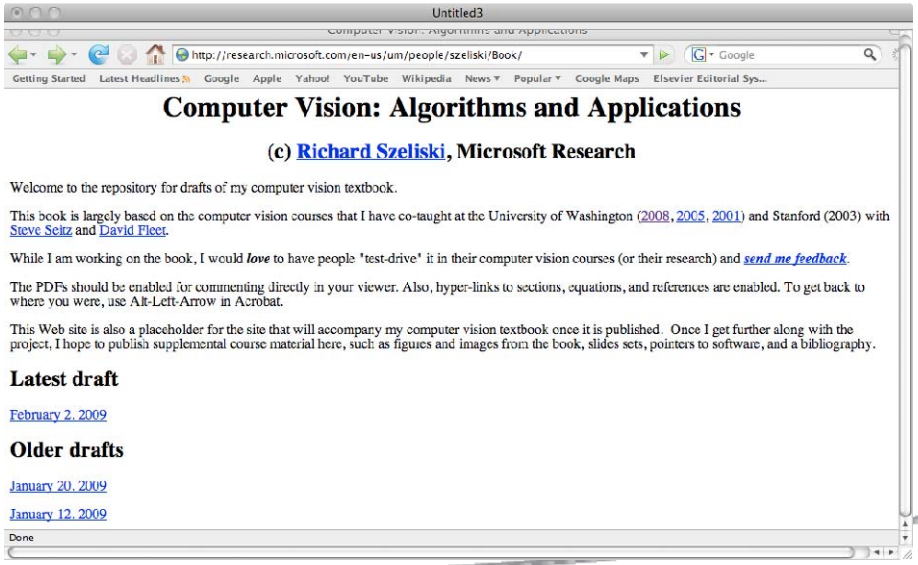
Share

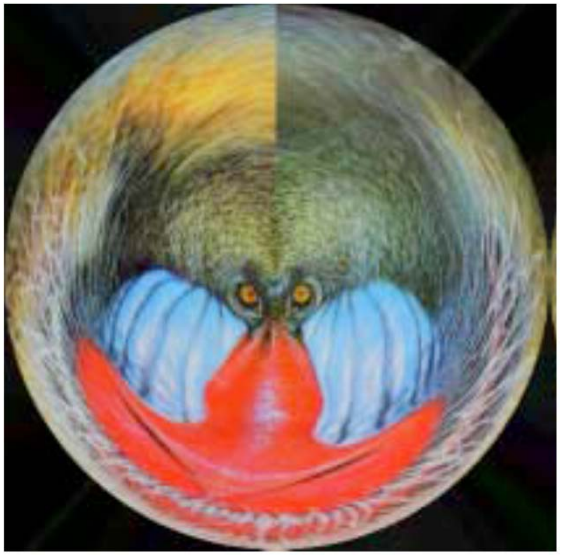
Readings

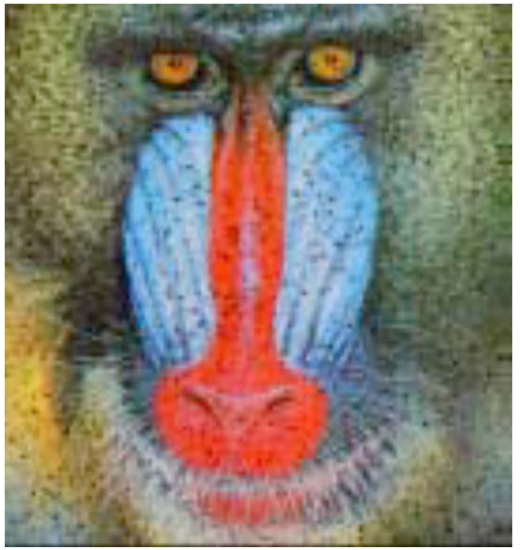


- Richard Szeliski, „Computer Vision: Algorithms and Applications“, Springer-Verlag London, 2011
  - http://link.springer.com/book/10.1007/978-1-84882-935-0
  - http://szeliski.org/Book/





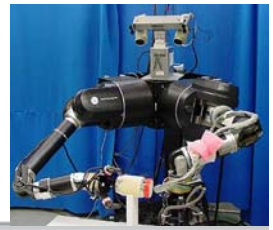


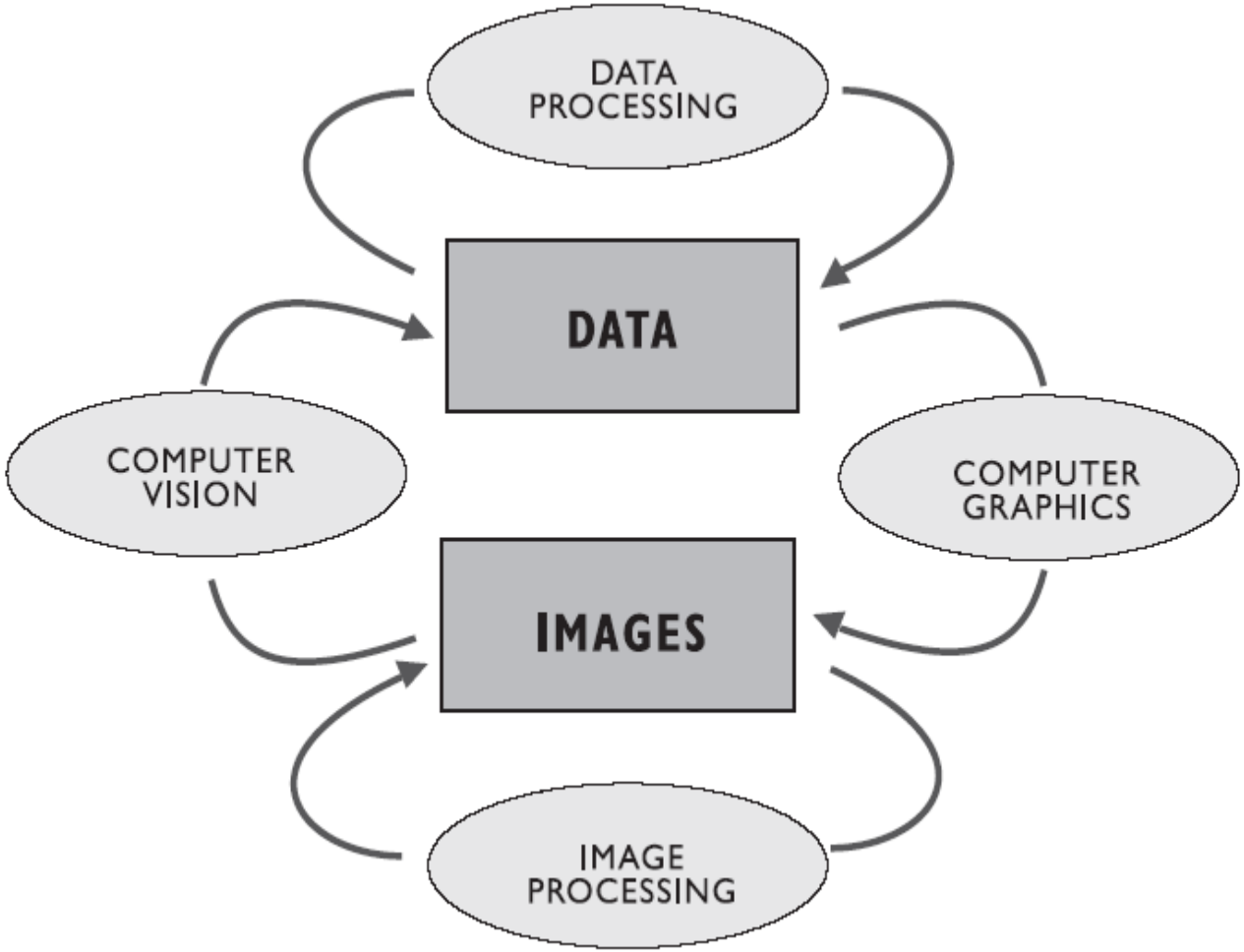


TU WIEN CVL Computer Vision Lab

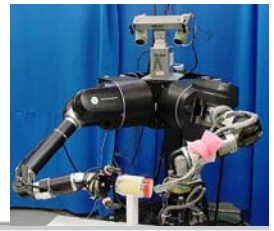
Introduction: What is Image Processing?

Computer Graphics vs. Computer Vision



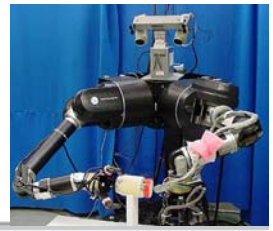


Categorization



- ***Image Processing***
  - *Manipulation of Image Data*,
  - Like removal of Noise, Correction of Sharpness on digital images.
- ***Computer Vision***
  - *Generation of non-graphical Data* from images,
  - Like Character-and Text Recognition, Segmentation of images into „interesting“ parts, Detection of lines and corners.
- ***Computer Graphics***
  - *Generation of Images* from non-graphical data,
  - like bar charts, 3d graphics „VR“ in real time, graphical outputs

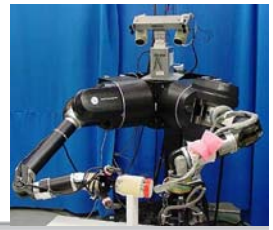
Categorization

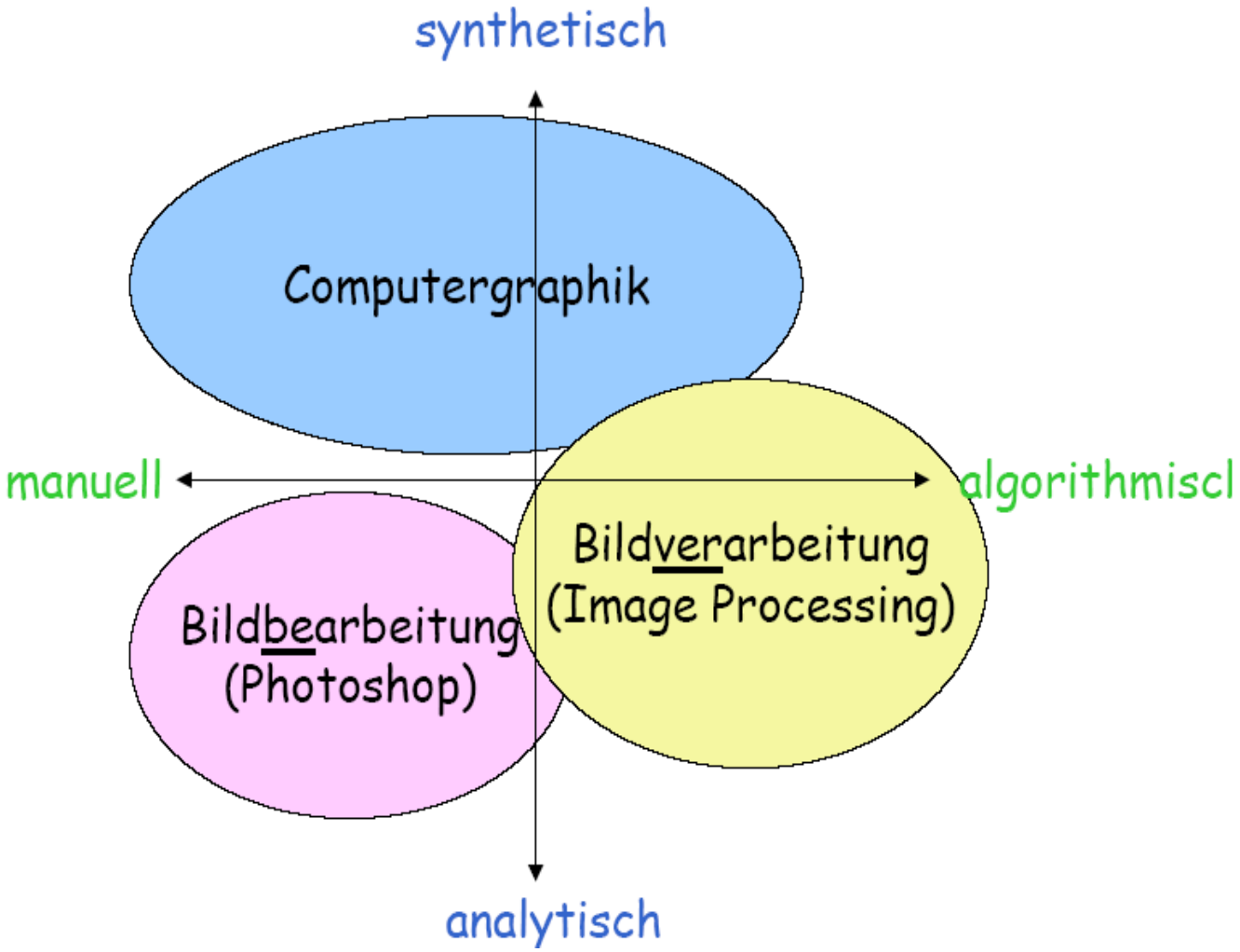


- ***Image Editing***: Manipulation of Images (e.g. Adobe Photoshop)
  - Visually
  - Interactive
  - User-defined parameters

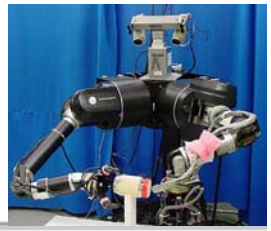
- ***Image Processing***: Mathematical algorithmic processes
  - Image enhancement
  - Image transformation (geometric)
  - Image compression
  - Image segmentation

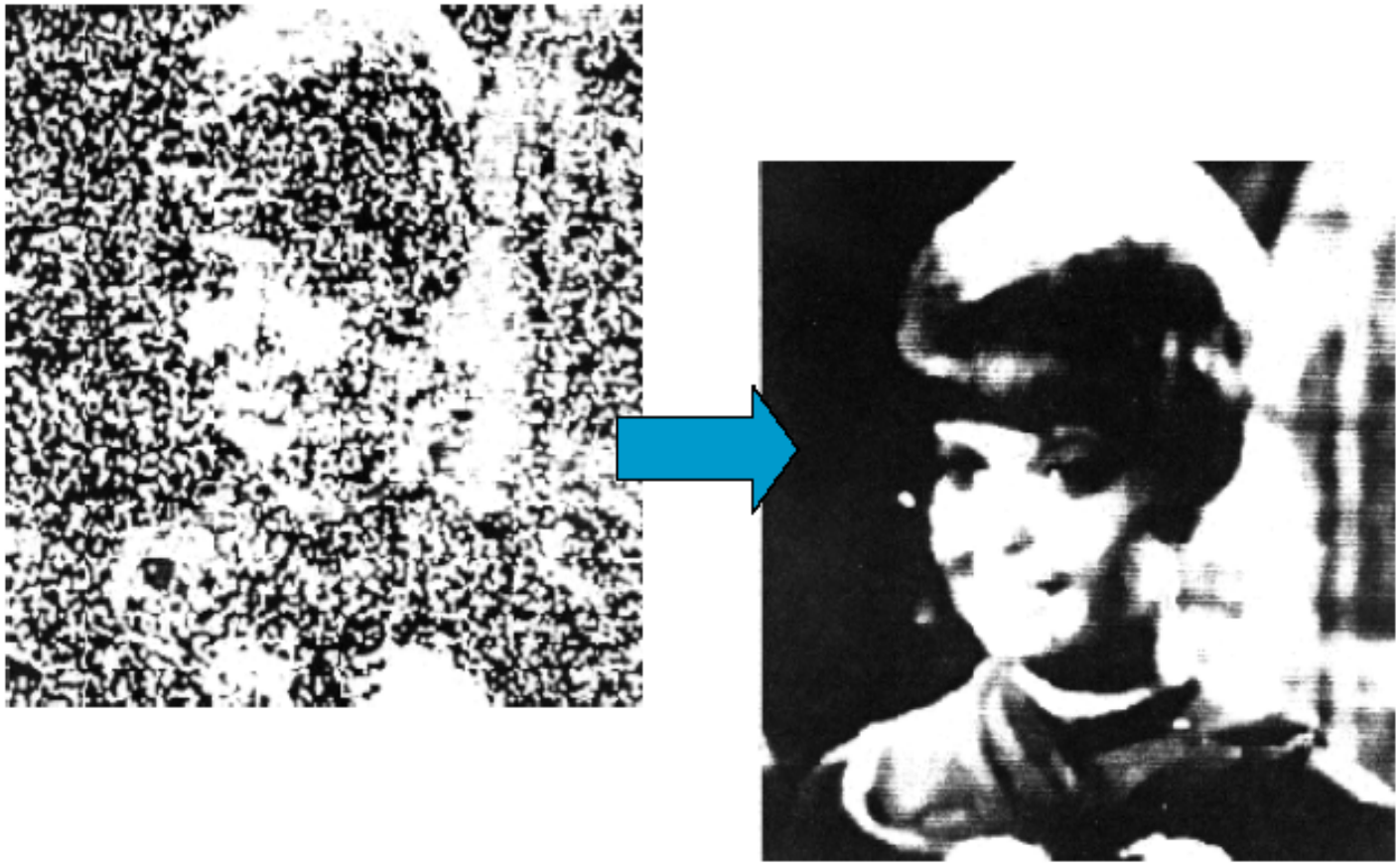
Kategorisierung



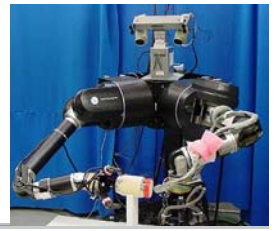


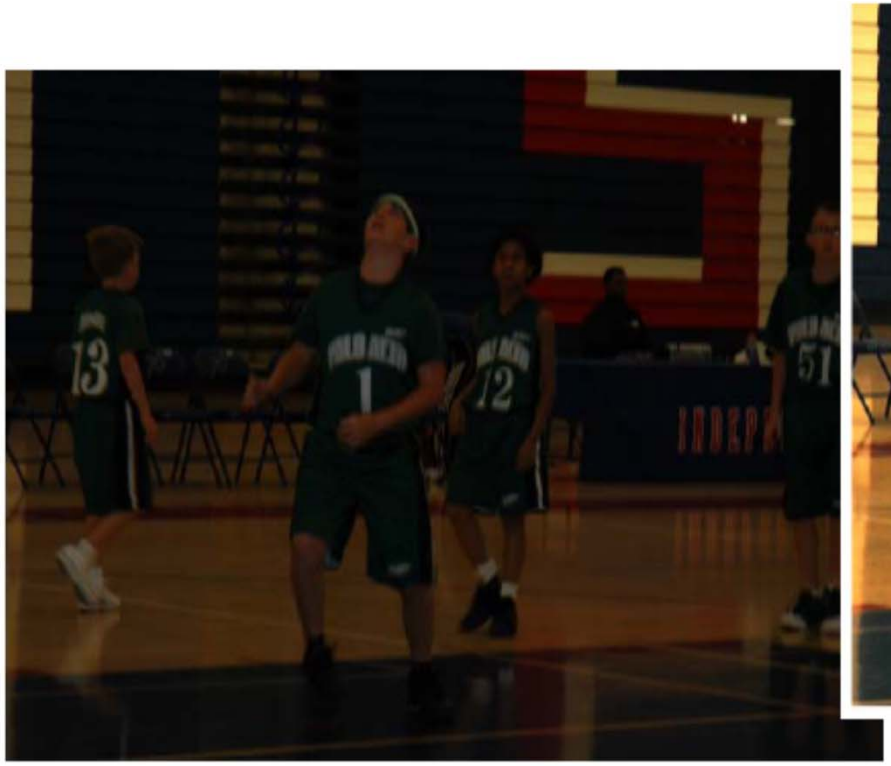
Example Image Processing: Filter (Noise Removal)





Example Image Processing: Image Enhancement

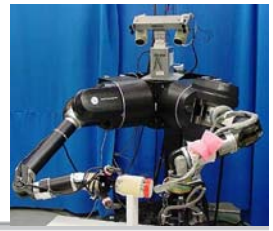


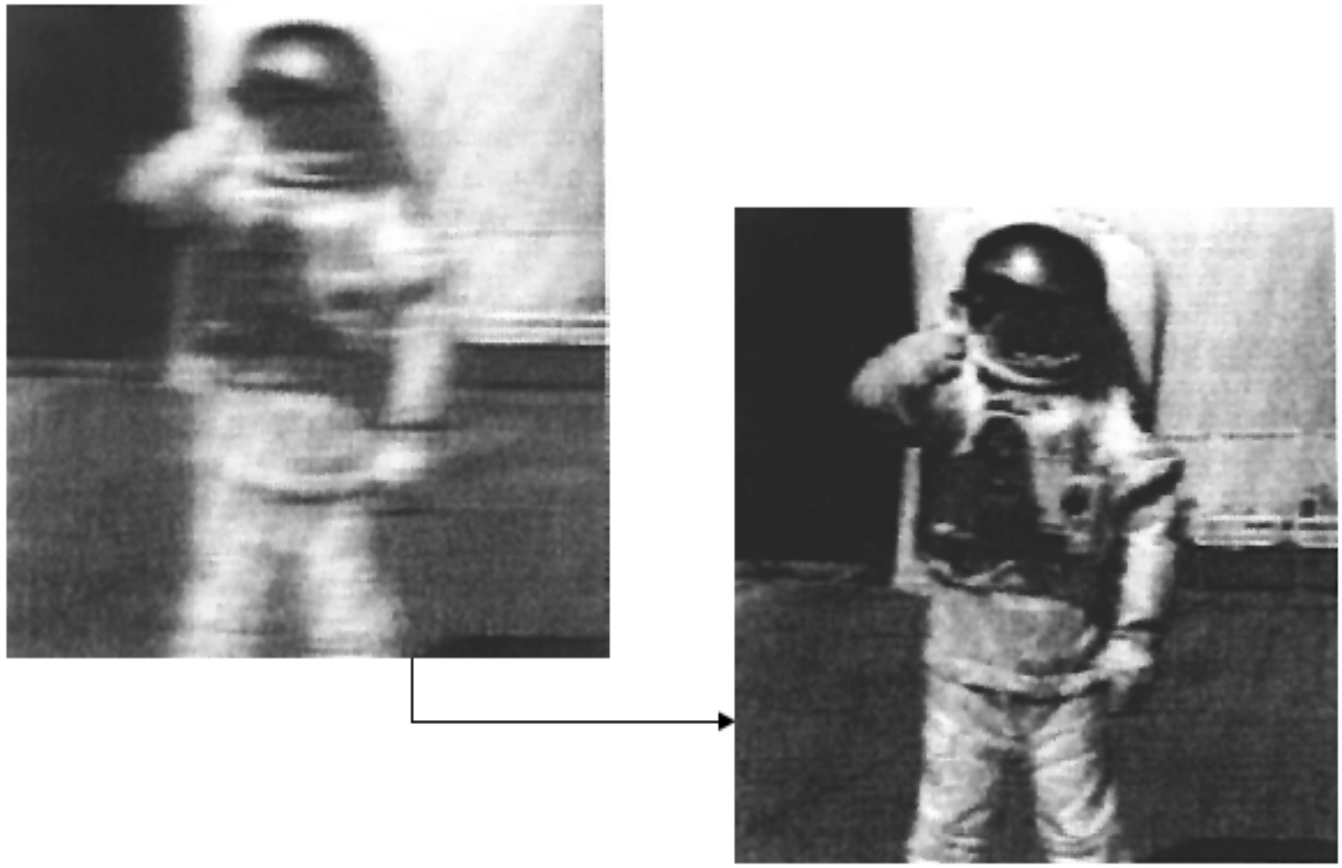


Original

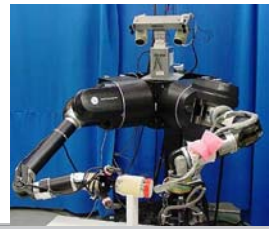
Automatic Enhancement

Example: Image Restoration

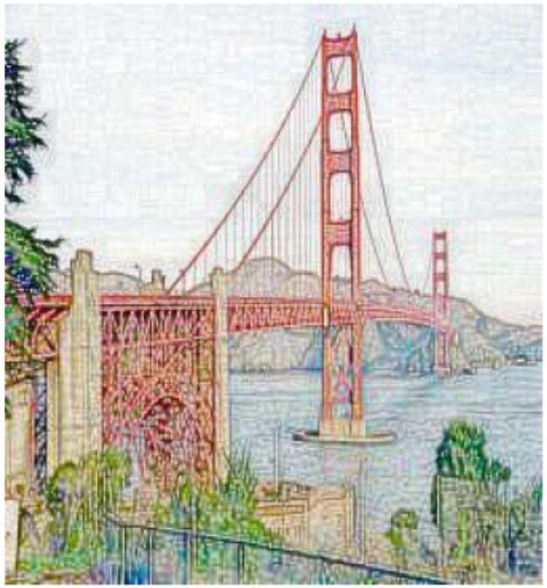




Example: Special Effects



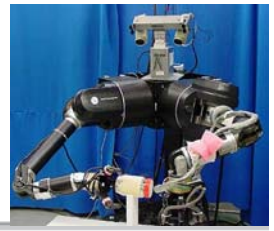
Photo



Simulated
color pencils

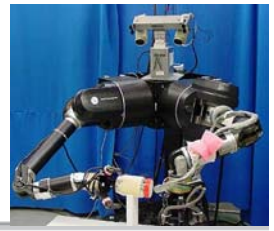
Simulated
oil painting

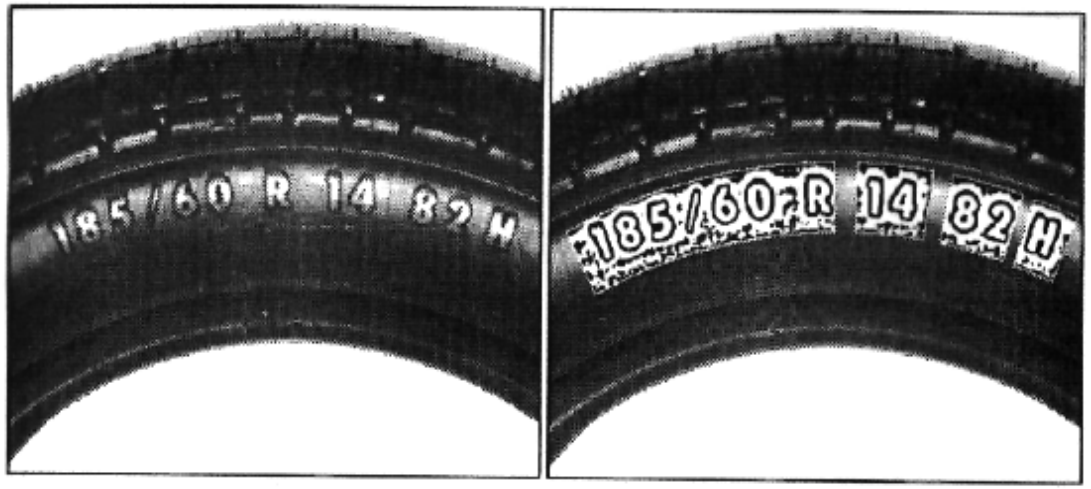
Difference: Pattern Recognition – Image Processing?



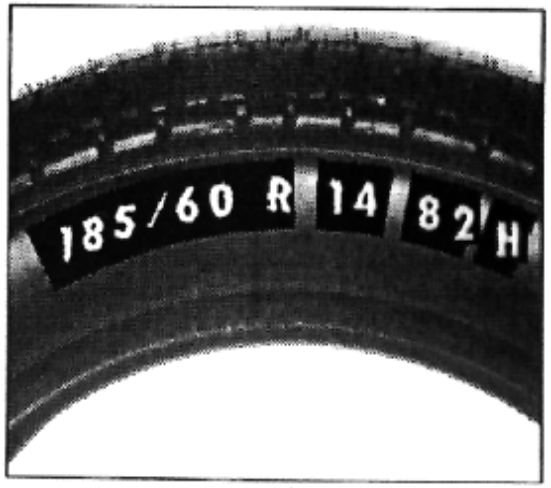
- ***Pattern Recognition***:
  - **Classification** of **Patterns** into a (finite) **number of** pre-defined **classes**
  - like 2-dimensional patterns, **OCR**
  - **Standard book**: Duda and Hart 1973, "Pattern Classification and Scene Analysis"
- ***Image Processing***:
  - **Processing** of an image to get a **new image** that is **better suited** for a specific **task**.
  - Image **enhancement**, image **transformation**, image **compression**, image **segmentation**, image **restauration**…
  - **Standard book**: Rosenfeld and Kak 1982, "Digital Picture Processing", 2nd Edition

Example: Pattern Recognition

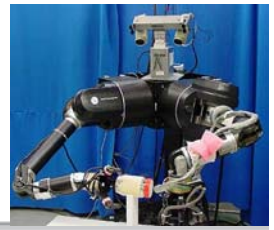




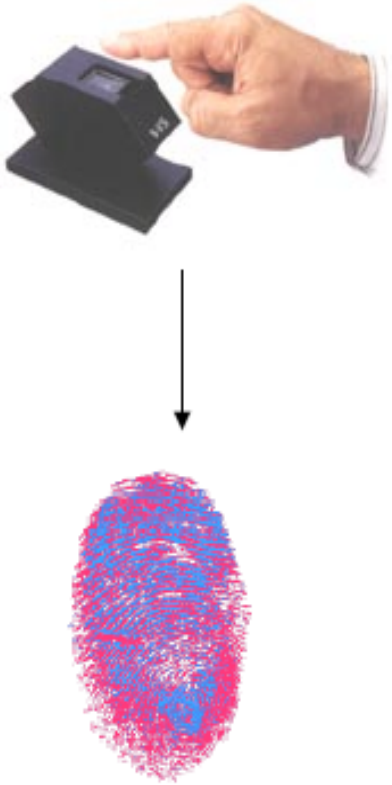
Optical Character Recognition (OCR)



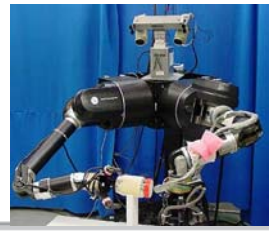
Example: Pattern Recognition



Fingerprint Recognition

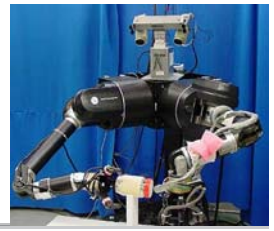


Example: Pattern Recognition

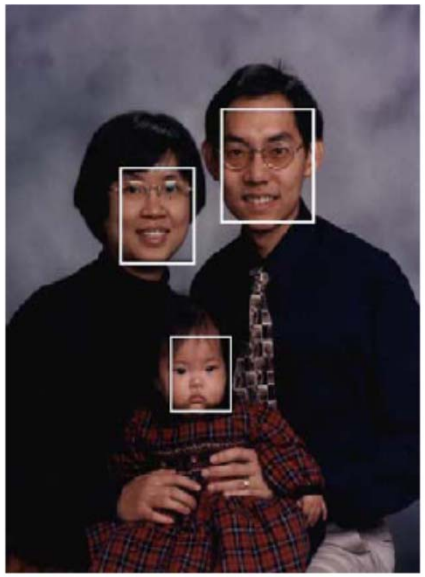


Face Recognition

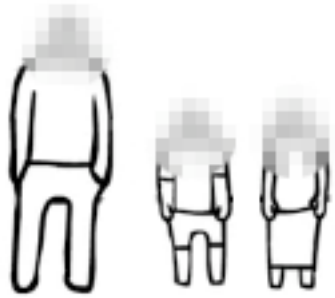
Example: Computer Vision

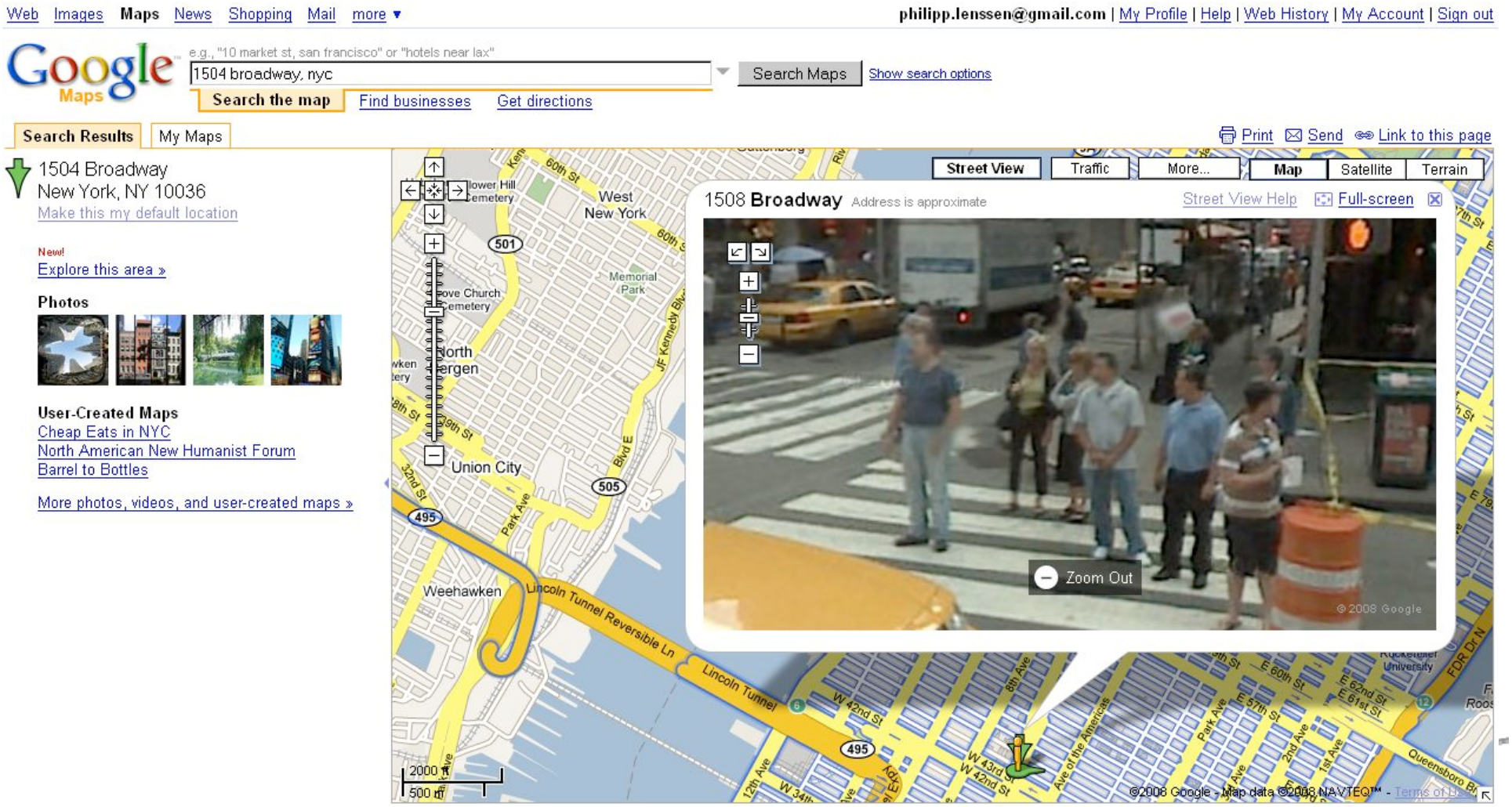


- Face Detection

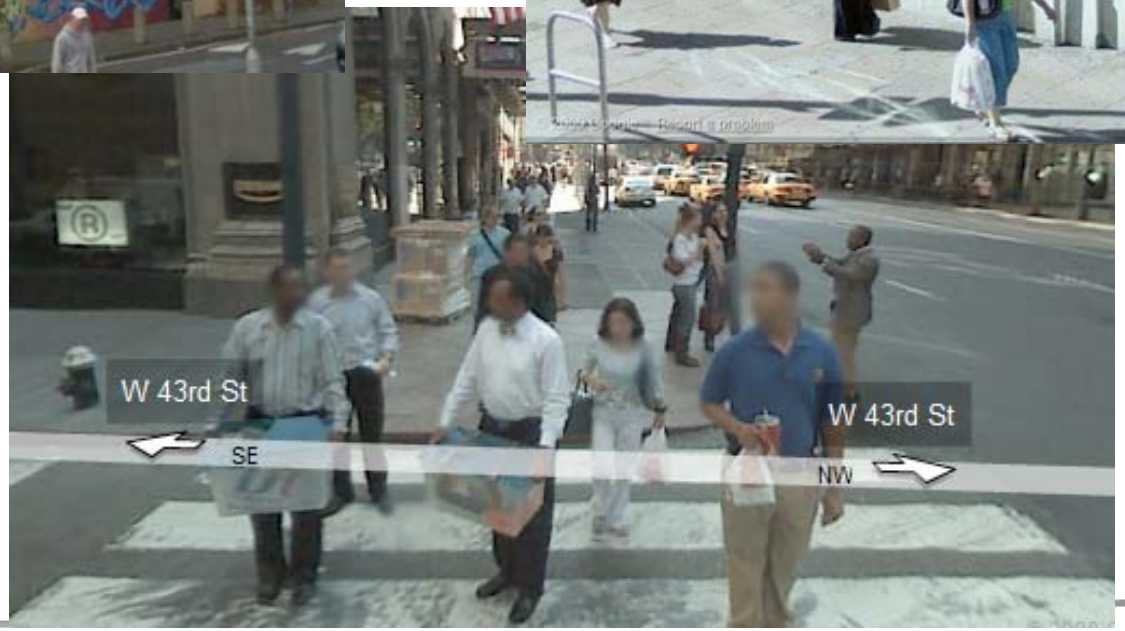


Google Street View





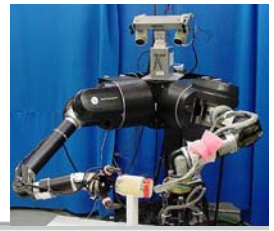
Google Street View



TU WIEN CVL Computer Vision Lab

Introduction: What is Computer Vision?

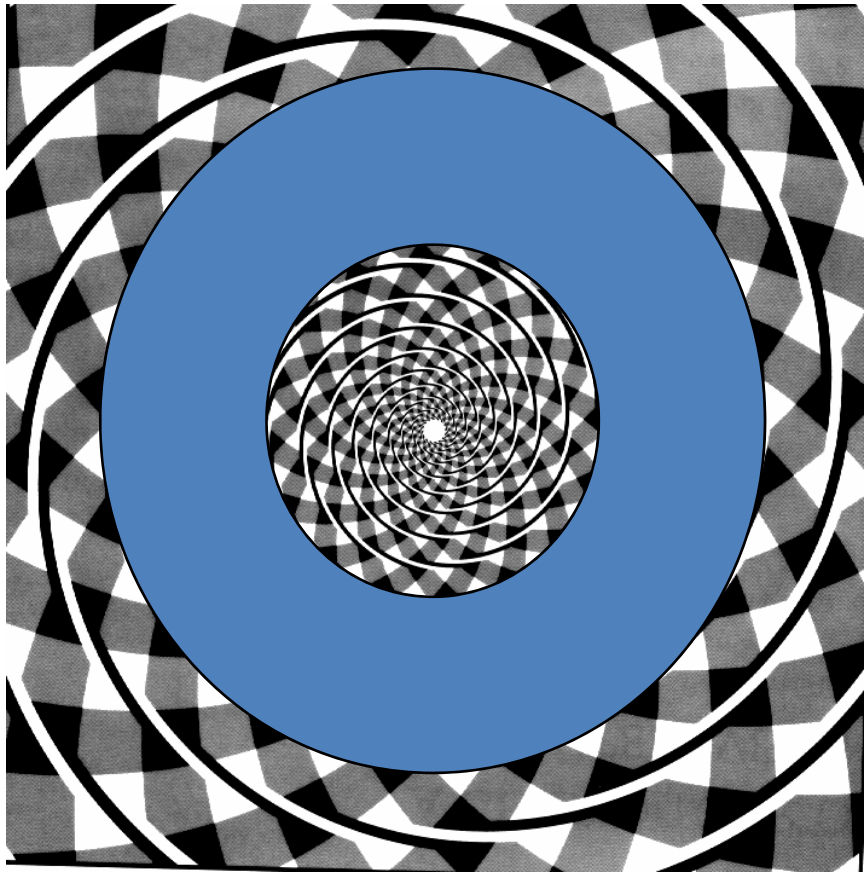
Computer Vision



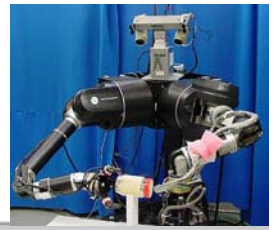
- Vision is derived from **Human Vision** (Human Visual System)
- Humans „see“ in **3 Dimensions**

  => Computer Vision has 3d components
- Evolution millions of years: Human visual system **not faultless**

  - => if human visual system is not faultless how can we expect from a machine that it is?



What is Computer Vision ?

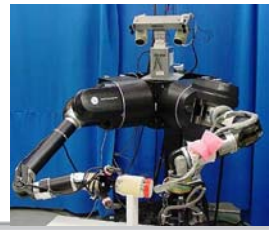


"***Computer Vision*** *describes the* ***automatic deduction*** *of the structure and the properties of a (possible dynamic)* ***three-dimensional world*** *from either a* ***single*** *or* ***multiple two-dimensional images*** *of the world*"

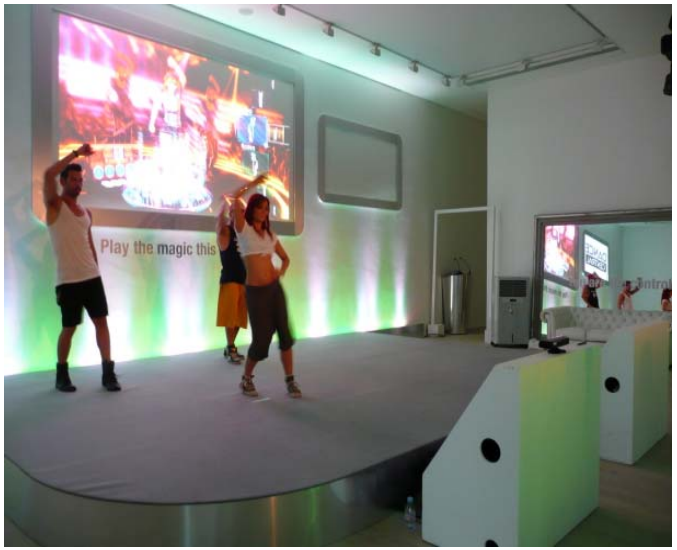
- Vishvjit S. Nalwa: *A guided tour of computer vision*. Addison-Wesley 1993

- Images: Color or Grayscale
- Camera: Fixed or movable

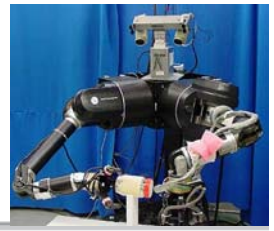
Computer Vision – Industry Related



- Computer Vision is an ***exciting new research area*** that studies how to make computers efficiently ***perceive, process,*** and ***understand*** visual data such as images and videos. The ultimate goal is for computers to emulate the ***striking perceptual capability of human eyes and brains***, or even to ***surpass and assist*** the human in certain ways. – *Microsoft Research*

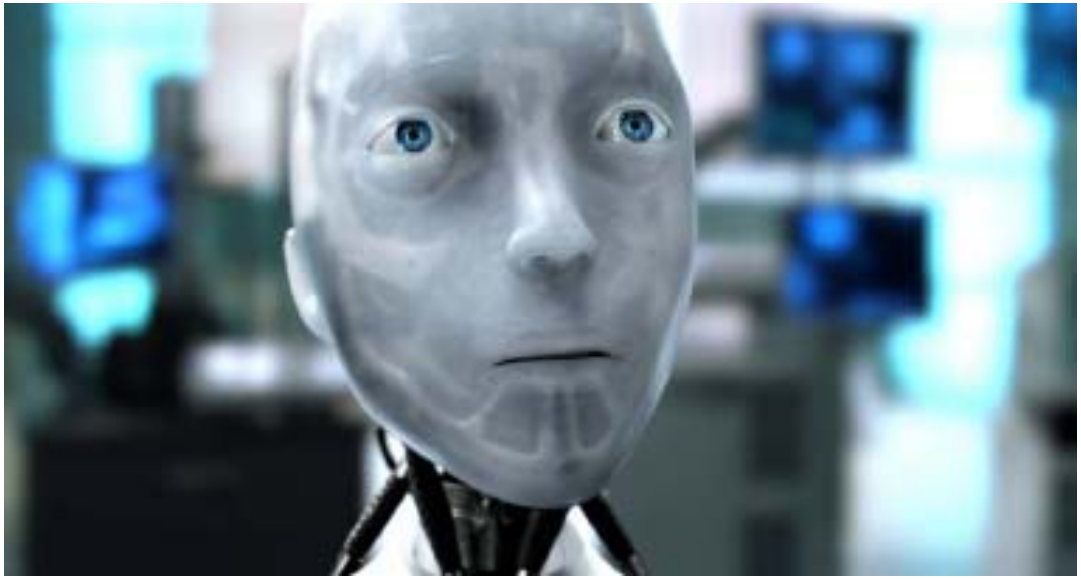


Computer Vision

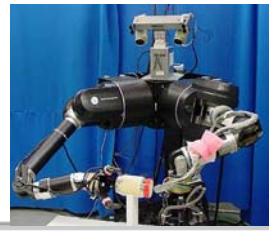


At least three goals:

1. Understand biological visual systems
2. ***Build machines that see***
3. Understand fundamental processes of seeing



Computer Vision

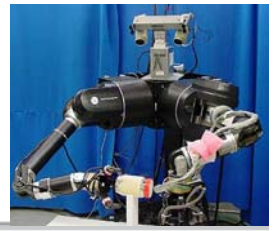


We still do not know:

- Is vision a well organized process with fundamental principles or

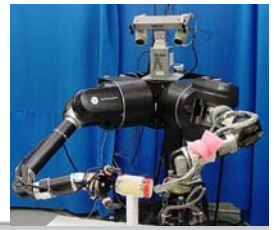
- A bag of tricks?

Goals and Applications of Computer Vision



- It is ***not the goal*** of Computer Vision to develop a ***robot*** that is ***similar to humans*** [Whitney86]
- Goal is to ***surpass and assist humans***
- Applications:
  - Automation (Assembly line)
  - Inspection (Measuring of Parts)
  - Remote Sensing (Maps)
  - Human - Computer Interfaces
  - Systems for Disabled
  - Many more……

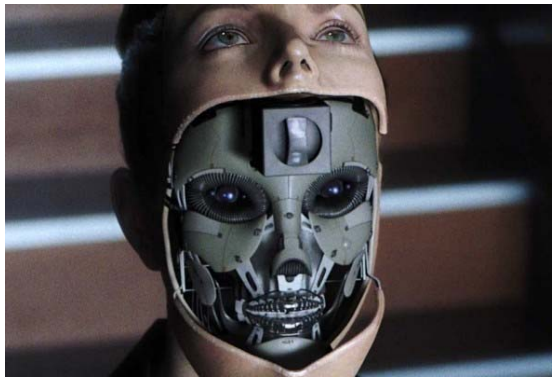
Computer Vision vs. Human Vision



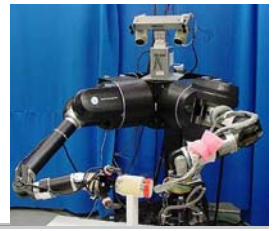
- Why not ***simply copy human vision*** researched by neurophysiologists, psychologists, and psychophysics?

- ***Eye*** research is ***finished*** – ***Human Vision*** research is ***not***!
- Seeing is ***not only a process within the eye*** – eye is only ***producing images*** formed to "impressions" by the brain

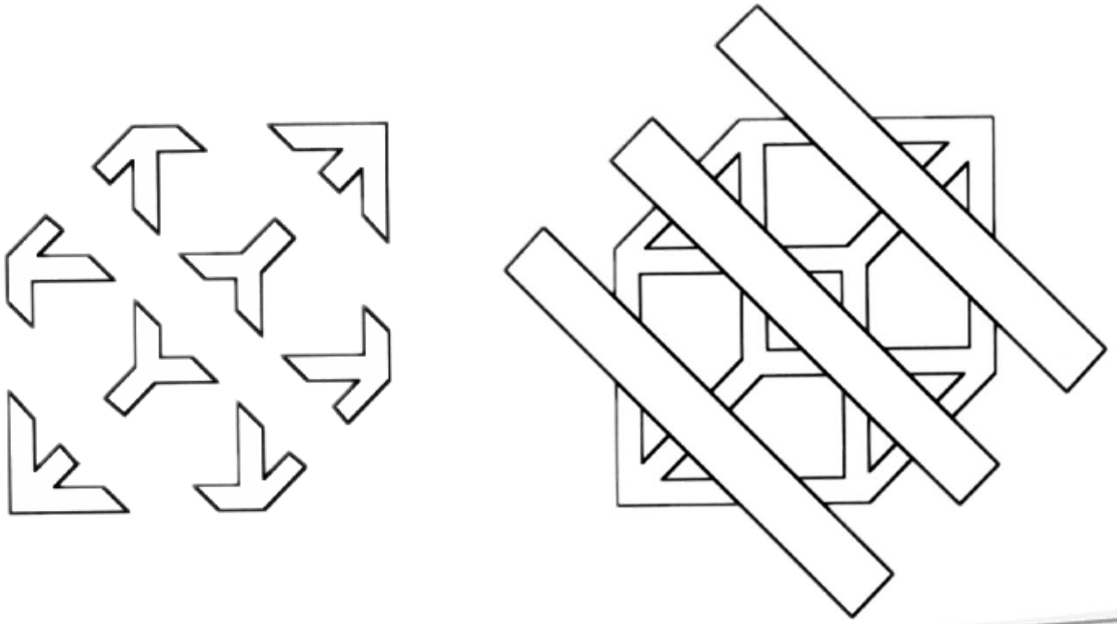
- => ***Beginning*** of Computer Vision in the area of ***Artificial Intelligence***



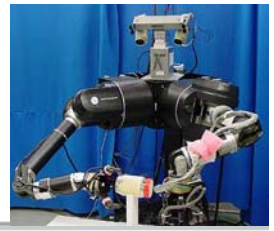
Computer Vision vs. Seeing



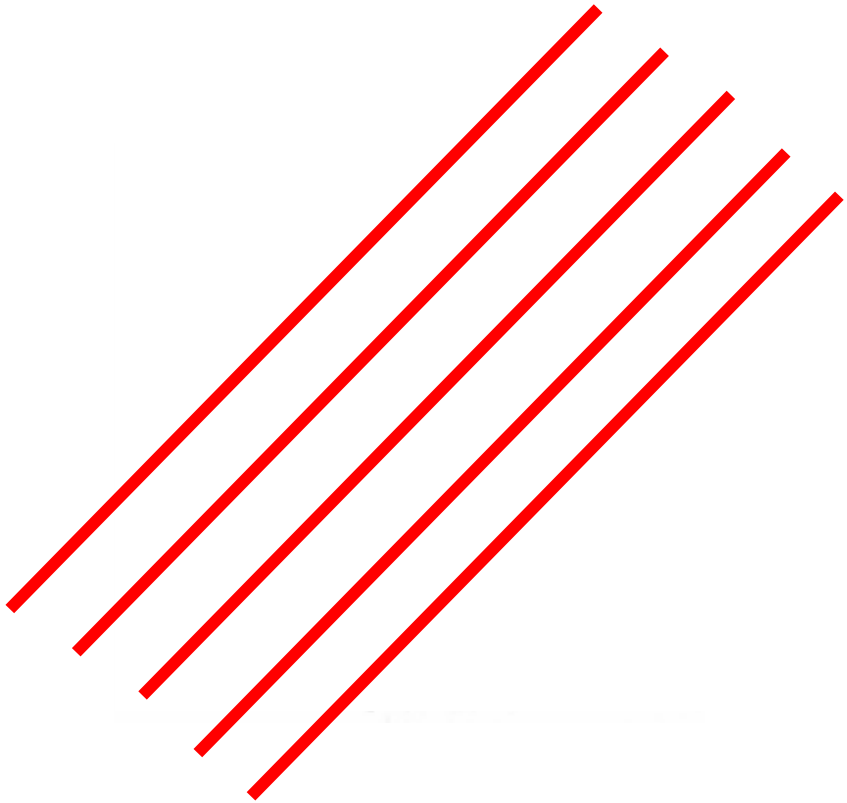
- Seeing has adopted itself to environment and therefore not faultless!
- Is Seeing an integral part of intelligence?
- Do we see reality – or what we want to see?
- **Is Seeing and Thinking separable**?



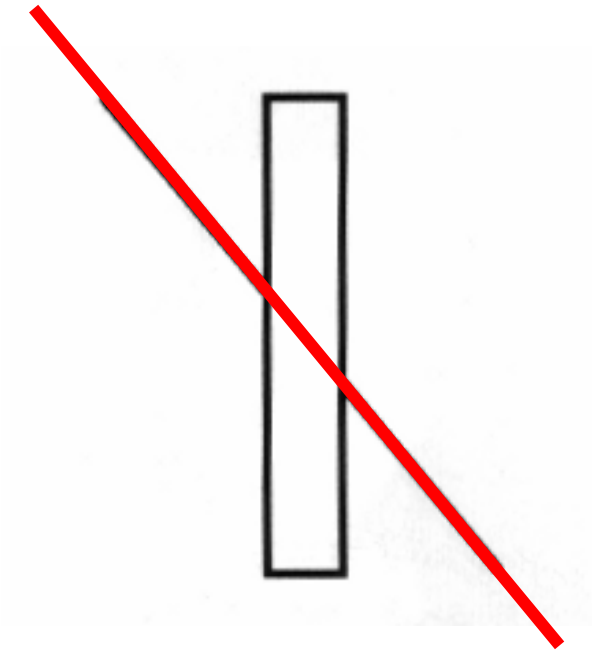
It’s Just An Illusion: Visual Illusions



- Classical optical illusions

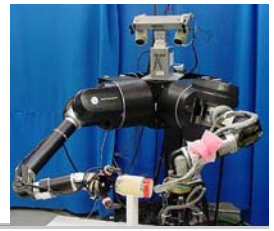


Zöllner Illusion (1860)

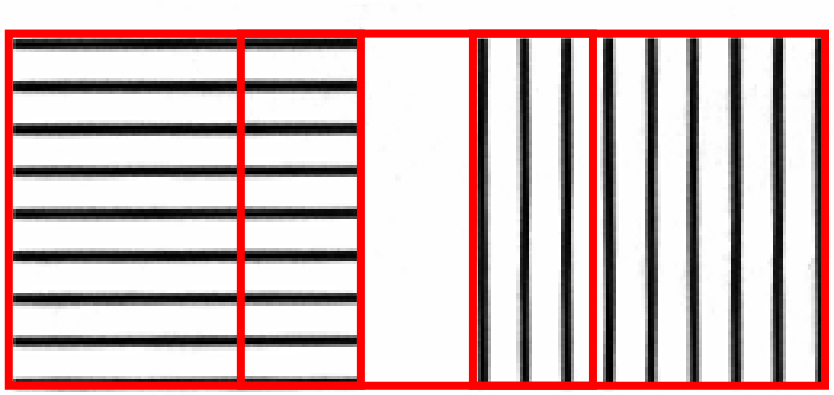


Poggendorf Illusion (1860)

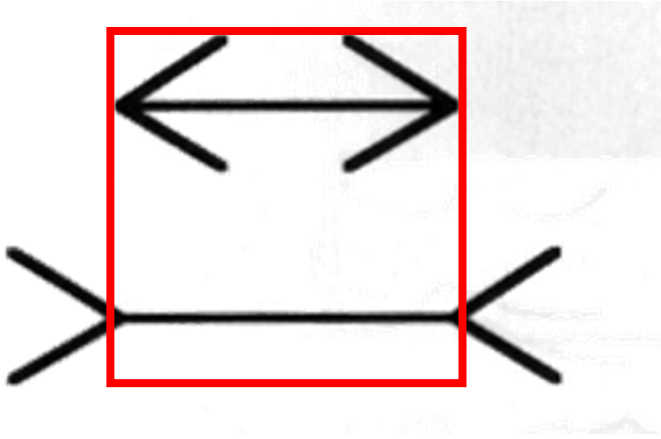
Visual Illusions



- Classical optical illusions

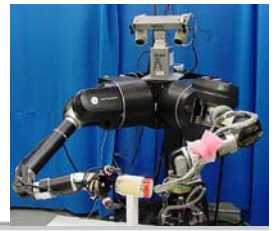


Helmholtz Squares (1866)

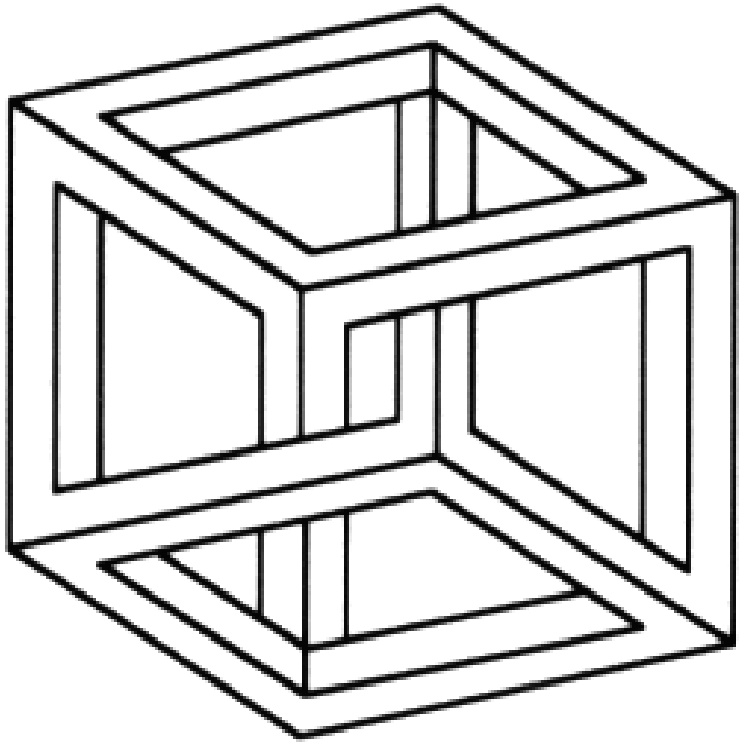


Müller-Lyer Illusion (1860)

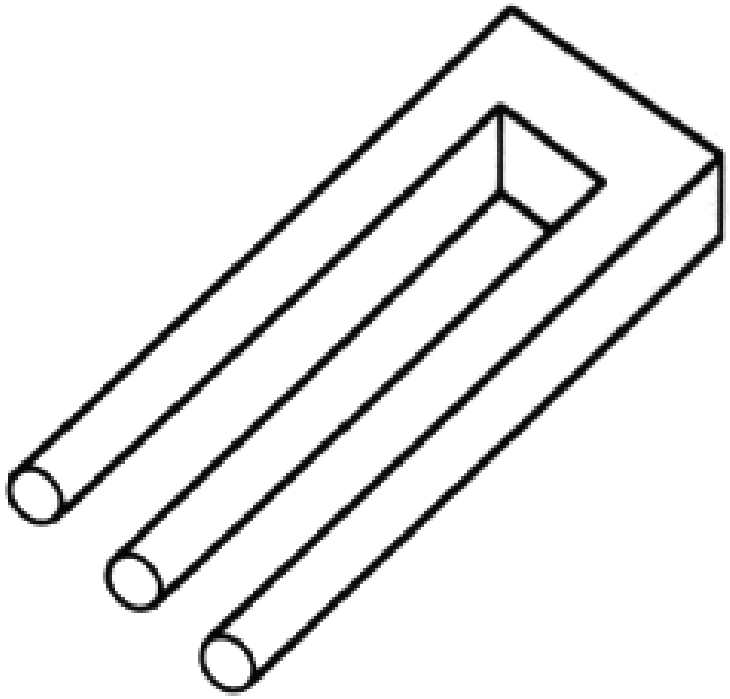
Visual Illusions



- Non existing 3D objects:

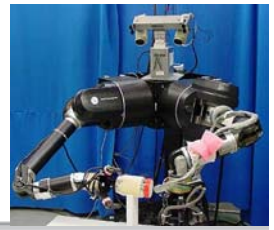


Escher Cube



Two-Pronged Trident

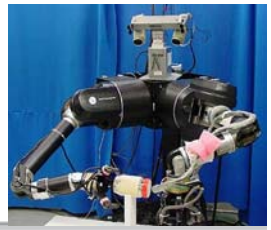
Perspective Illusions by Julian Beever



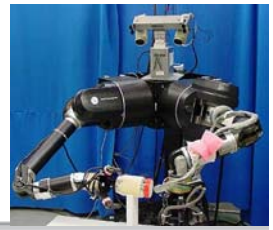
- http://www.julianbeever.net/

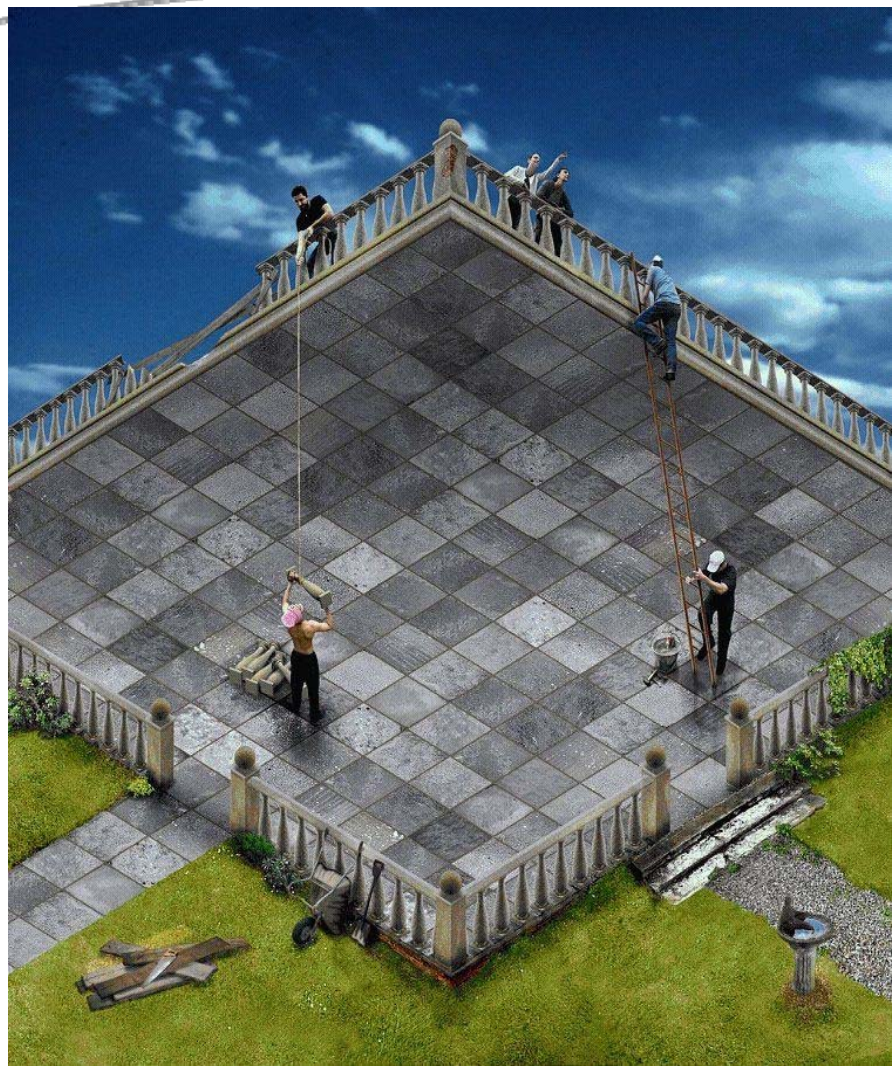
Babyfood...

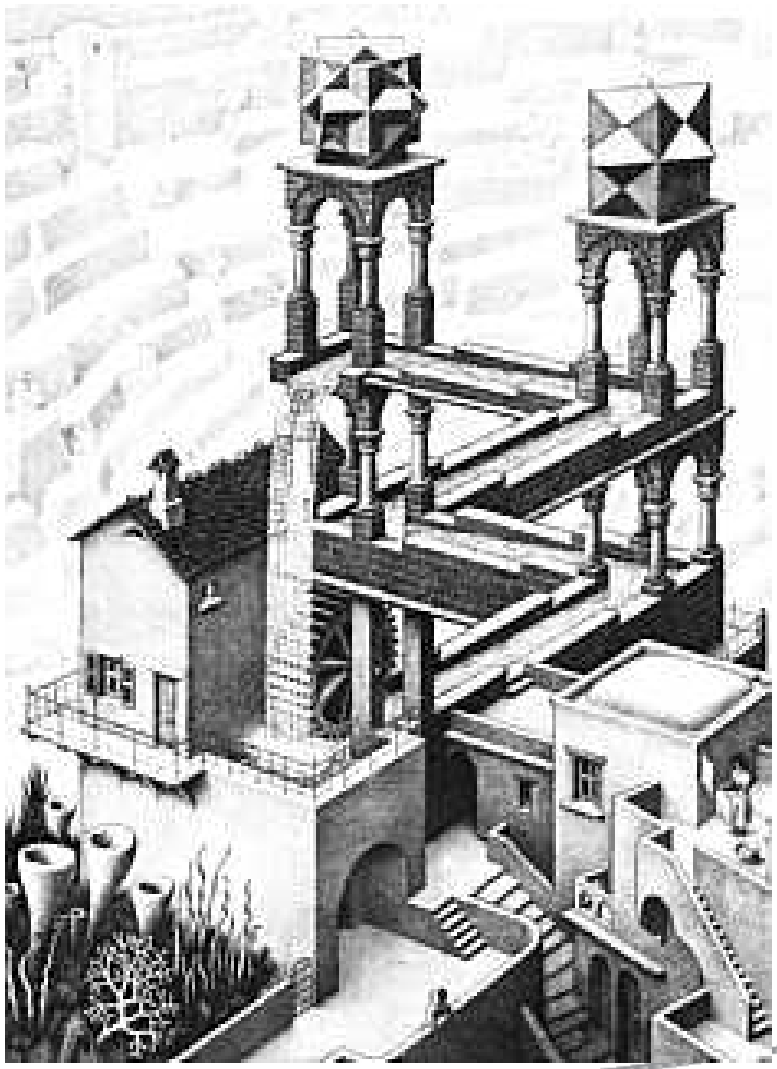
Make Poverty History



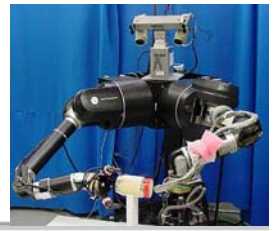
M.C. Escher







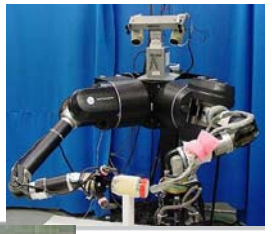
Ambigious Interpretations

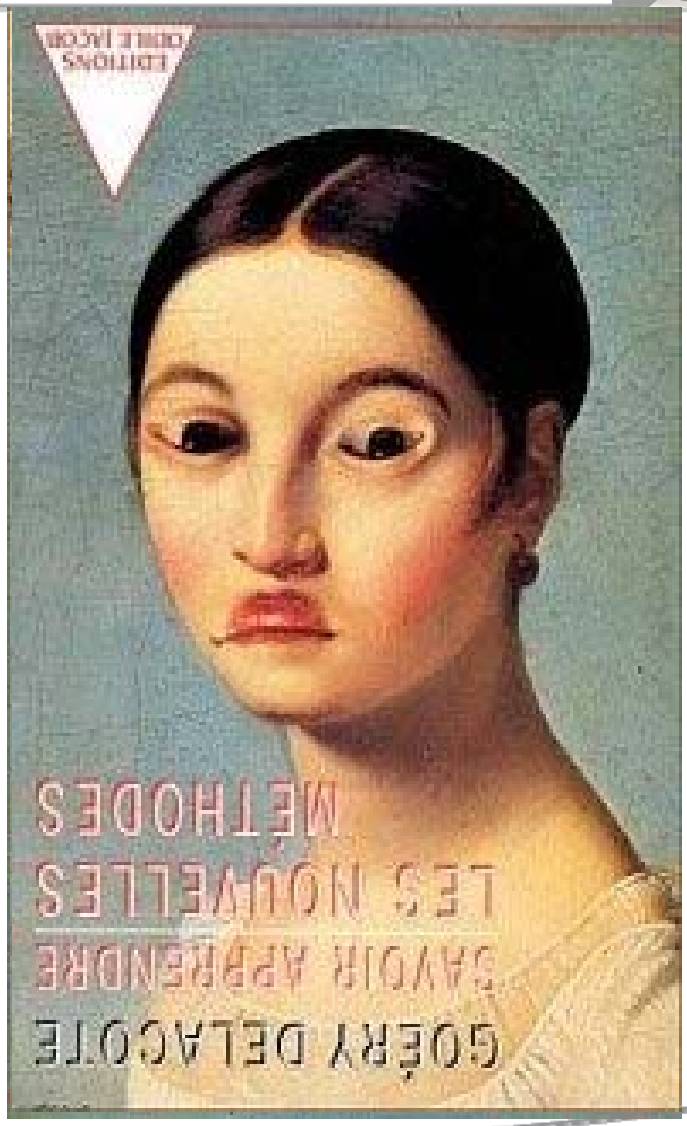


Amerindian vs. Inuit

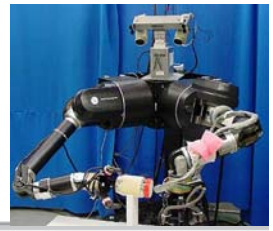
Young/Old Lady

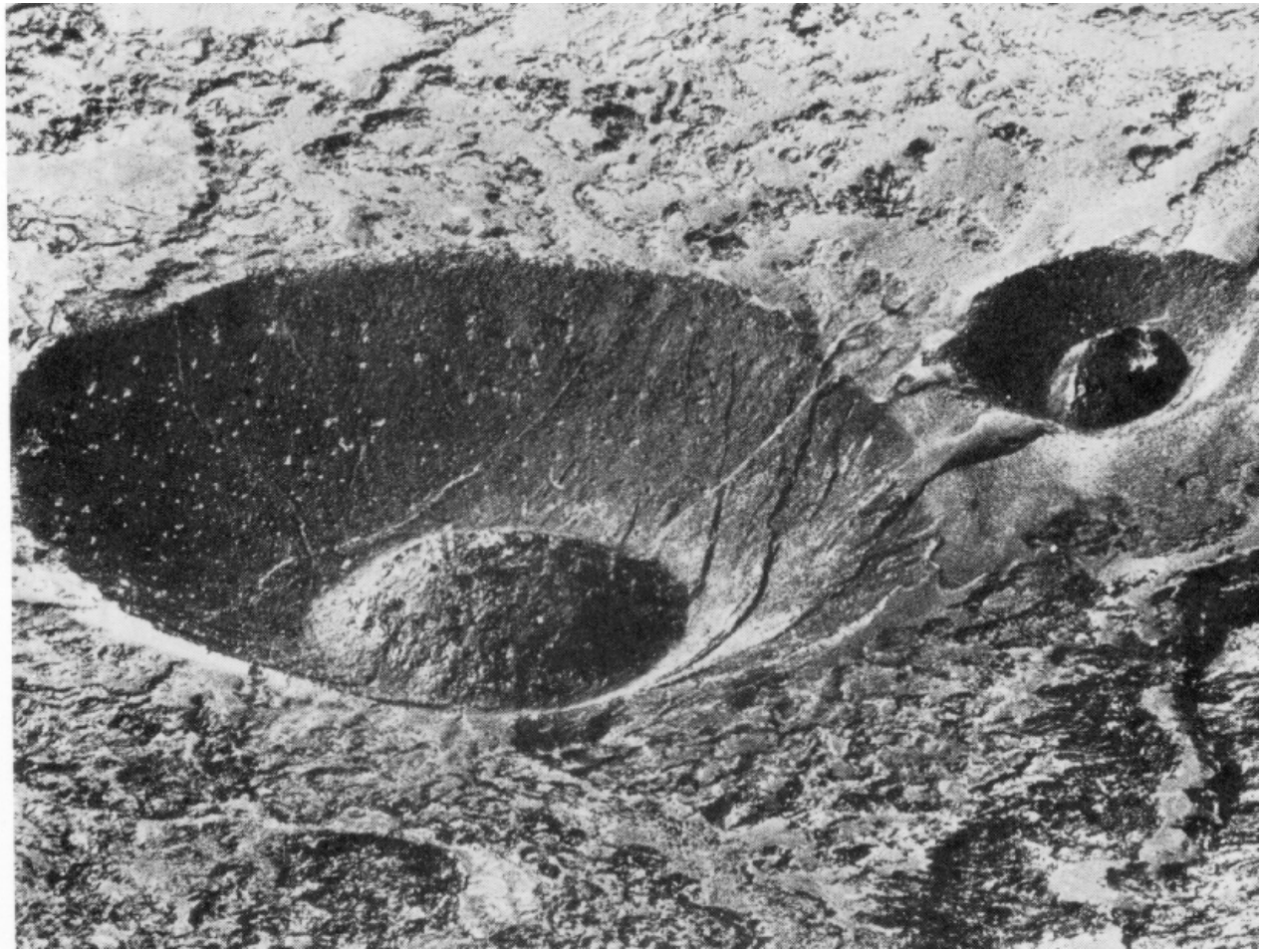
Rotary Effects



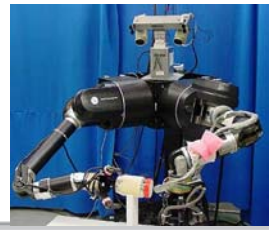


Are these phenomena caused by manipulation of the visual system by unreal images?

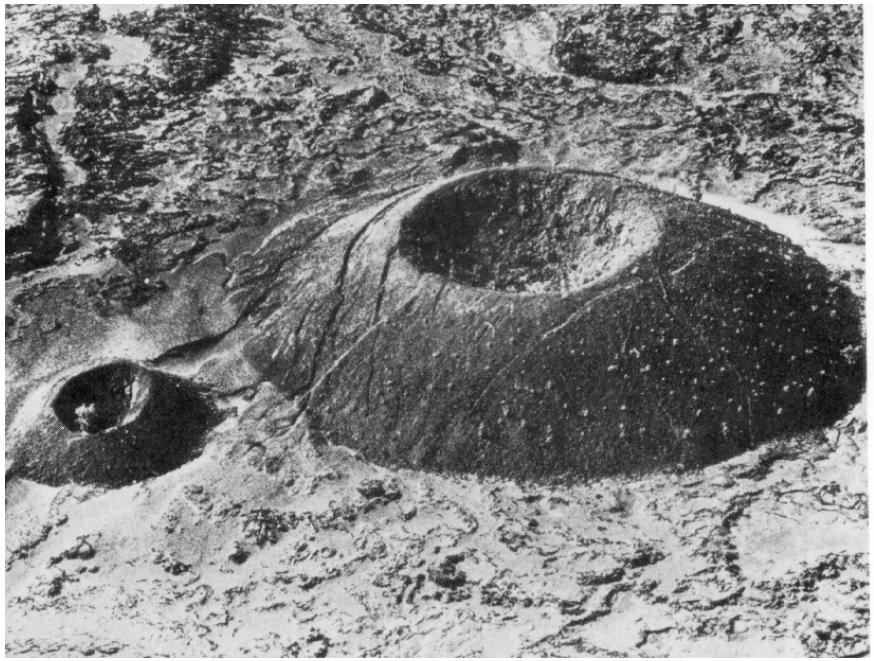


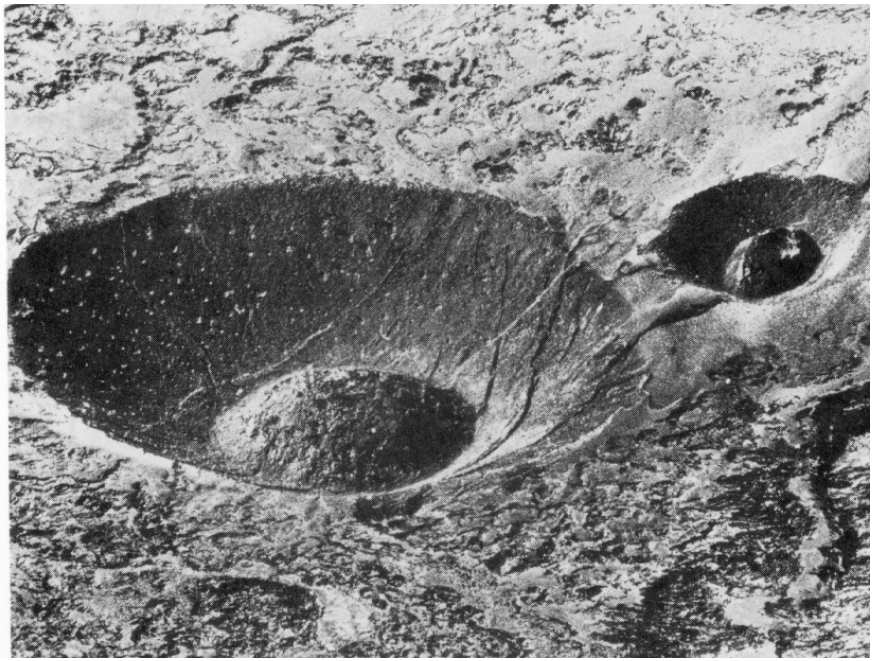


Are these Phenomena caused by Manipulation of the Visual System by Unreal Images?

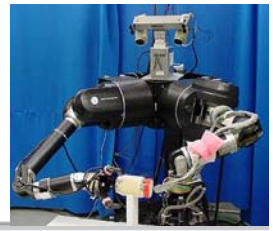


*Every image is an **image of an object**, which is understandable only to those who **know about its origins** and are able to **create a corresponding image in** their **imagination** (Helmholtz, 1910)*

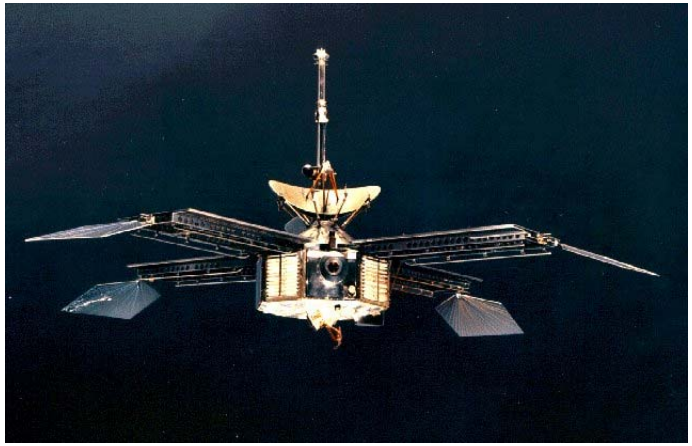




History

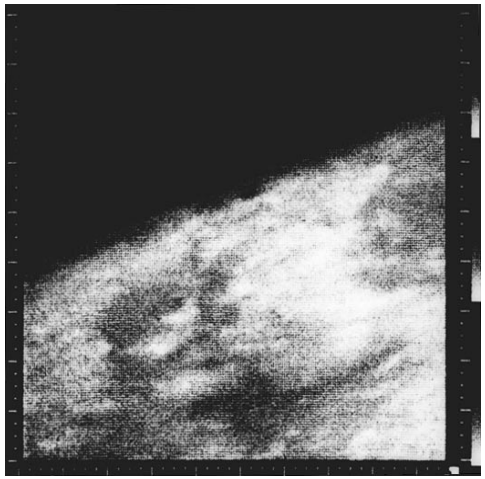


- Serious attempts to create computer vision systems have now a history of 40-50 years.
- First digital image 1964 (Mariner 4)
- Focus on Sensors → Digital Image Processing
- Analysis Focus → **Computer Vision**



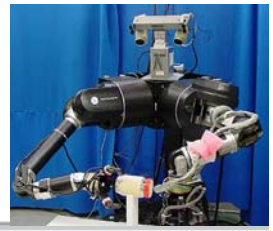
Source: NASA

Mariner 4: First the first close-up image ever taken of Mars 1964



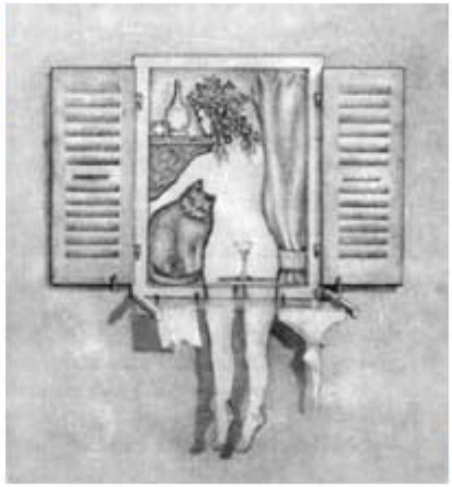
Source: NASA

Computer Vision

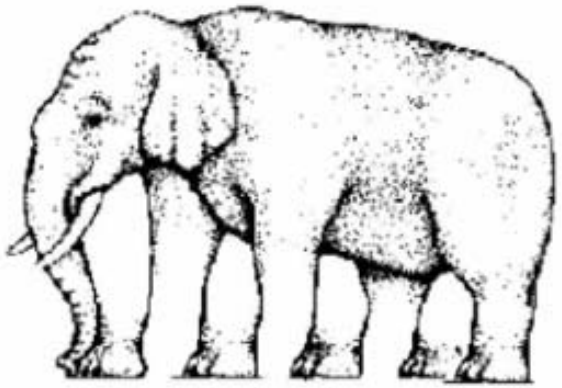


The systems today are still exceedingly limited in their performance → **considerable room for improvement**

Where are chairs?

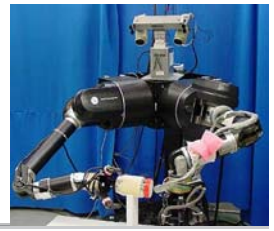


Two interpretations?



How many feet?

Future Challenges of Computer Vision



- Where do the innovations come from?
- 1. Hardware

Wavi Xtion

Kinect

- 2. Algorithms/Software

GigaPan

Microsoft Research

Microsoft Photosynth

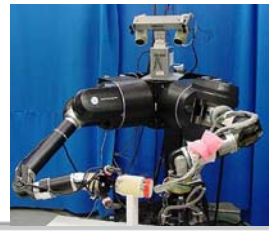
http://www.gigapixel.com

CLAUSS

CVL Computer Vision Lab

TU WIEN

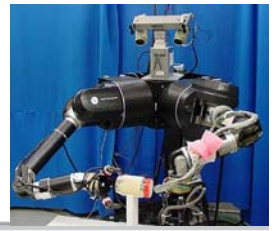
Hardware



- **First time that HW is no longer a real limitation !!**

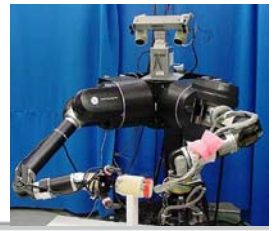
- Processing
- Image Resolution
- Storage
- Internet
- Mobile Devices
- Networks of cameras

Processing



- Moore's Law still holds!
- Multi-core CPUs
- Highly Parallel $\rightarrow$ GPUs (+ Software eg. Cuda)

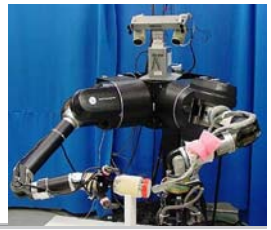
Processing



- What to expect:
  - Image Processing (Feature Extraction) will be instantaneous
  - Real-time Libs: Basic algorithms (IPP, Cuda …)
  - Real time vision (cf. Real time Rendering)

- Parallelization (GPU implementation) is a feature of an algorithm

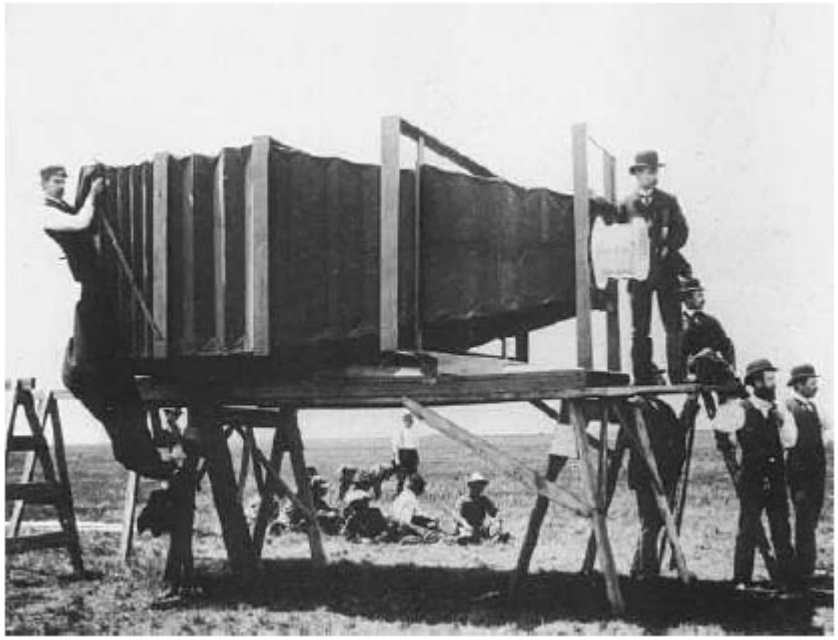
Resolution



Ever growing resolution:

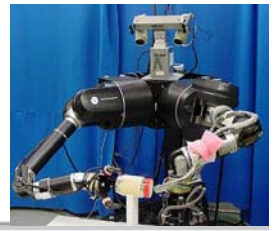
- 1975: 100 x 100 = 0.01 MP
- 2009: 13.280 x 9.184 Pixel = 120 MP

- 2014: UltraCam Eagle
  - 20,010 x 13,080 = 260 MP
  - 842 MB/Image
  - frame rate < 1.8 sec. per frame



1900 Chicago & Alton Railroad Train (photograph a train), $5000

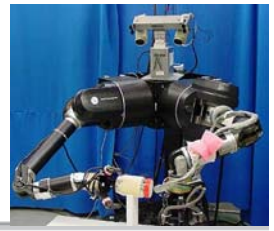
What can we do with that?



Assorted Pixels (Nayar)

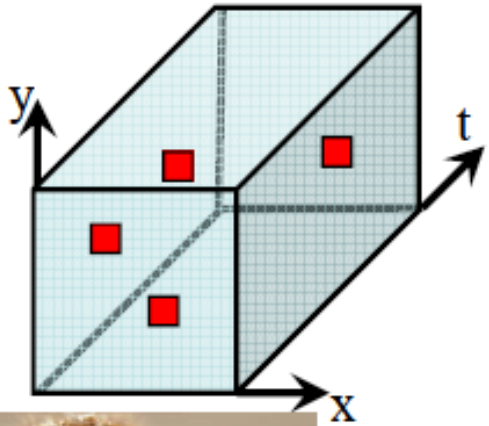
Intensity-and-color-and-polarization mosaic:

Some Questions to Tackle



- How/What shall we sample in space, time, wavelengths, polarization, ….?

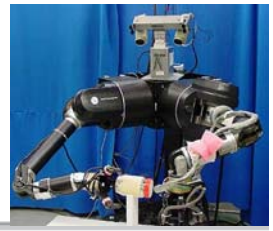
Hundley: Time Space Mixtures



Agrawala et al.,
Digital Photomontage

Freeman 2003

Some Questions to Tackle



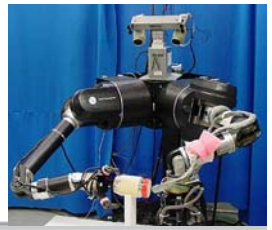
Optimal sampling strategies in 3D/4D …

- No constraints of view-points
- Multiple Images → **Redundancy**
- Control the illumination of each pixel

Image Fulgurator,
Julius Bismarck

- How real are images?

Storage



- We have huge disks and we fill them
- A color VGA image ~1 MB
- Every 10 second 1 image

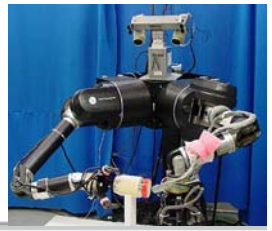
  $\rightarrow$ 8.4 GB a day

  $\rightarrow$ 240 TB a Life

- Can we index that? $\rightarrow$ **Algorithms**

Life Logs with wearable webcam

Internet



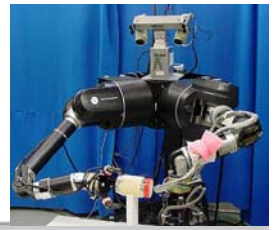
Huge repository of images

- Flickr:
  - Aug. 2011 ~ 6 Billion Photos On-line
  - 4.5 million photo added per day
- YouTube:
  - 65.000 new Videos a day
  - 1 trillion video playbacks
  - 20% of Internet Traffic
- Facebook:
  - 600 Million users
  - 3 Billion photos added per month

What can we do with these images?

Source: Internet 2011 in numbers

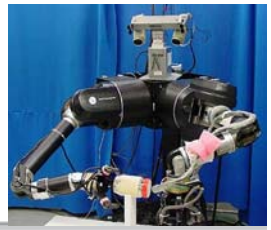
What is Vision?



- What does it mean, to see? "to know what is where by looking".
- How to discover from images what is present in the world, where things are, what actions are taking place.

from Marr, 1982

The Importance of Images



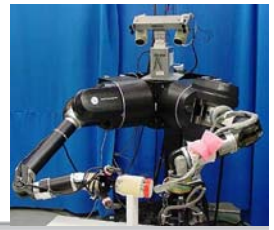
- Some images are more important than others
- 100 million $

"Dora Maar au Chat"
Pablo Picasso, 1941

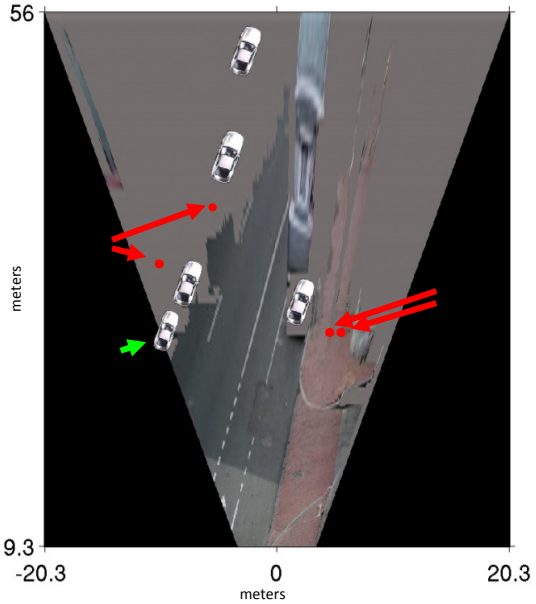
TU WIEN CVL Computer Vision Lab

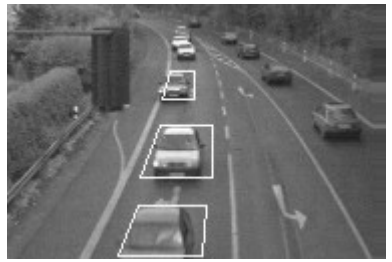
Where is now Computer Vision?
(only a few examples)

Assisted Driving

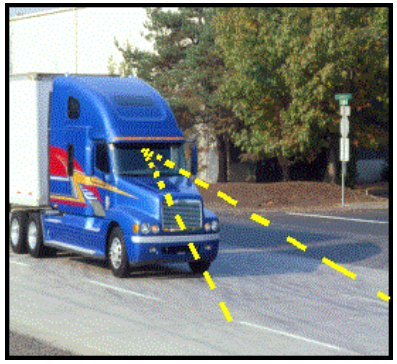


Pedestrian and car detection



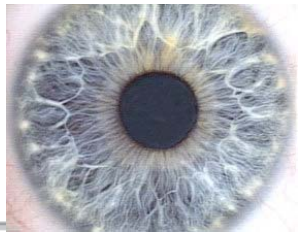


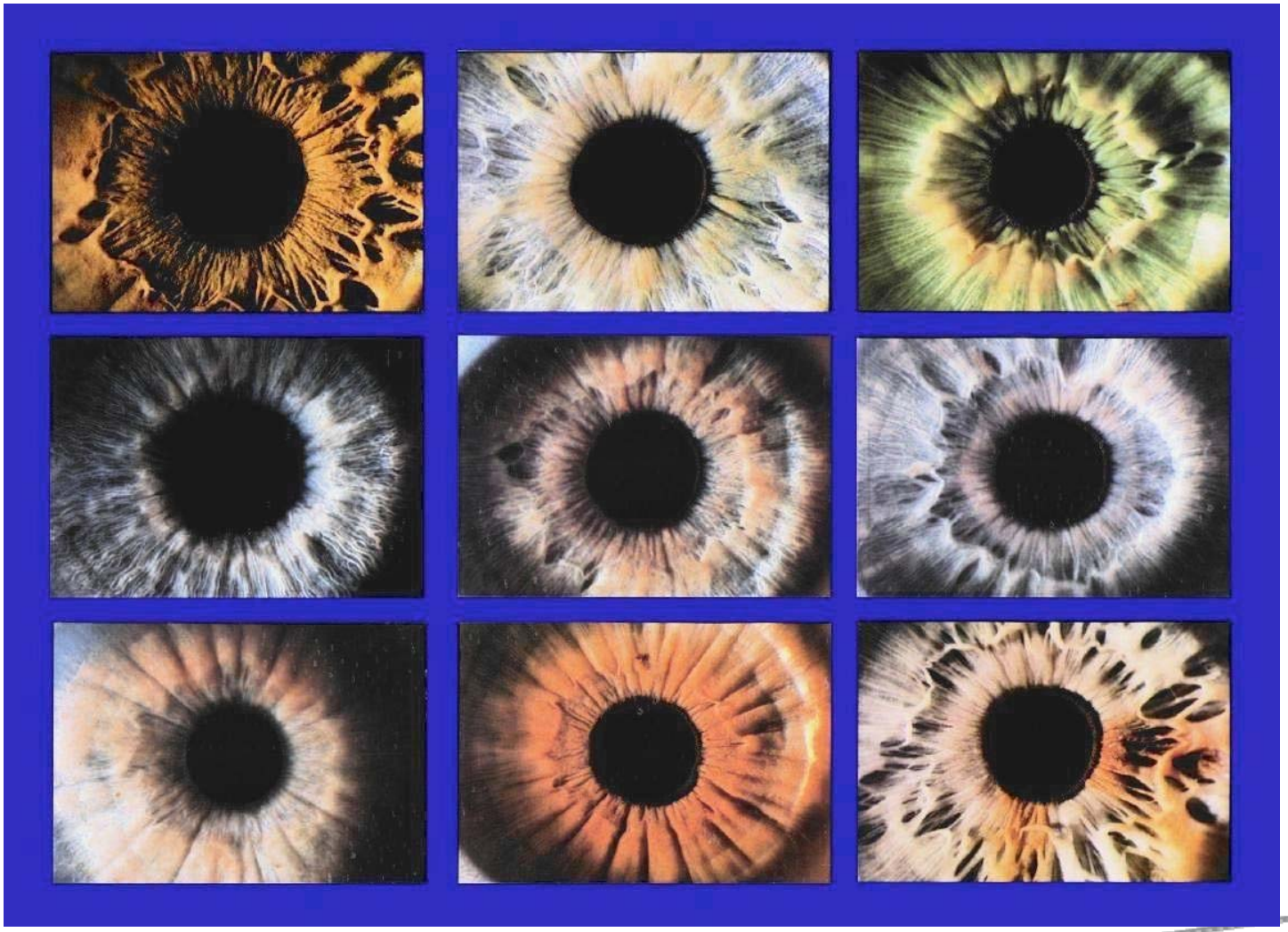
Lane detection



- Collision warning systems with adaptive cruise control
- Lane departure warning systems
- Rear object detection systems

Iris Recognition





JOHN DAUGMAN

http://www.cl.cam.ac.uk/~jgd1000/iriscollage.jpg

Image Stitching

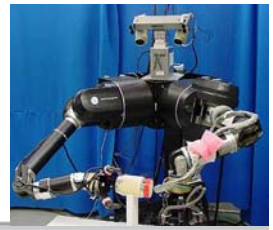
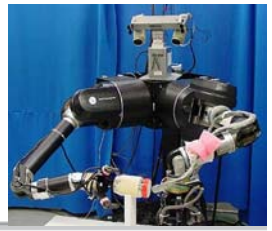


Image Stitching



(a) Image 1

(b) Image 2

(c) SIFT matches 1

(d) SIFT matches 2

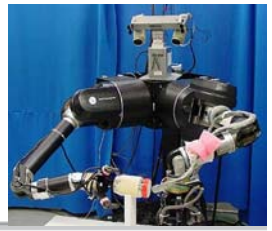
(e) RANSAC inliers 1

(f) RANSAC inliers 2

(g) Images aligned according to a homography

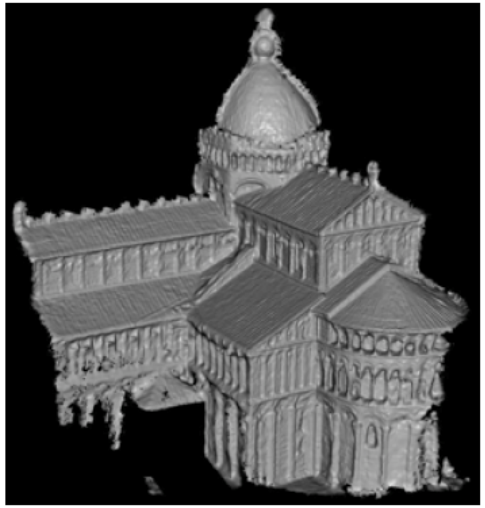
Brown, Lowe, 2007

Photo Tourism



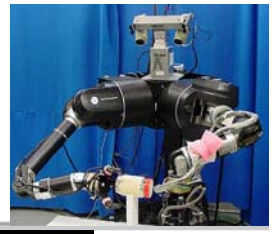
PhotoSynth

Snavely et al. 2006



(Goesele et al. 2007).

Finding Paths through the World's Photos



Finding Paths Through the World's Photos

Noah Snavely
Rahul Garg
Steven M. Seitz
Richard Szeliski

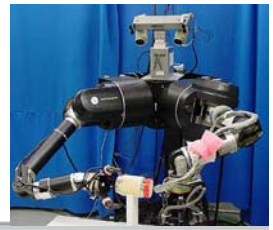
University of Washington
Microsoft Research

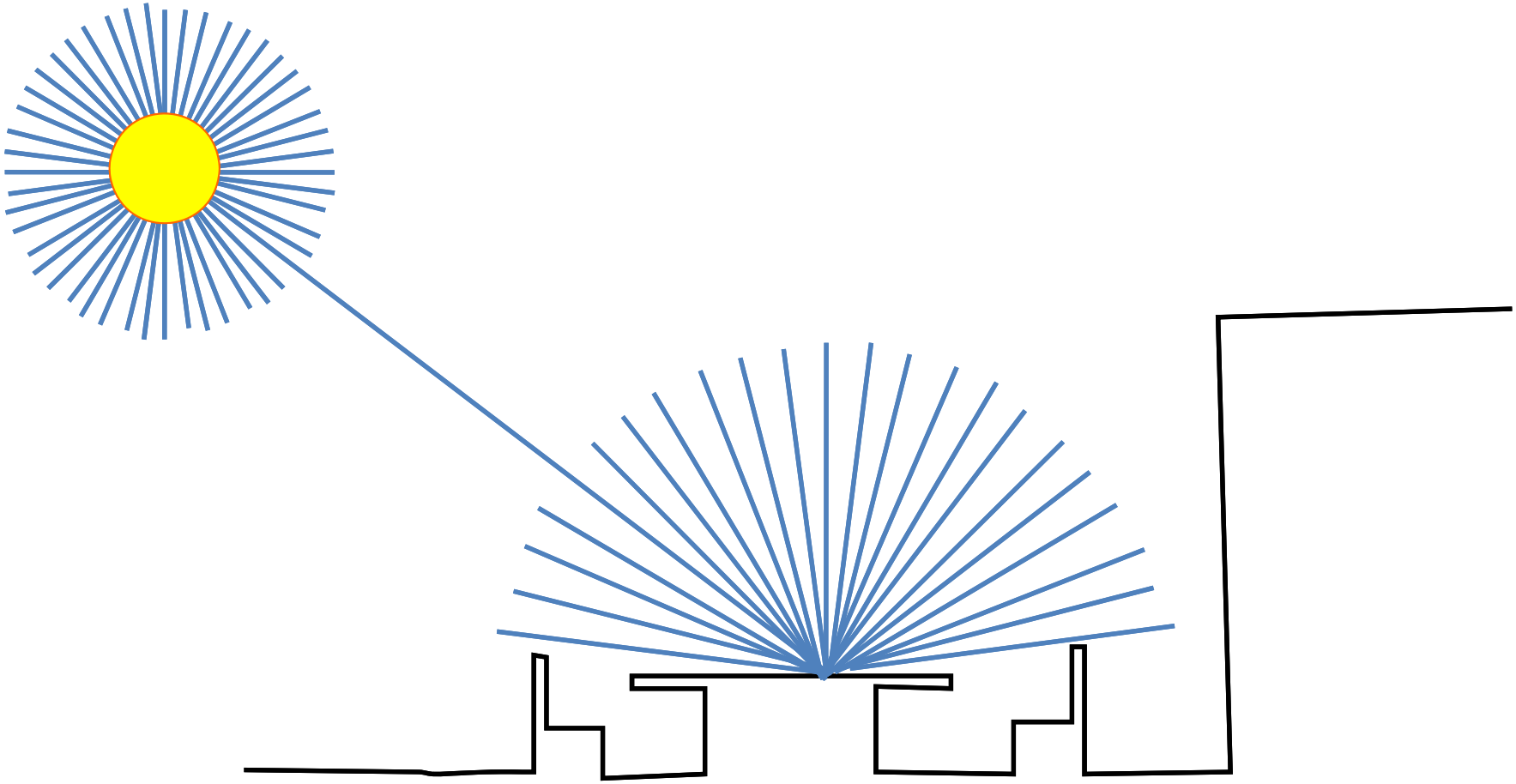
SIGGRAPH 2008

TU WIEN CVL Computer Vision Lab

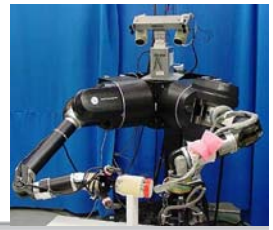
Why is Vision hard – The Plenoptic Function

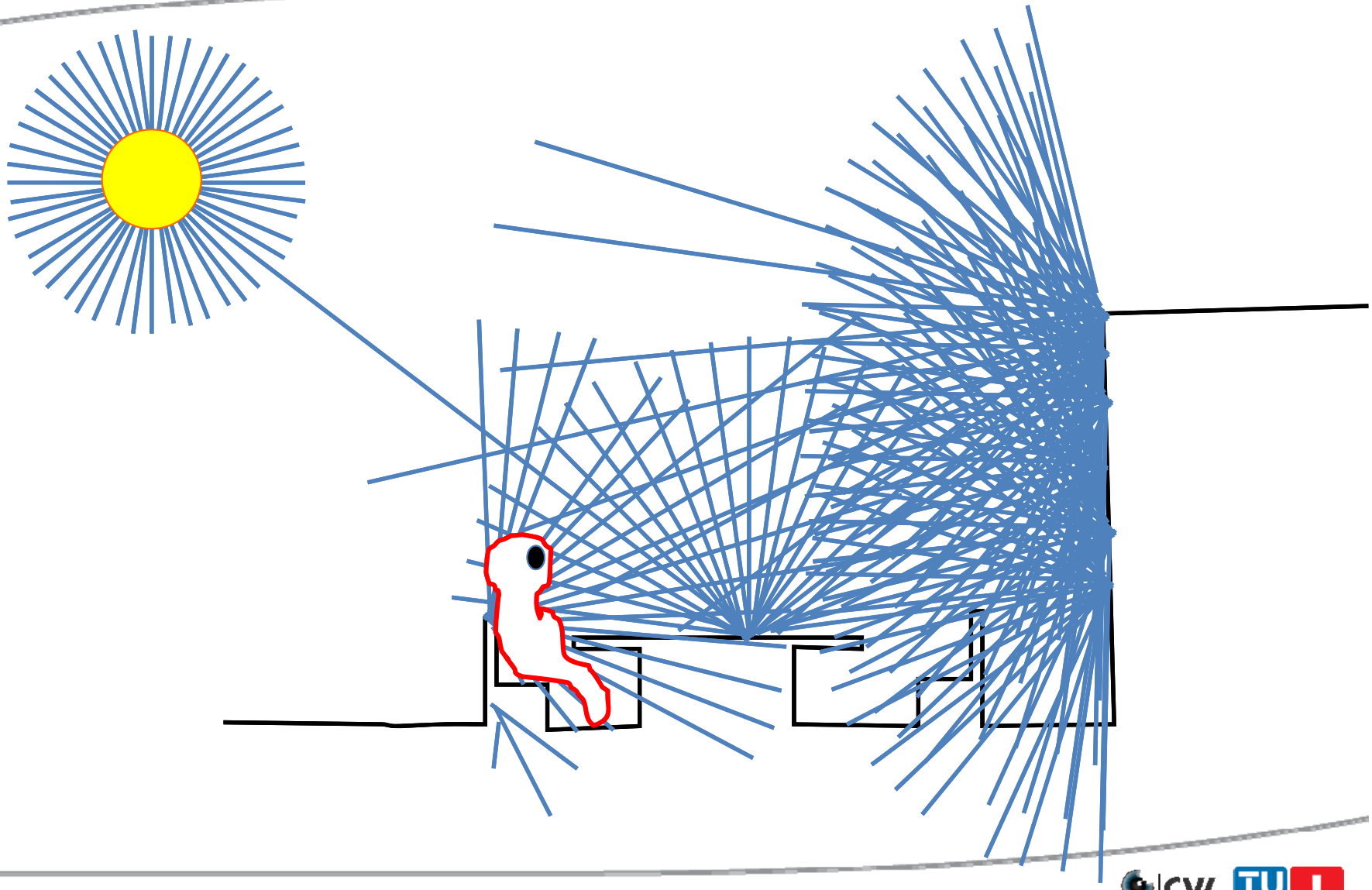
The Structure of Ambient Light



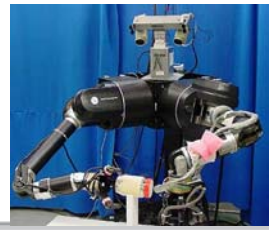


The Structure of Ambient Light

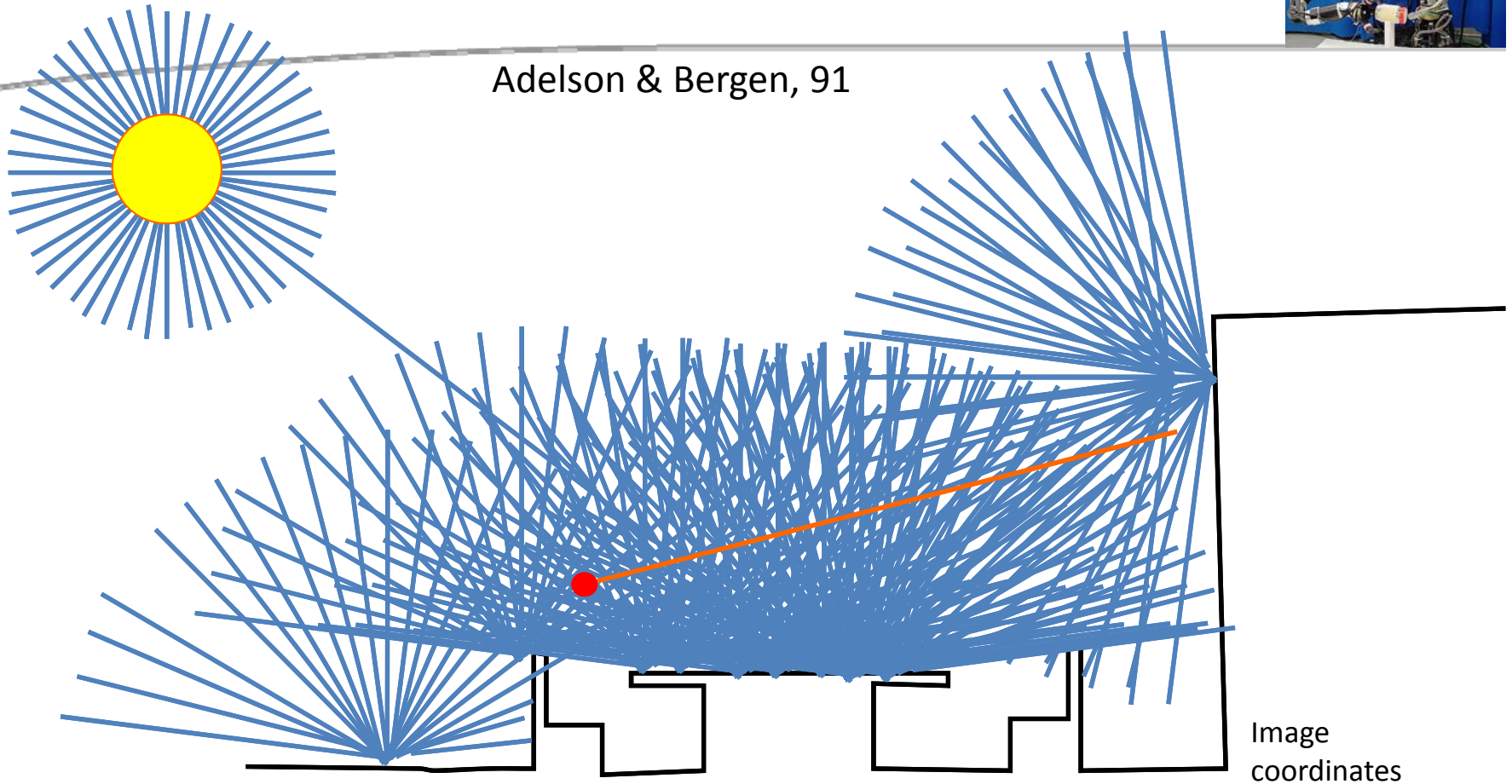




The Plenoptic Function



Adelson & Bergen, 91



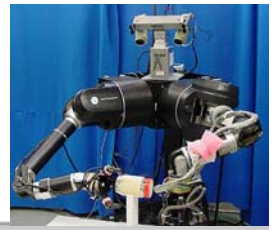
The intensity P can be parameterized as:

$$P(\theta, \phi, \lambda, t, Vx, Vy, Vz)$$

Image coordinates (sperical)
Color
Time
3D space

"The complete set of all convergence points constitutes the permanent possibilities of vision."
Gibson

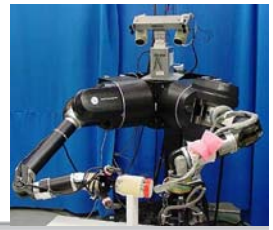
Measuring the Plenoptic Function

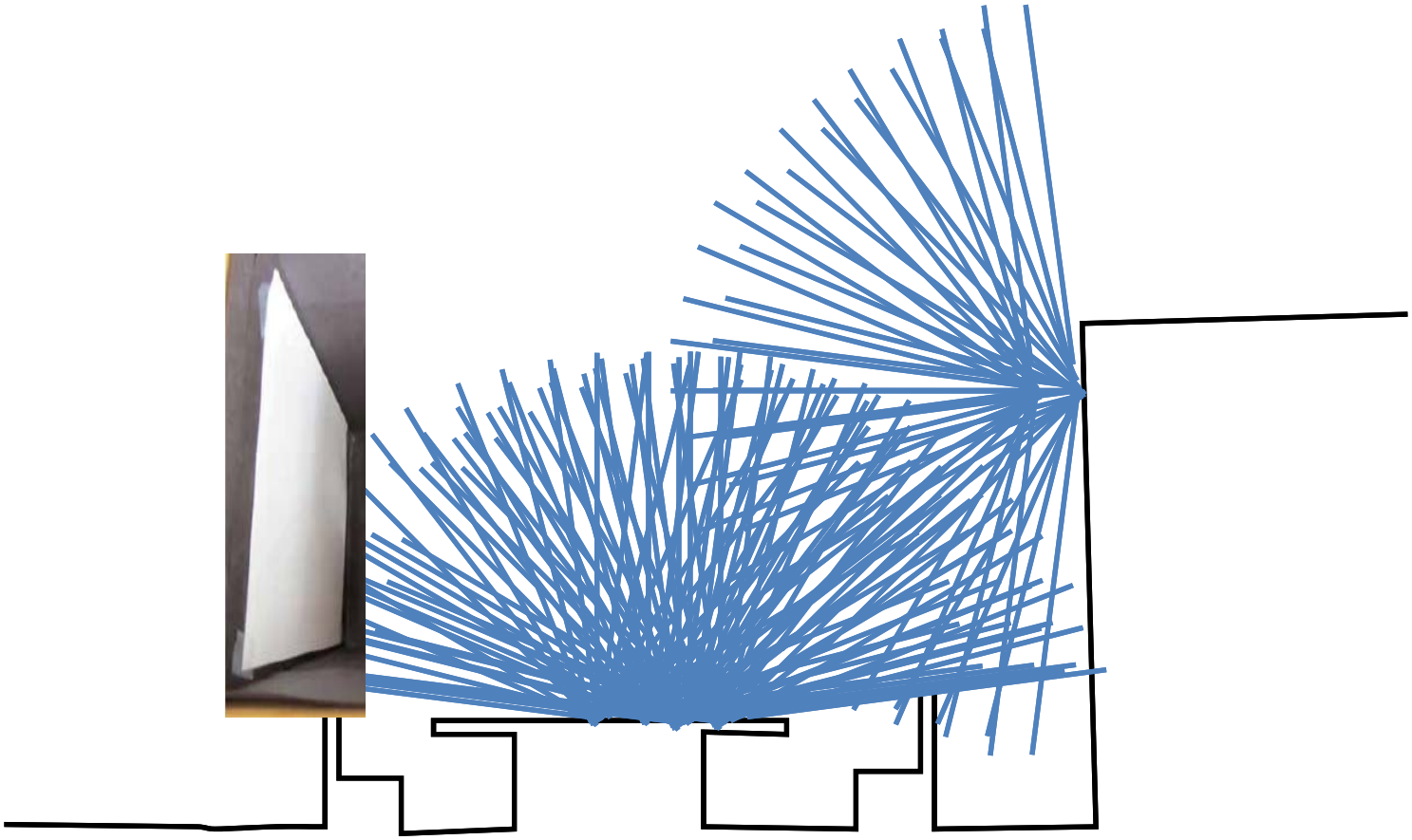


- *"The significance of the plenoptic function is this: The world is **made of 3D objects**, but these objects **do not communicate their properties** directly to an observer.*

  *Rather, the objects **fill the space** around them with the **pattern of light rays** that constitutes the plenoptic function, and the **observer takes samples** from this function*." Adelson & Bergen 91.

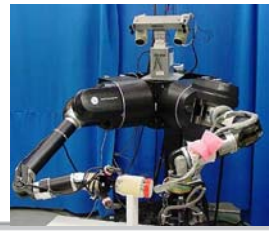
Measuring the Plenoptic Function



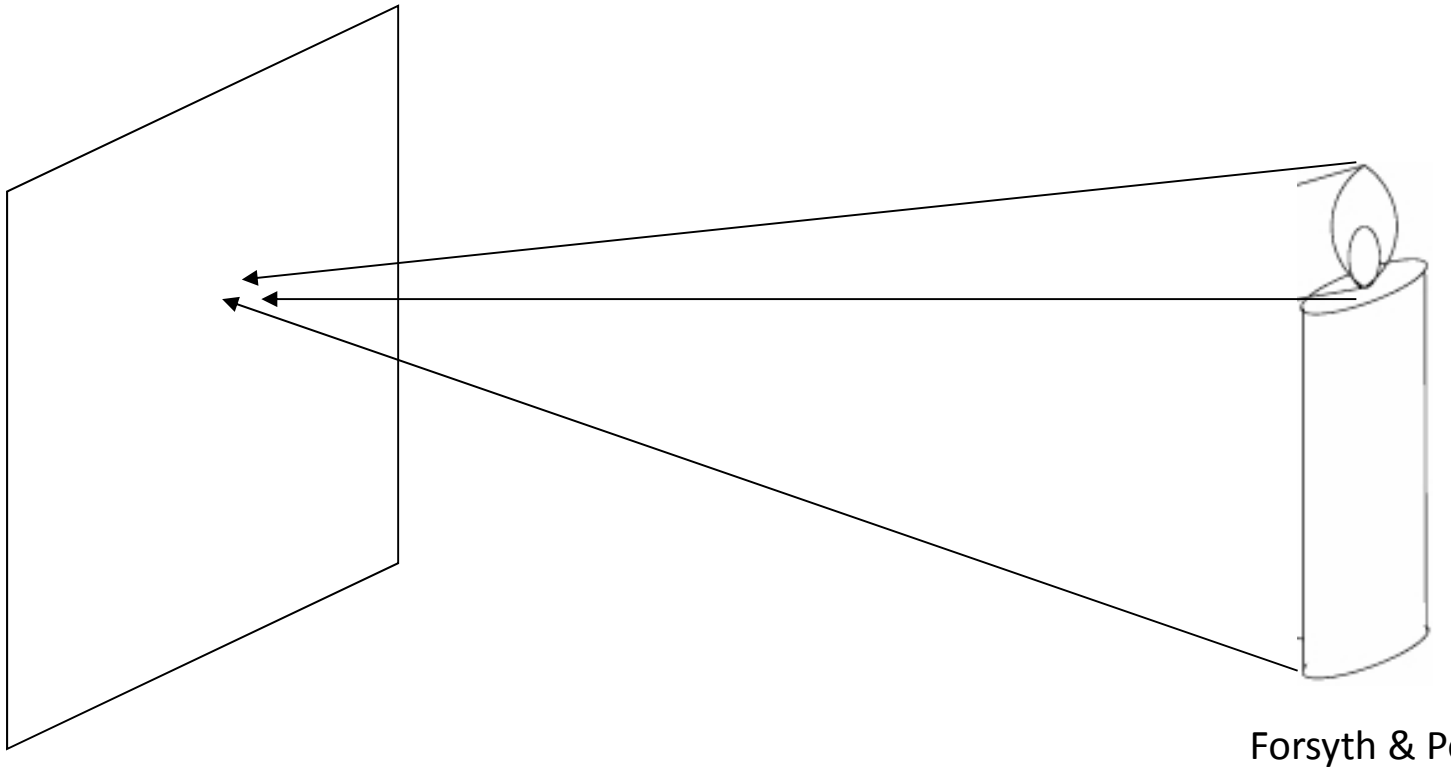


Why is there no picture appearing on the paper?

Measuring the Plenoptic Function



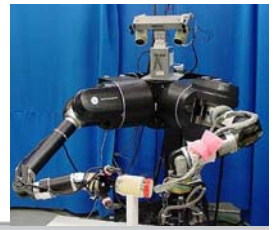
- Light rays from many different parts of the scene strike the same point on the paper.



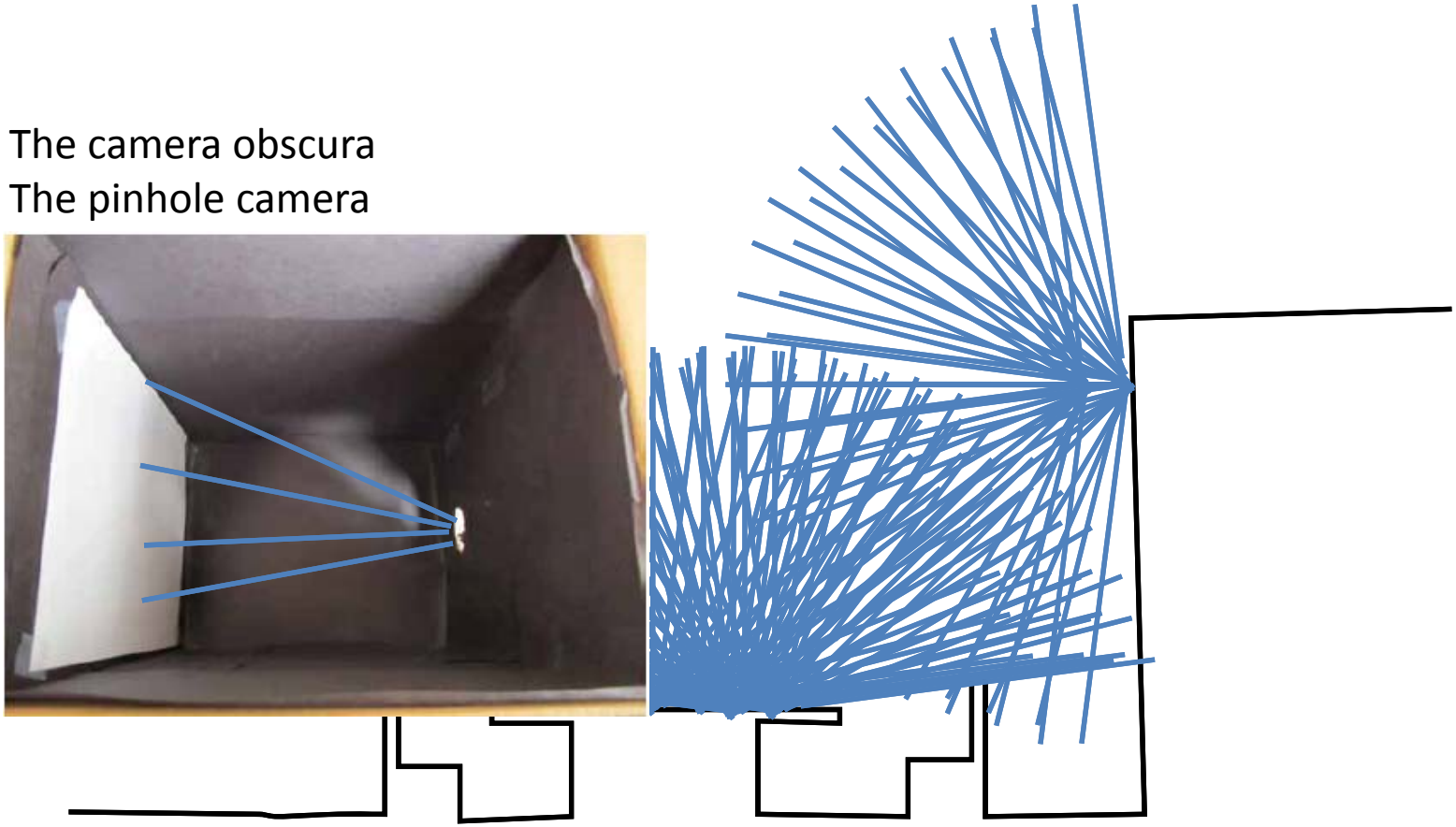
Forsyth & Ponce

Camera Obscura

Measuring the Plenoptic Function

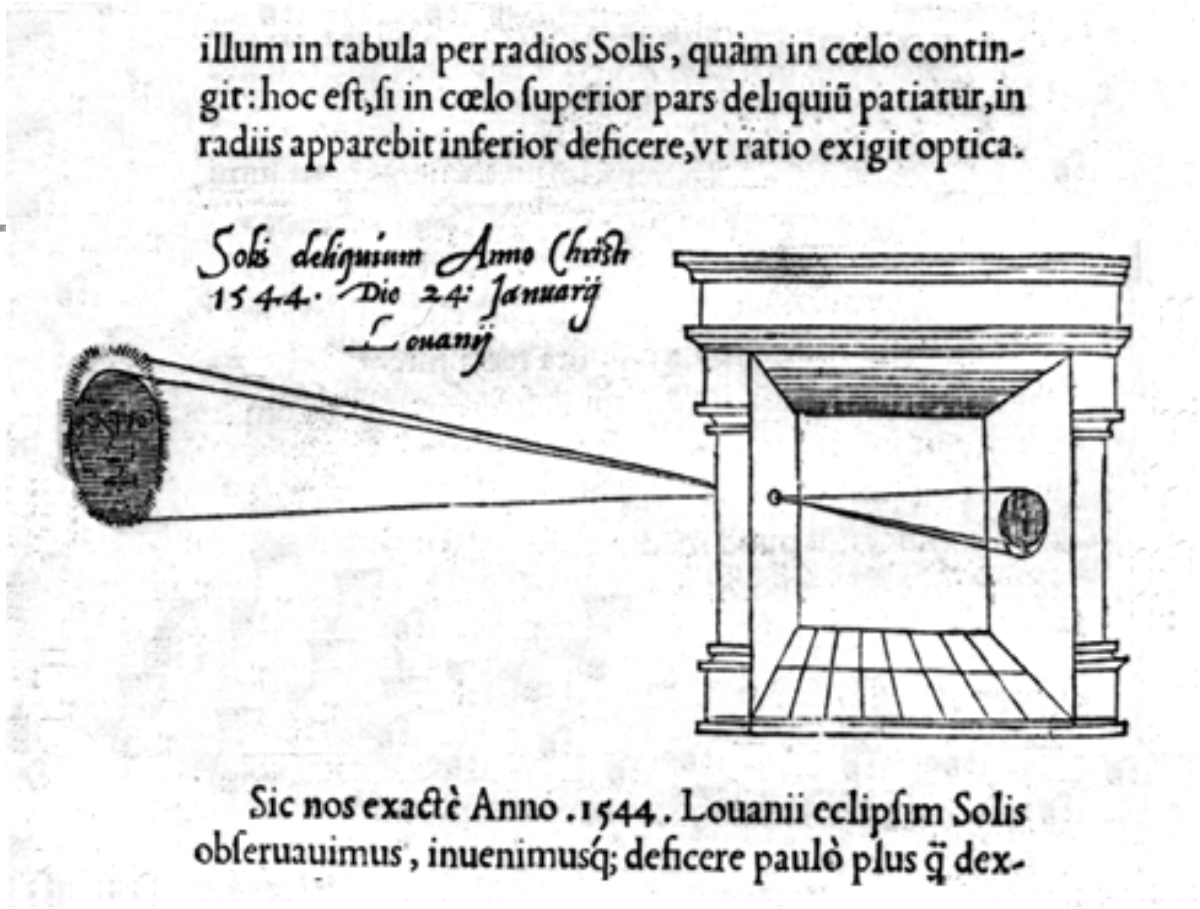


The camera obscura
The pinhole camera



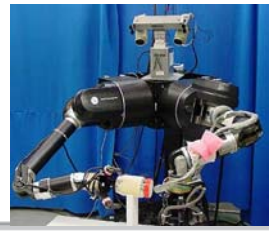
Camera Obscura

- Latin:
  - Camera for "vaulted chamber/room"
  - obscura for "dark"
  - together "darkened chamber/room“

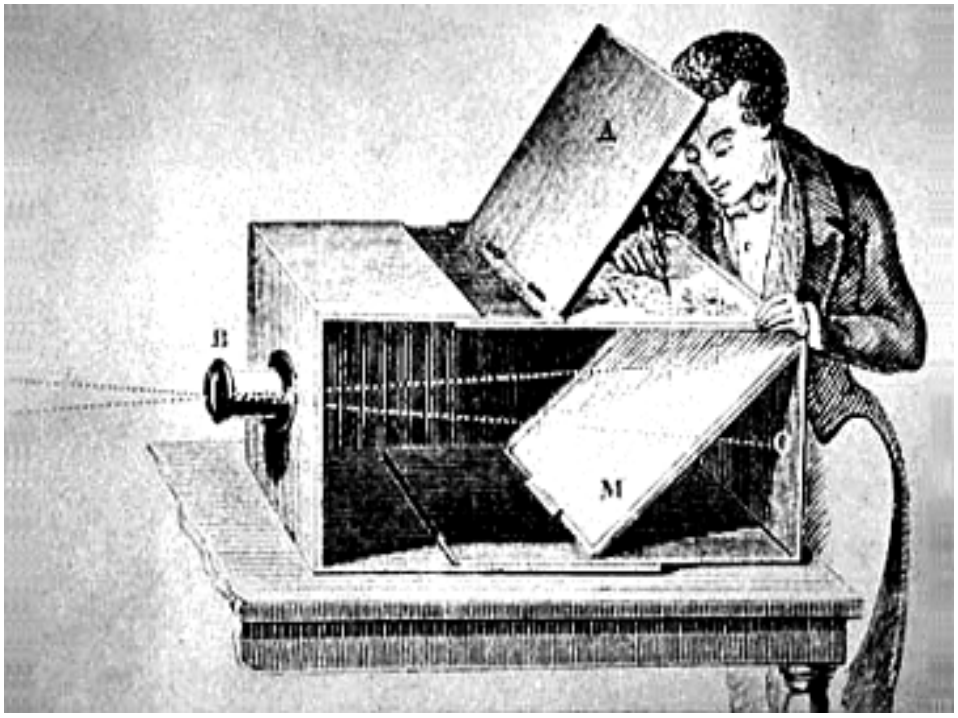


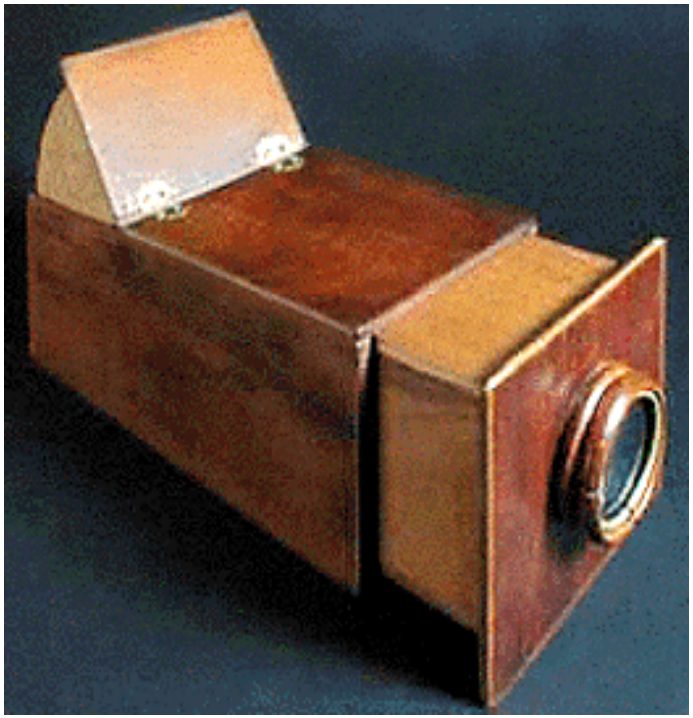
- "When images of illuminated objects ... penetrate through a small hole into a very dark room ... you will see [on the opposite wall] these objects in their proper form and color, reduced in size ... in a reversed position, owing to the intersection of the rays". - Da Vinci
  http://www.acmi.net.au/AIC/CAMERA_OBSCURA.html (Russell Naughton)

Camera Obscura

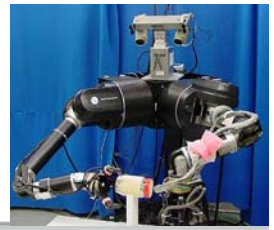


- Used to observe eclipses (eg., Bacon, 1214-1294)
- By artists (eg., Vermeer).

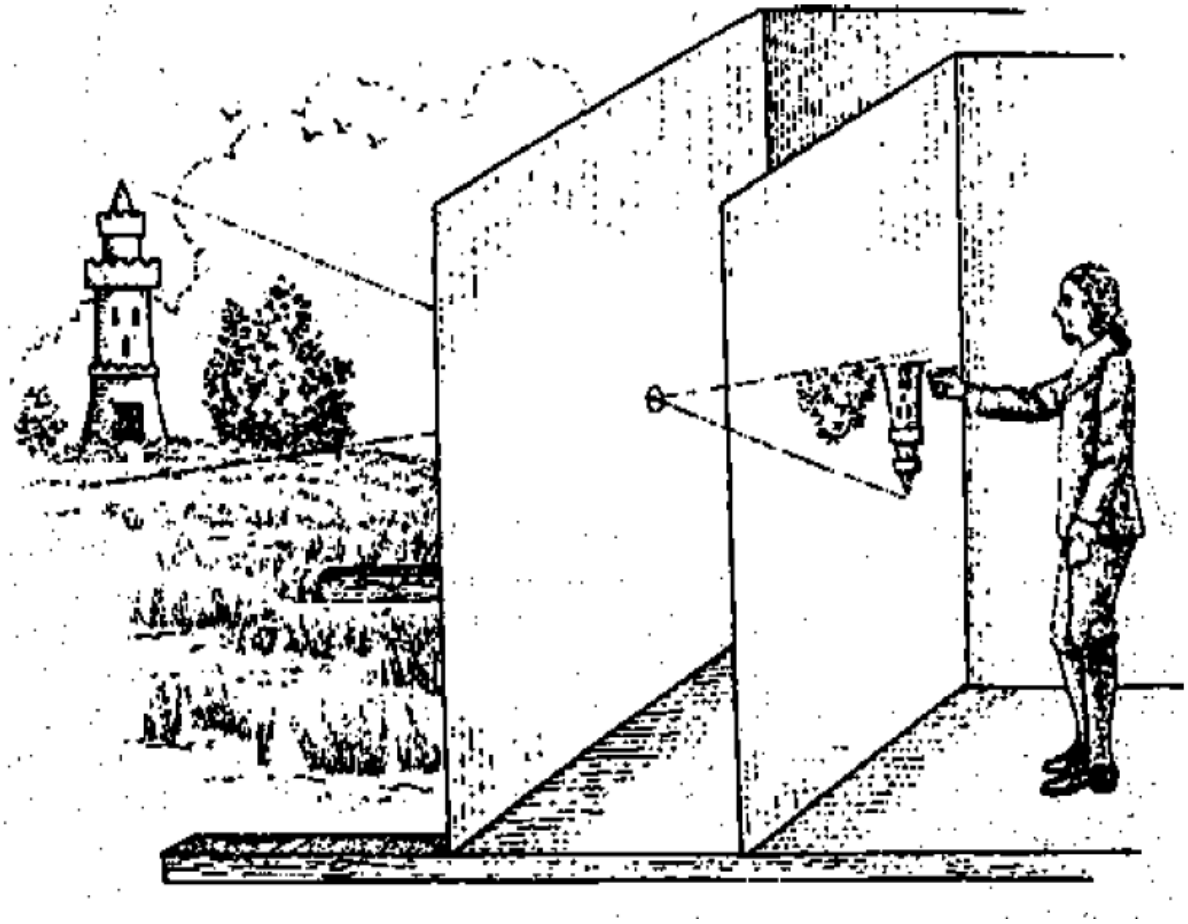




Camera Obscura



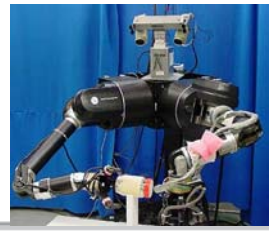
Drawing from "The Great Art of Light and Shadow"
Jesuit Athanasius Kircher, 1646.



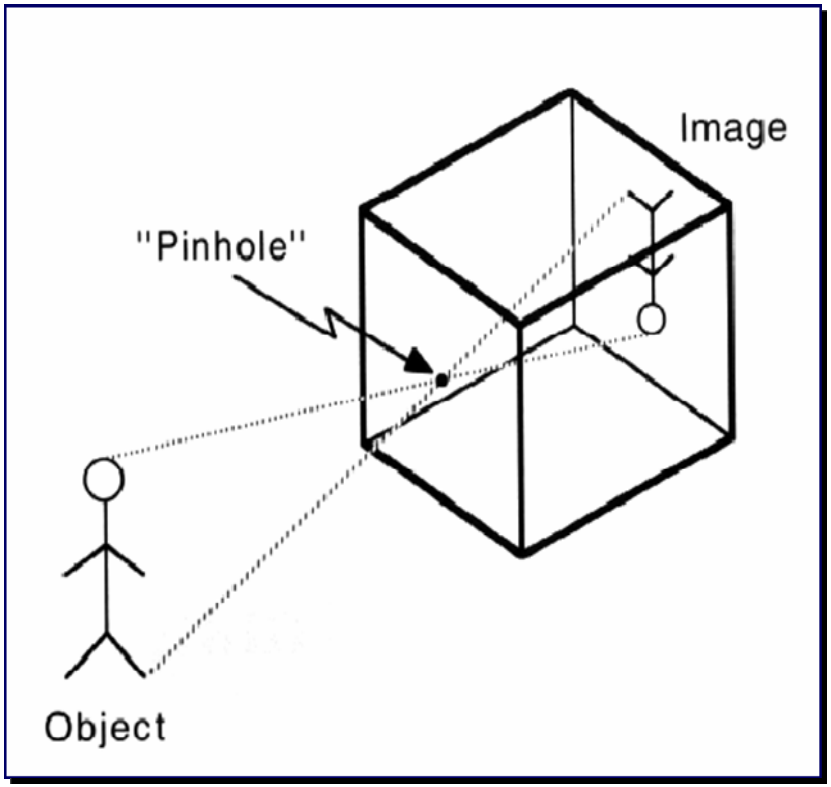
Camera Obscura

Jetty at Margate England, 1898.

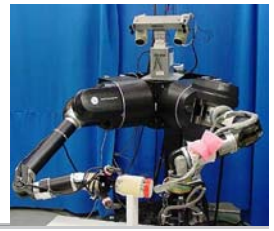
Pinhole Camera



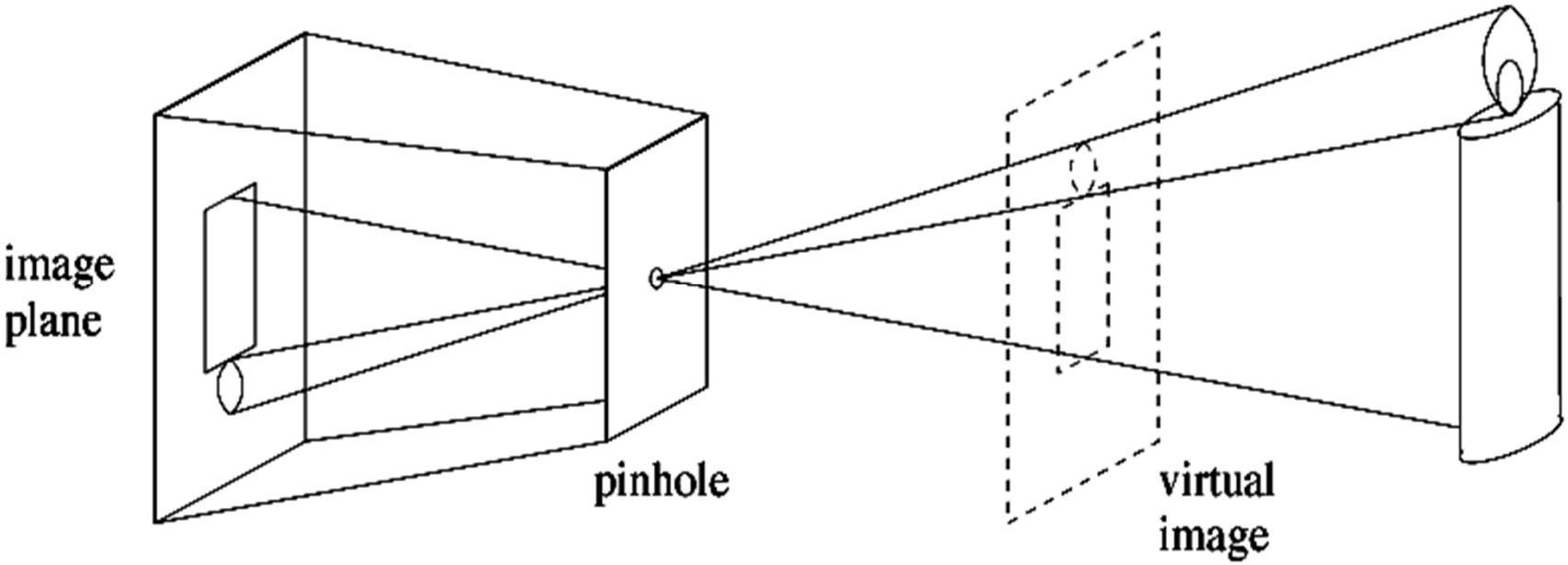
- Simple Model of Camera Obscura: Pinhole camera
  - Very small hole (aperture ~ 0), Light passes through the hole and forms image on back (upside down and flipped)



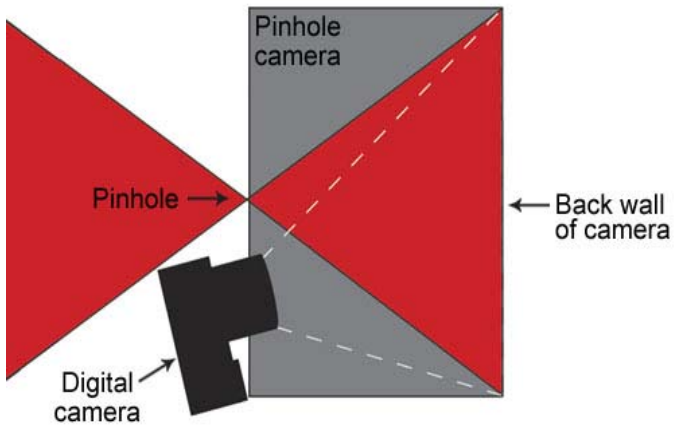
Pinhole Camera

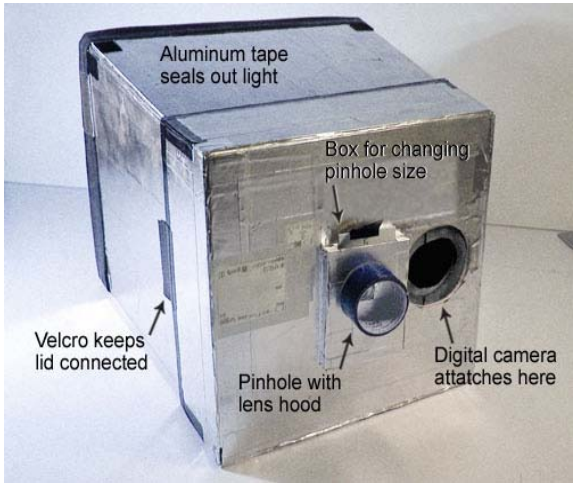


- Abstract camera model - box with a small hole in it
- Pinhole cameras work in practice

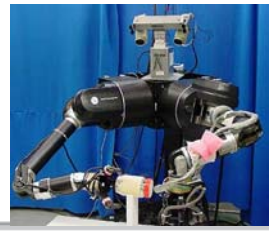


Commercial Pinhole Cameras

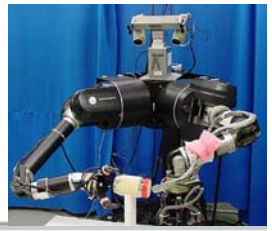


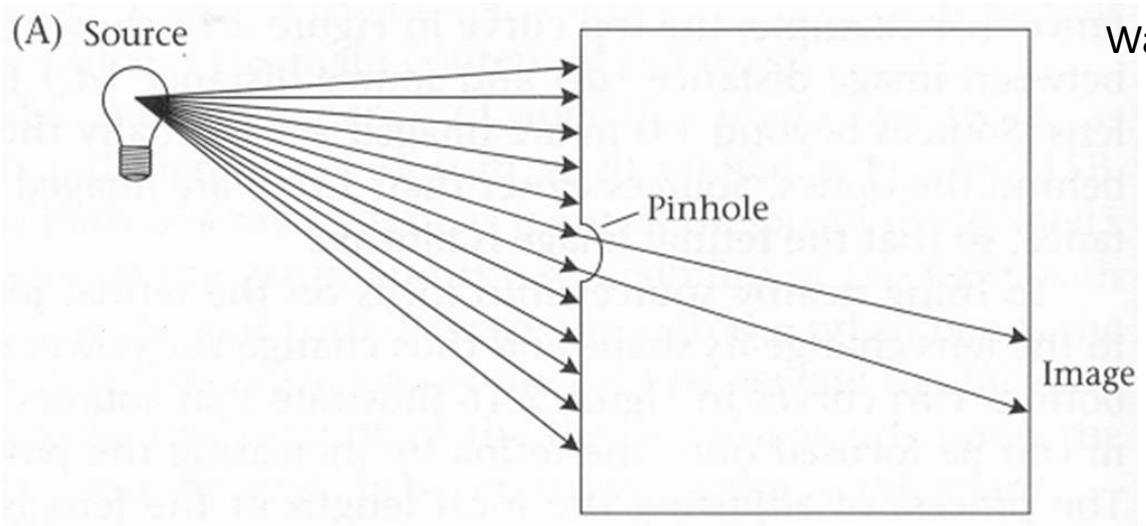


Playing with Pinholes

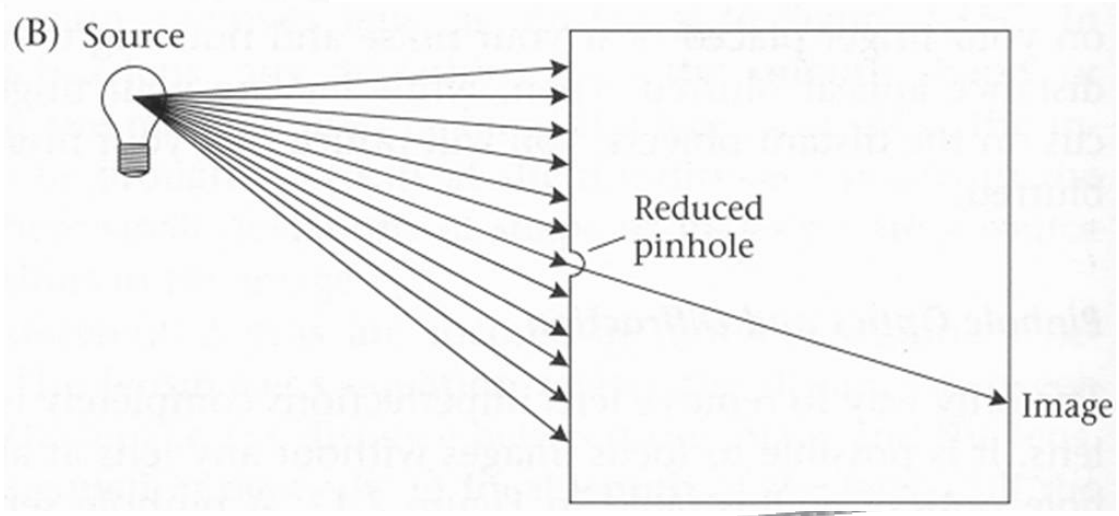


Effect of Pinhole Size

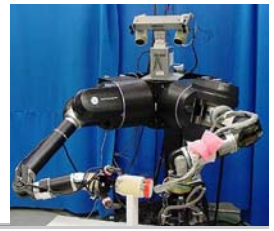




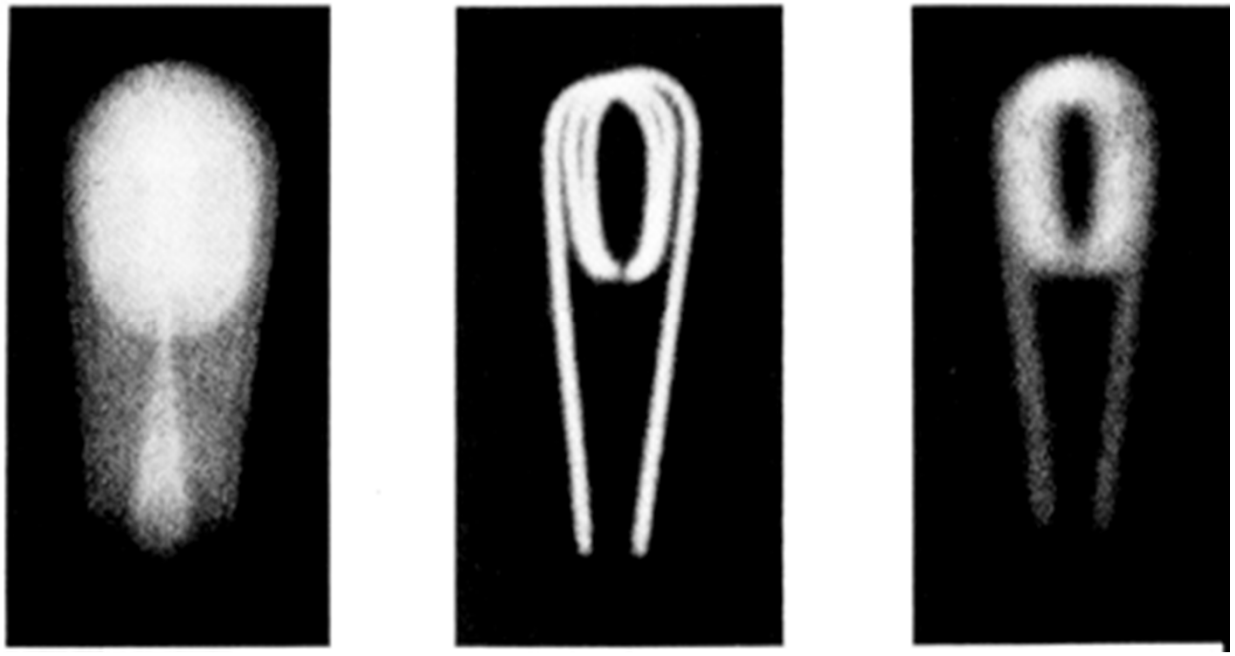
Wandell, Foundations of Vision, Sinauer, 1995



Limits of Pinhole Cameras

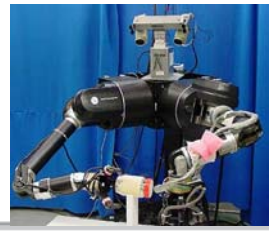


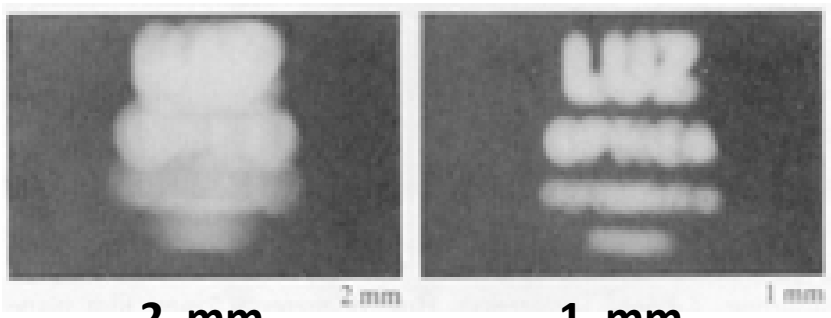
- A picture of a filament taken with a pinhole camera. In the image on the left, the hole was too big (blurring), and in the image on the right, the hole was too small (diffraction).



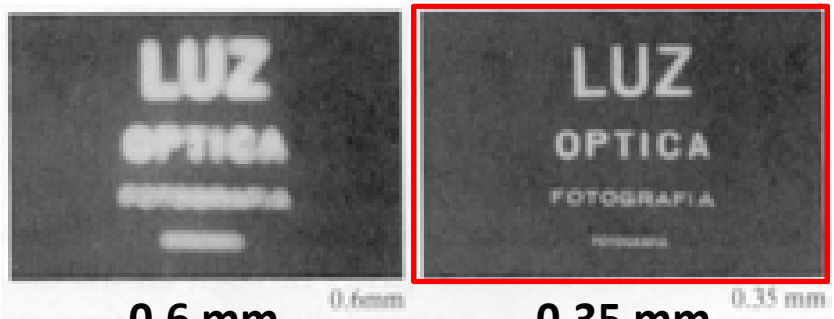
Ruechardt, 1958

Pinhole Camera Images with Variable Aperture



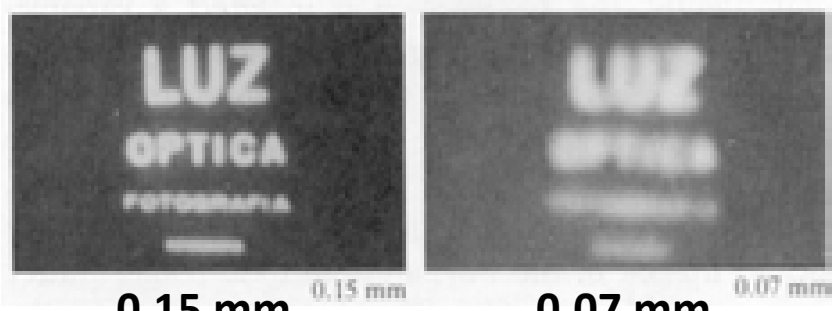


2 mm **1 mm**



0.6 mm **0.35 mm**

- Why not making the aperture as small as possible?
  - Less light gets through
  - Diffraction effect



0.15 mm **0.07 mm**