Image Representation and Formation

Instructor

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Outline

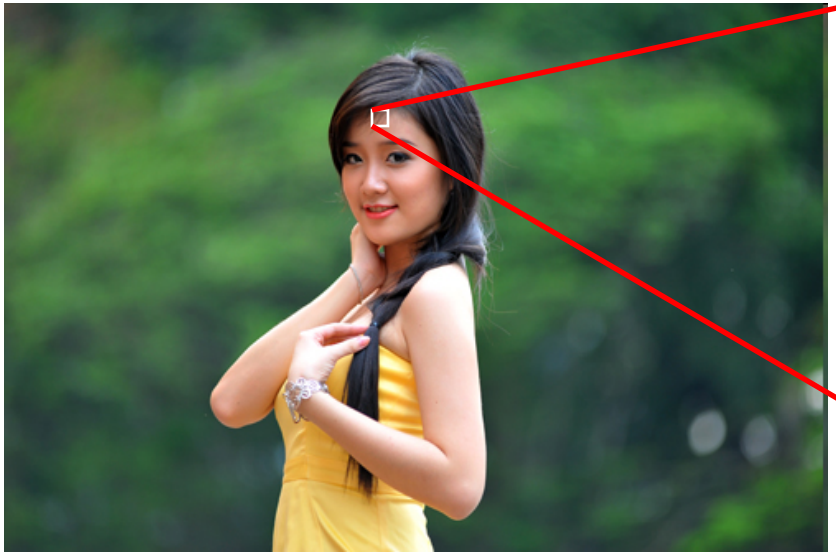
- What are (digital) images?
- What is image/video processing?
- What are basic components of image/video processing systems?
- Why should students study image/video processing?
- How do we represent digital images?
- How can we acquire digital images?
- Is there any tool/library for processing images?

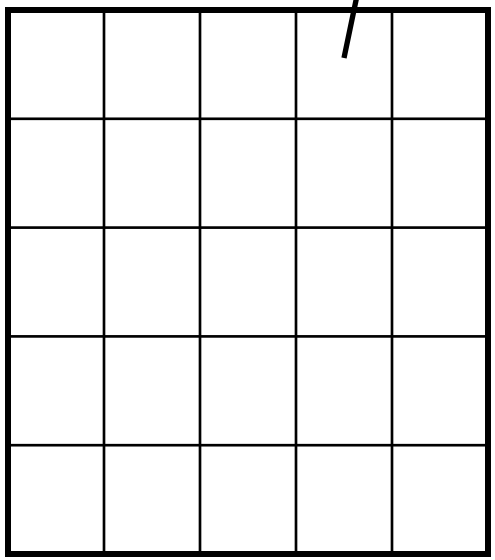
Images: What are about?

- Images:
  - **Rectangular shapes of shades or colors**

Digital Images: What are about?

- Digital Images:
  - **Space (rectangular shape): is digitalized into matrix of rectangular cells which is called pixels.**





Digital Images: What are about?

- Digital Images:
  - **Shades or colors: are digitalized into discrete sets.**
    - ✓Gray images: that set is [0,255]
    - ✓RGB Color images: each set for Red, Green, and Blue color, values in the sets range from 0 to 255.

Image/Video Processing: What is about?

- Multi-kinds of processing tasks:
  - **Simple: Scaling, rotating an image**
  - **Others:**
    - ✓ Enhancement:
      - Obtain a better image from a bad image.
    - ✓ Restoration
      - Recover from damaged images.
    - ✓ Compression
      - Reduce the size of images with/without loss of the quality.
    - ✓ Segmentation
      - Obtain interested objects from the whole image.
    - ✓ Recognition
      - Recognize, classify, or identify objects.
    - ✓ …

Image/video processing systems: basic components

Input

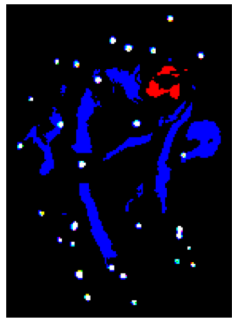
CPU, GPU

Output

Controllers

Image/video processing systems: basic components

- Hardware:
  - **PC: Host and run processing modules**
  - **Input: cameras, scanner,…**
  - **Output: Display, Recorder, other controller**
- Software:
  - **Libraries**
  - **Processing modules (typical: the following figure)**



Point 1: 22,33
Point 2: 24,39
…..

Segmentation

Representation and description

Actor sitting

Preprocessing

Knowledge base

Recognition and Interpretation

Result

Problem domain

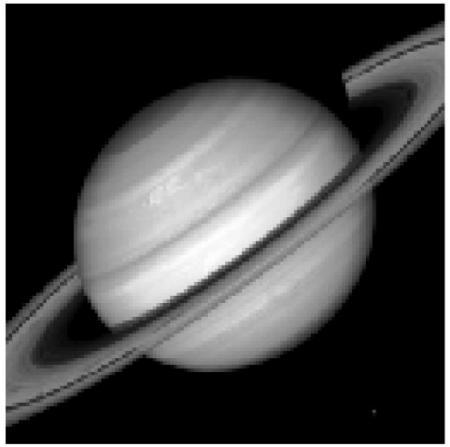
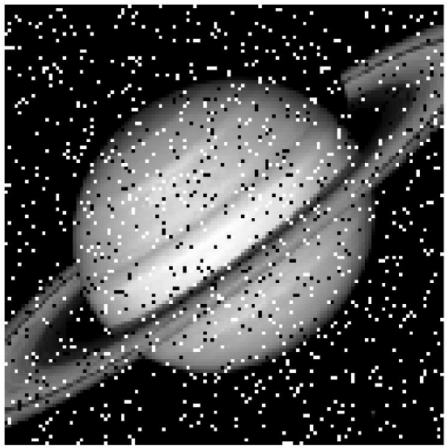
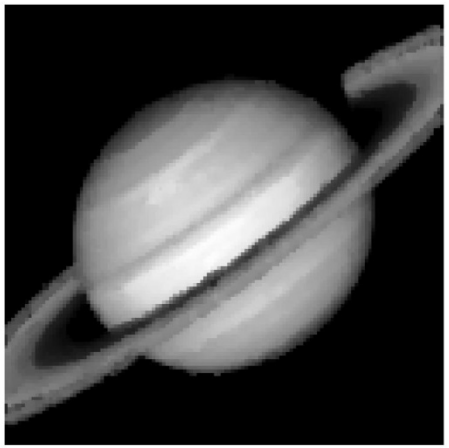
Image acquisition

Why should students study image/video processing?

- Why should students study image/video processing?
  - **Usefulness/Applications**
  - **Challenge**
  - **Activeness**

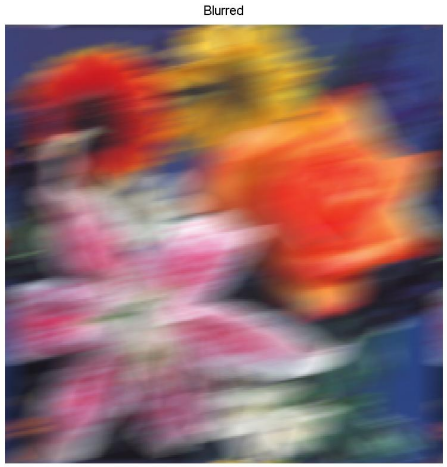
Applications

Examples: Image Correction

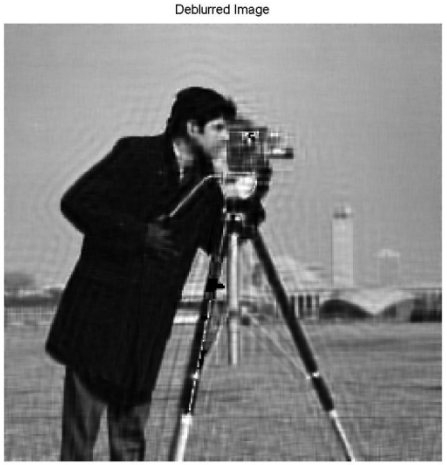
- Needed when image data is erroneous:
  - **Bad transmission**
  - **Bits are missing: *Salt & Pepper Noise***

Image Deblurring: Motion Blur



- Can be used when a camera or object is moved during exposure

Deblurring



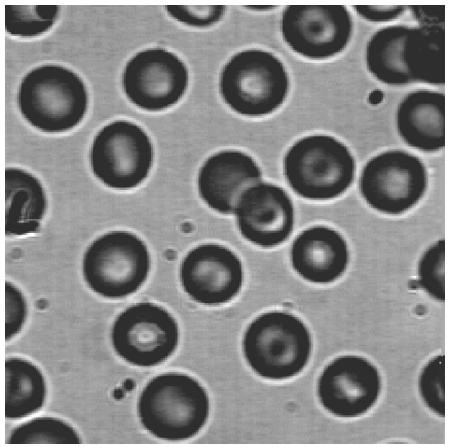
- Can be used when the camera was not focused properly!!

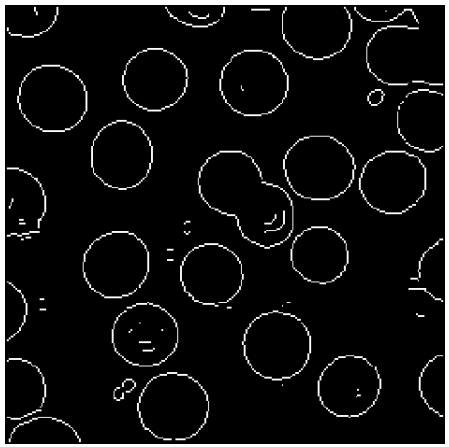
Image manipulation

- Image improvement, e.g. too dark image

- Rotate + scale

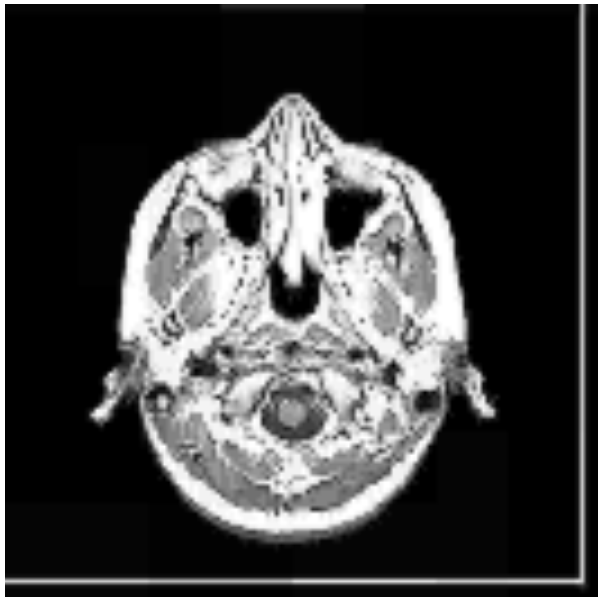
Medical Image Processing





- Image Processing is widely used
- E.g. Analysis of microscopic images

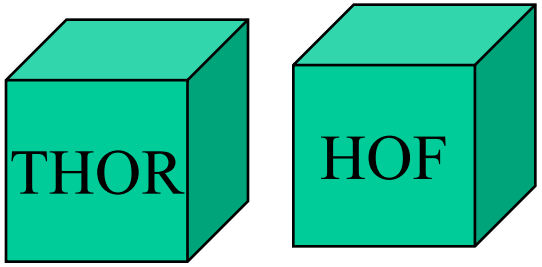
Medical Image Processing



- MR/CT Imaging of a human body
- Use for Brain Surgery

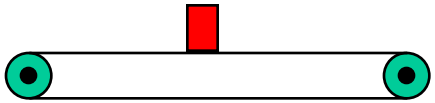
Machine vision applications

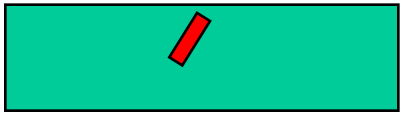
❖ Classification



❖ Pose estimation

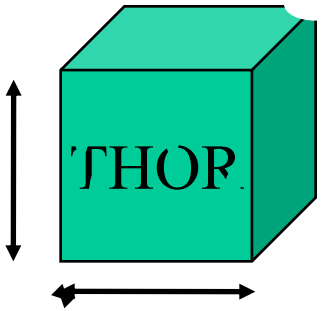
- **Pick and place applications**



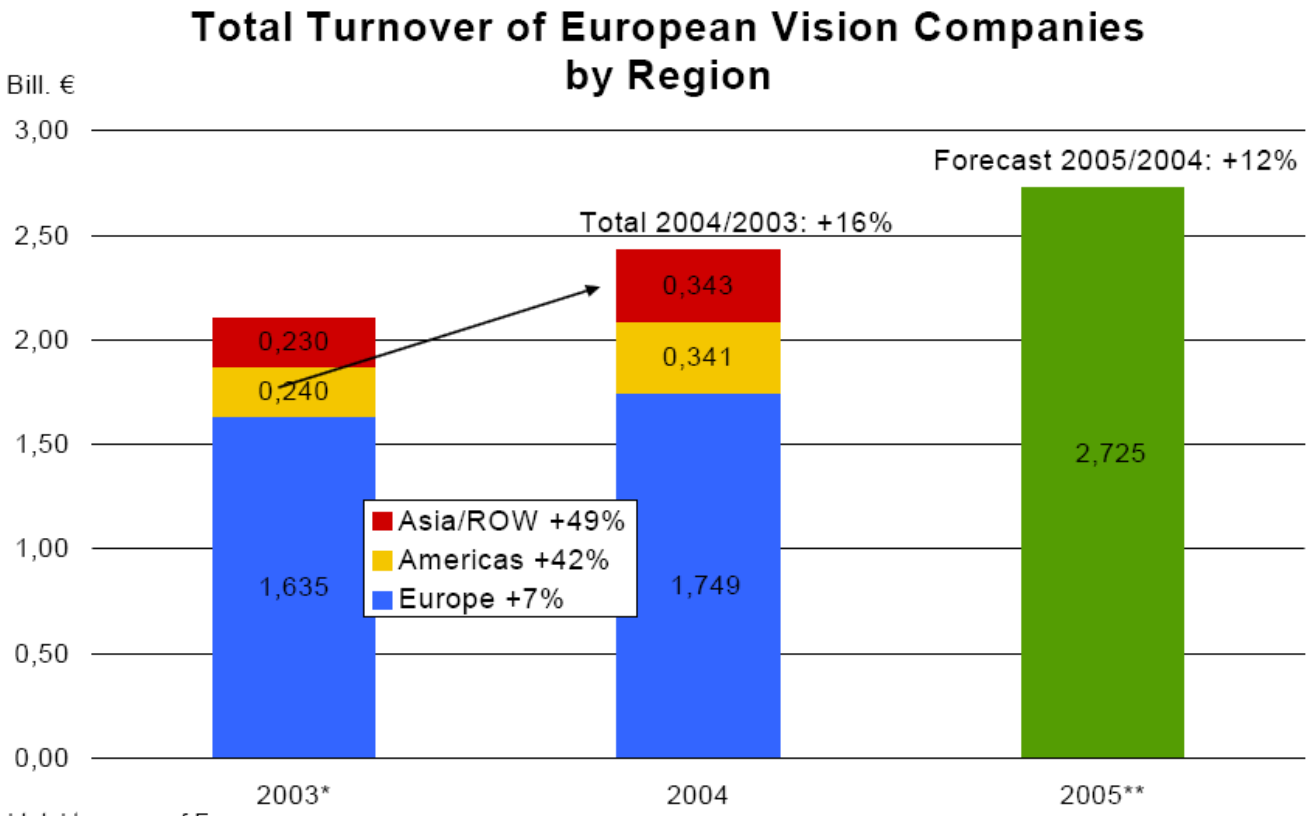


- **Bin-picking**

❖ Quality control



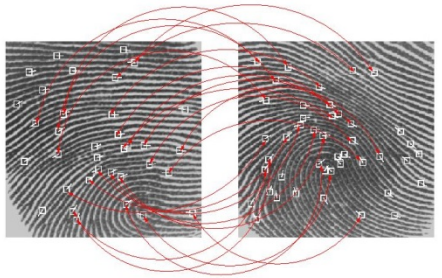
Machine vision

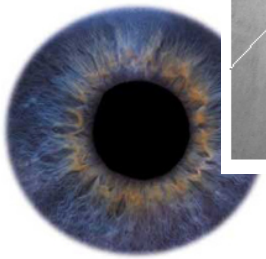


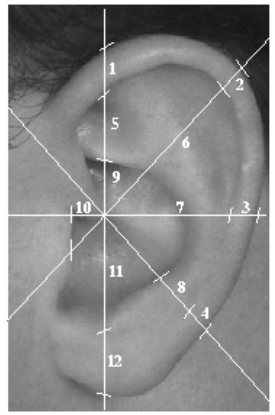
* estimated total turnover of Europe
**based on forecasts of 60 companies

Biometrics

- Recognizing/verifying the identity of a person by analyzing one or more characteristics of the human body
- Characteristics:
  - **Fingerprint, eye (retina, iris), ear, face, heat profile, shape (3D face, hand), motion (gait, writing), ..**
- Applications:
  - **Verifying: Access control (bio-passports)**
  - **Recognizing, tracking: Surveillance**

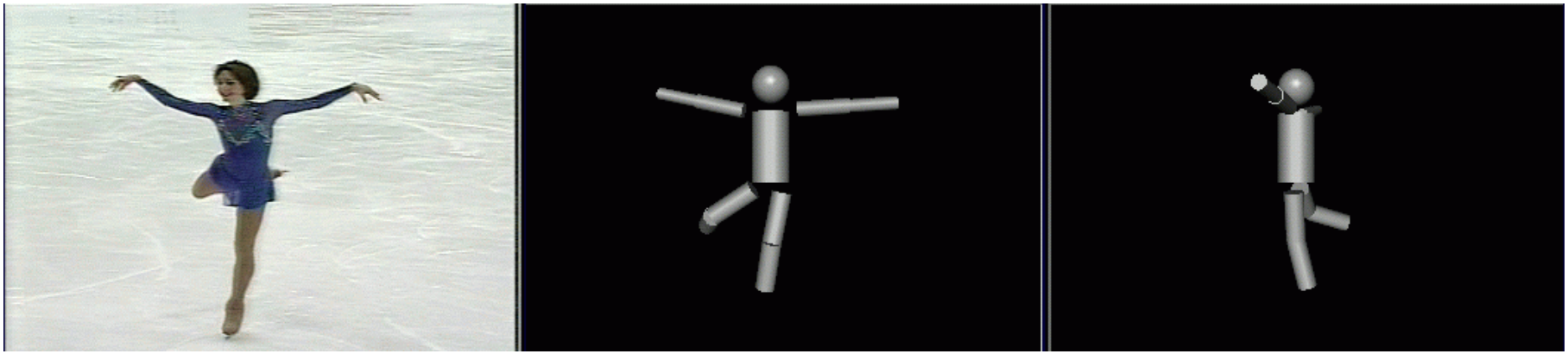






Chroma keying

Analysis of Sport Motions



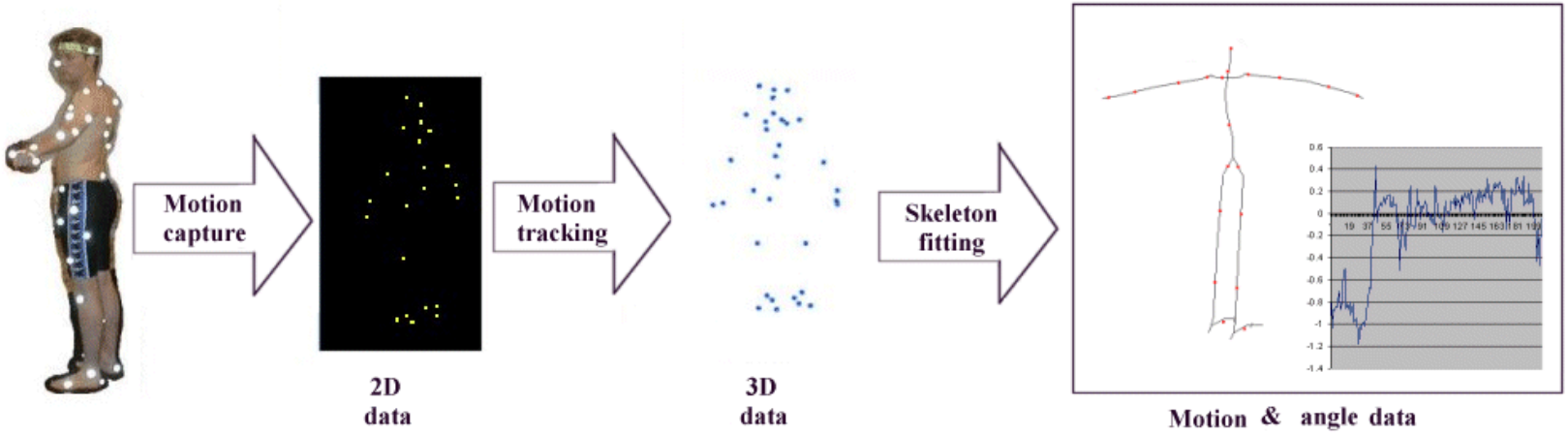
- Here: Analysis of motion of Sarah Hughes
- 3D Tracking of body parts
- Motion interpretation
- Action recognition

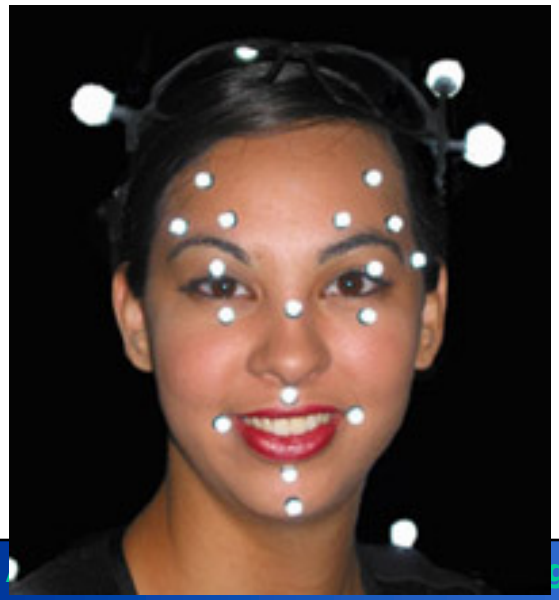
Motion Capture

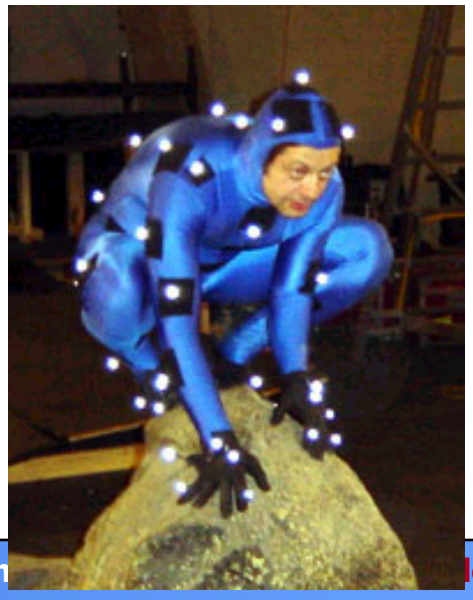
- Special effects
  - **Advertising**
  - **Movies**

Andy Serkis

Motion Capture







Challenges

Image/Video Processing: Challenges

- Almost of processing tasks in image/video processing need further improvements for being done automatically, being done more efficiently, being realistic
  - **Enhancement**: We have many techniques, all of them can not results the same quality for every applications. They depend on many thresholds which affects the quality of the enhancement also.
  - **Compression**: How can we transmit in real-time a large amount of data from multiple cameras in the network to realize 3D applications?
  - **Analysis**:
    - ✓ How can we detect and analyze automatically the activities of humans in complex scenes like railway station, airport, etc ?
    - ✓ How can we detect and diagnose automatically diseases of human?

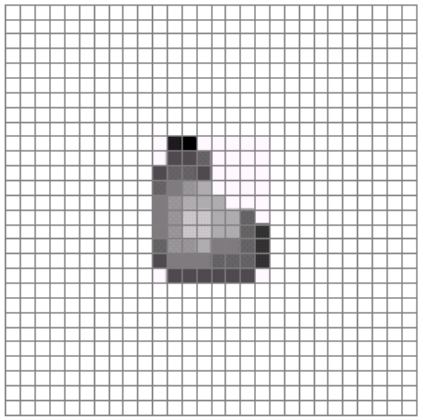
Activeness

Image/Video Processing: Activeness

- Many research groups around the world working on Image Processing and Computer Vision
- Many conferences and transactions organized for the field
  - ICIP: International Conference on Image Processing
  - CVPR: International Conference on Computer Vision and Pattern Recognition
  - IEEE Transactions on Image Processing
  - IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI)
  - ...

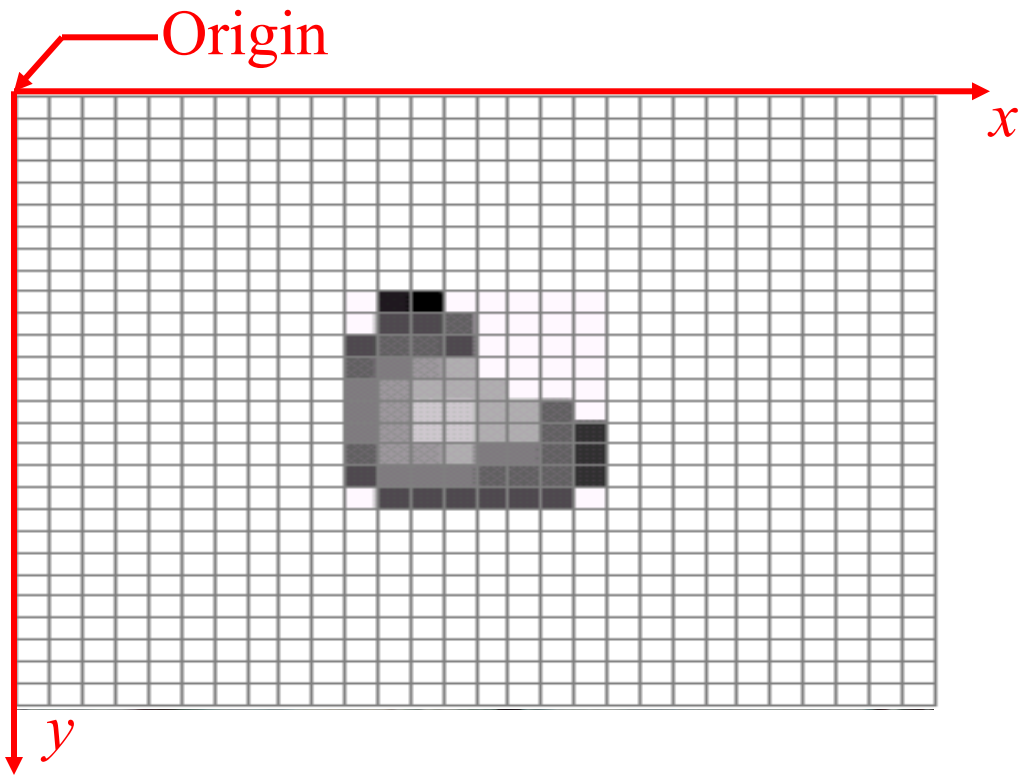
❖How do we represent images?

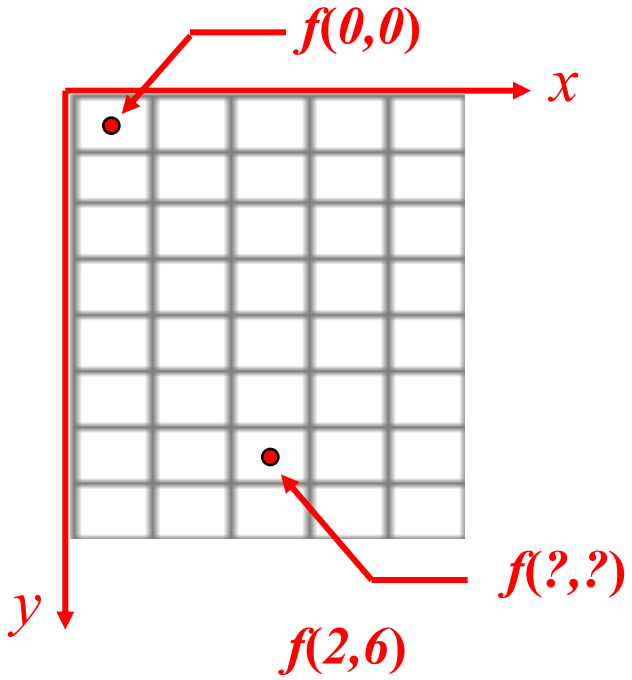
Digital Image Representation



- Image is seen as a **discrete function *f*(*x*,*y*)** as opposed to a continuous function (show)
- x and y **cannot** take on any value!

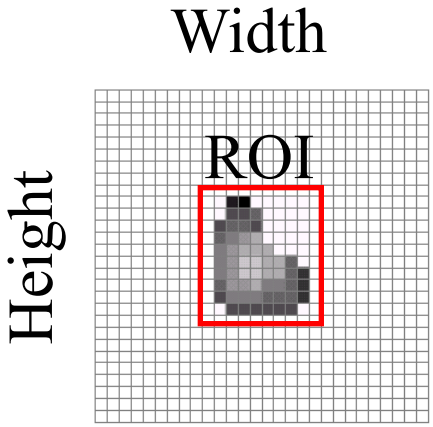
Discrete image coordinate system





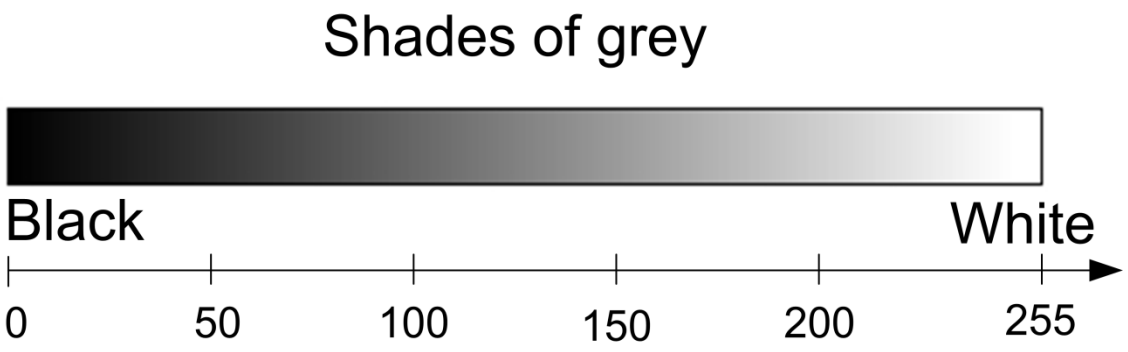
Digital Image Representation

- An image ***f(x,y)*** is represented as an 2D ***Array, matrix***
- Width =
  - **number of pixels in x-direction**
- Height =
  - **number of pixels in y-direction**
- Size (width × height)
- ROI = region of interest
  - **To reduce the amount of data**

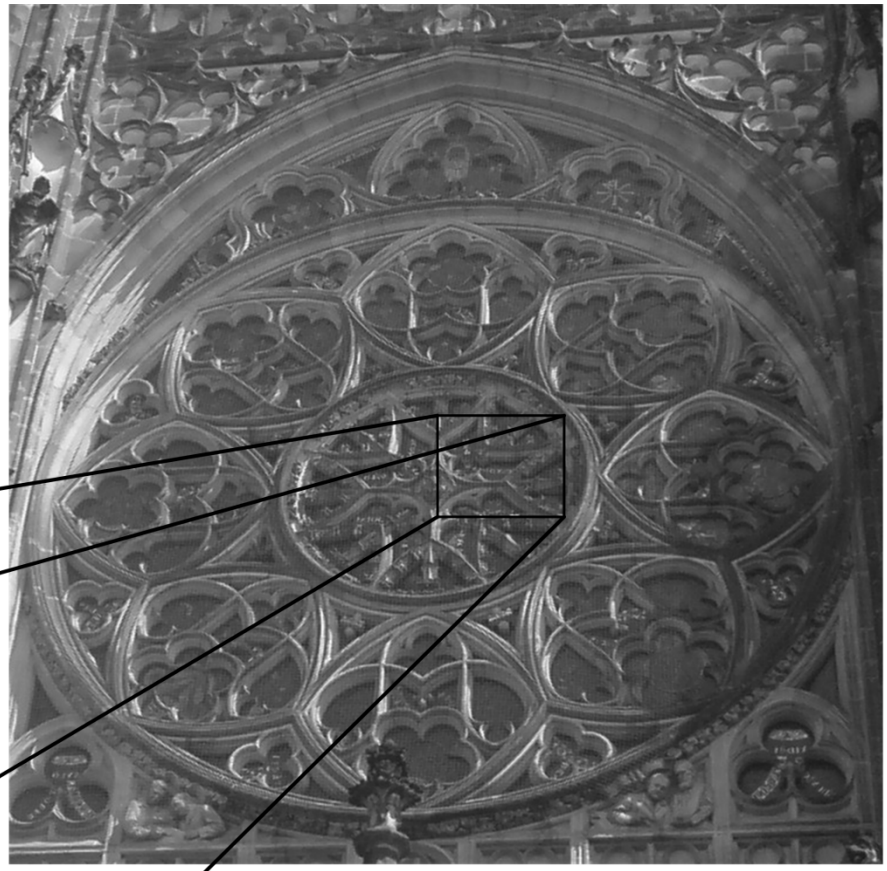


Digital Image Representation

- Pixel representation:
  - **Gray images:**
    - ✓ Pixel's values are on or inside of [0,255]
    - ✓ Pixel's value = 0: black
    - ✓ Pixel's value = 255: white



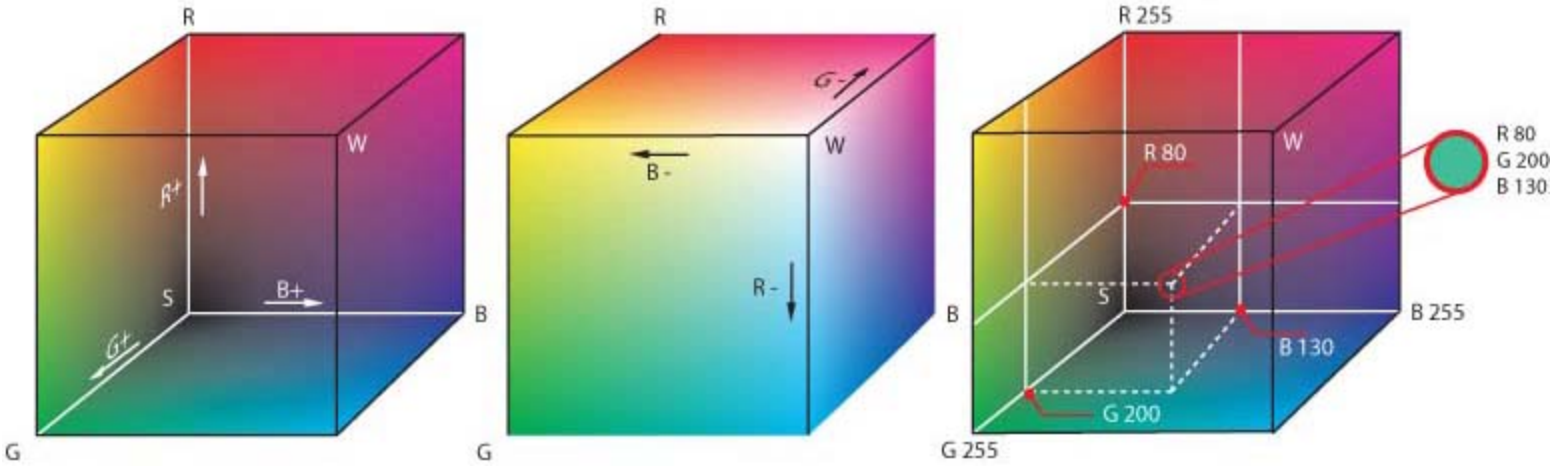
Digital Image Representation



202	134	112	122	...	112
209	133	112	126	...	102
223	151	94	108	...	106
233	166	109	115	...	126
...	...	...	...	...	...
132	138	147	131	...	95

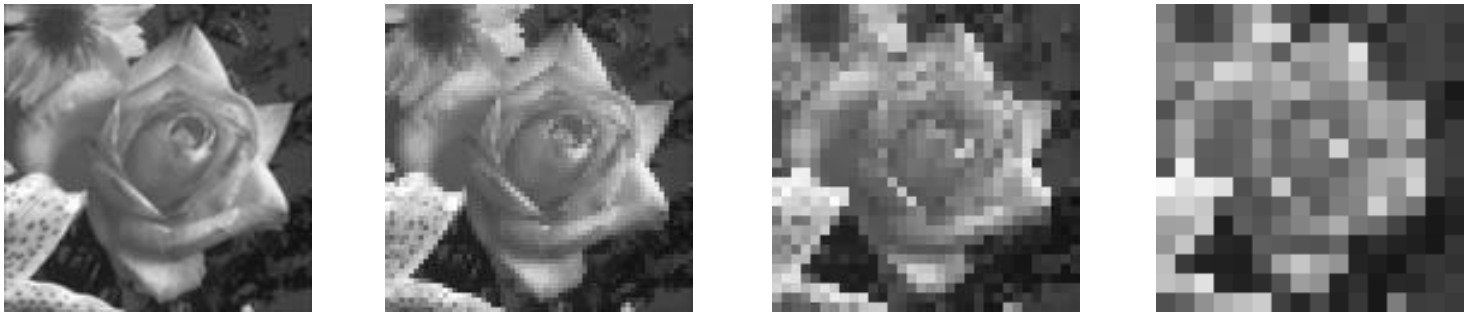
Digital Image Representation

- Pixel representation:
  - **Color images:**
    - ✓ A color = a combination of a red, a green, and a blue shade
    - ✓ An pixel is represented by a triple [R,G,B].
    - ✓ An image has 3 planes: R, G, and B-plane



Spatial Image Resolution:

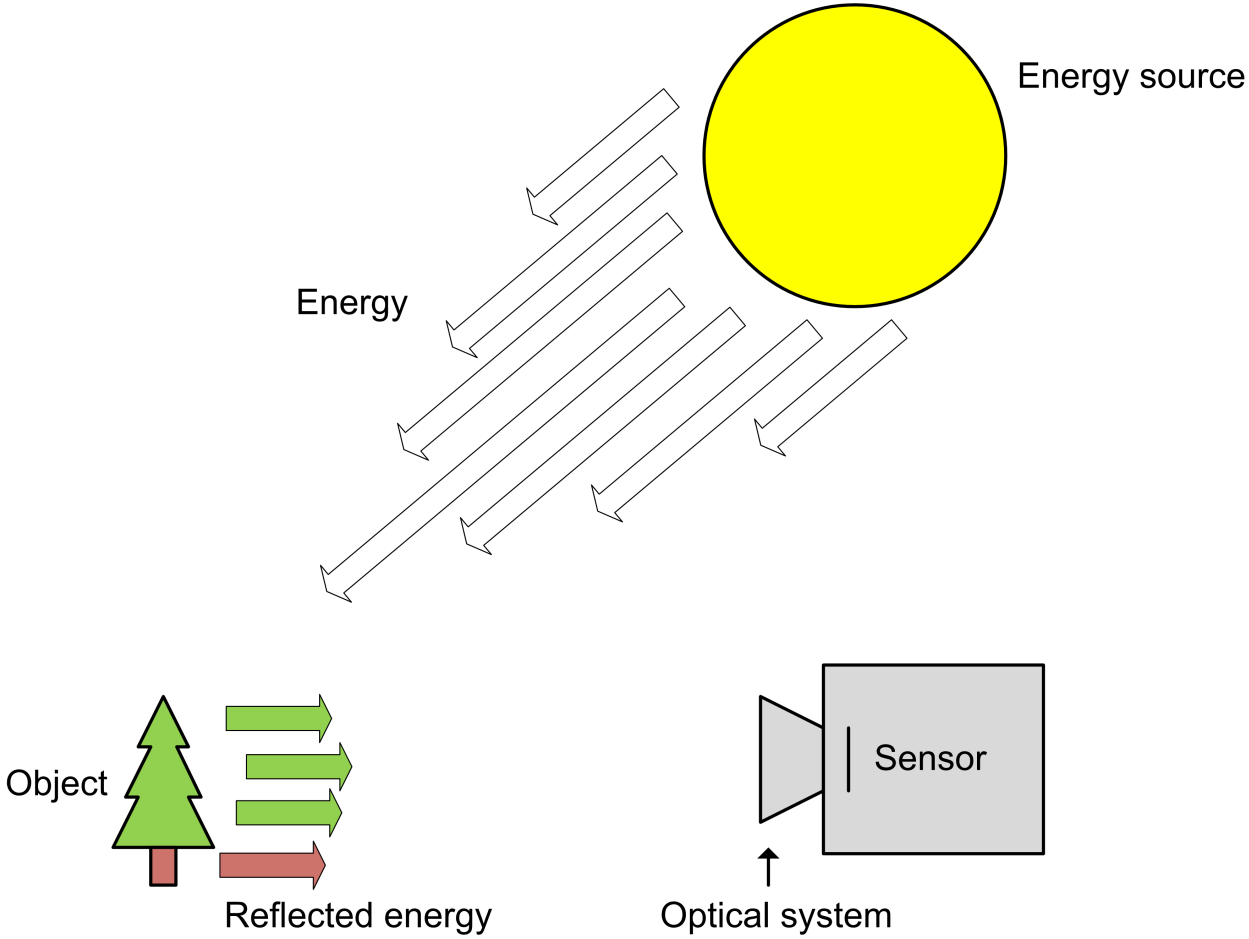
- Resolution
  - **The size of an area in a scene that is represented by one pixel in the image**
- Different Resolutions are possible (256x256….16x16)



- Lower resolution leads to data reduction!

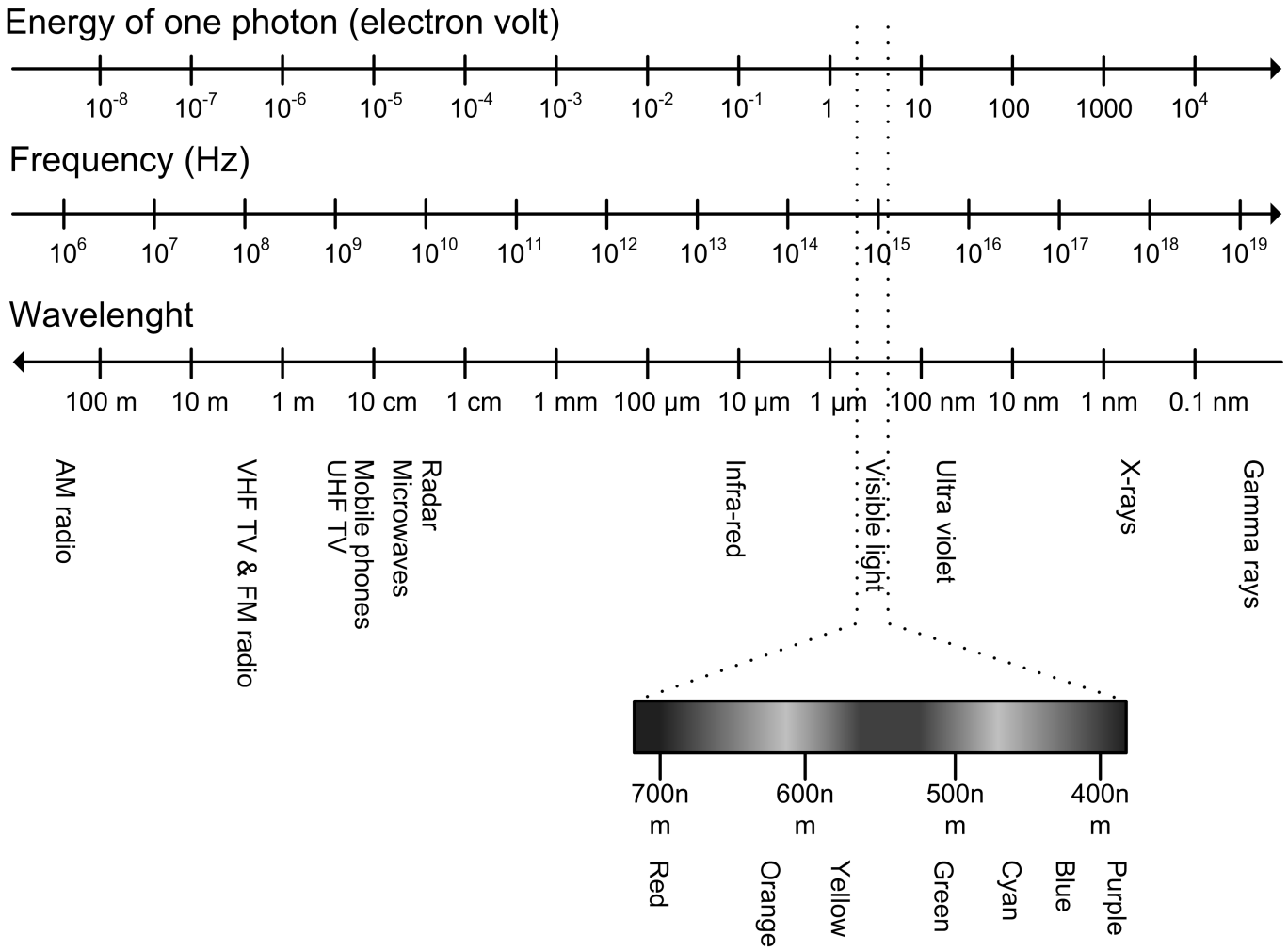
❖How can we acquire images?

Where does an image come from?



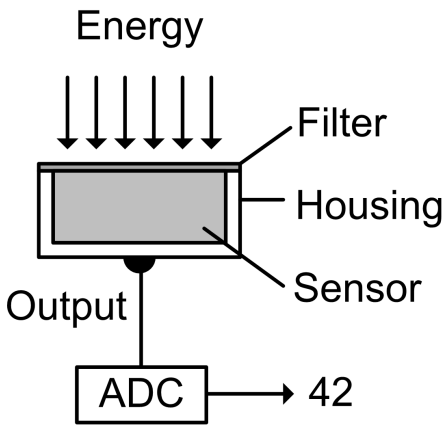
Where does an image come from?

Electromagnetic spectrum

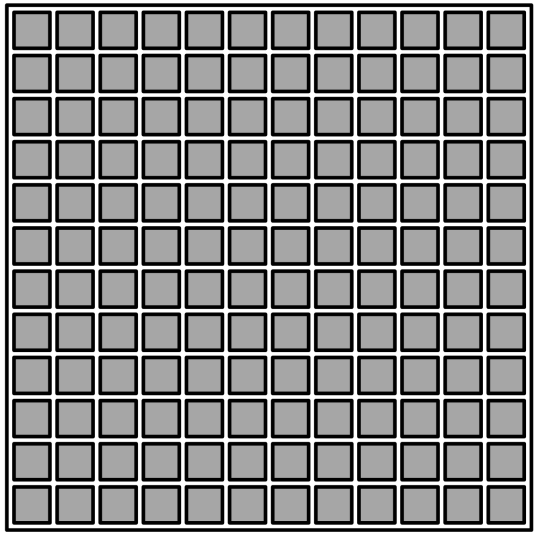


Where does an image come from?

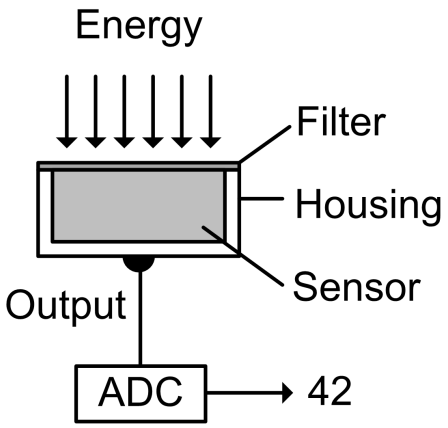
Single cell



Charged coupled device
CCD-chip



Where does an image come from?



Correctly exposed

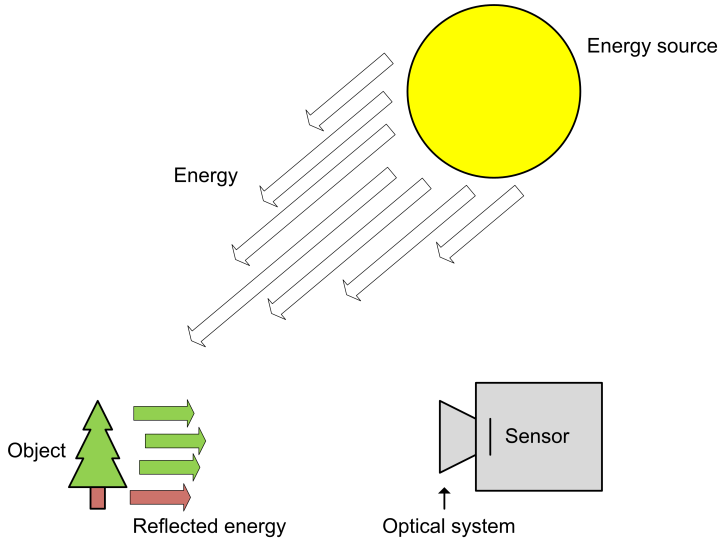
Over exposed

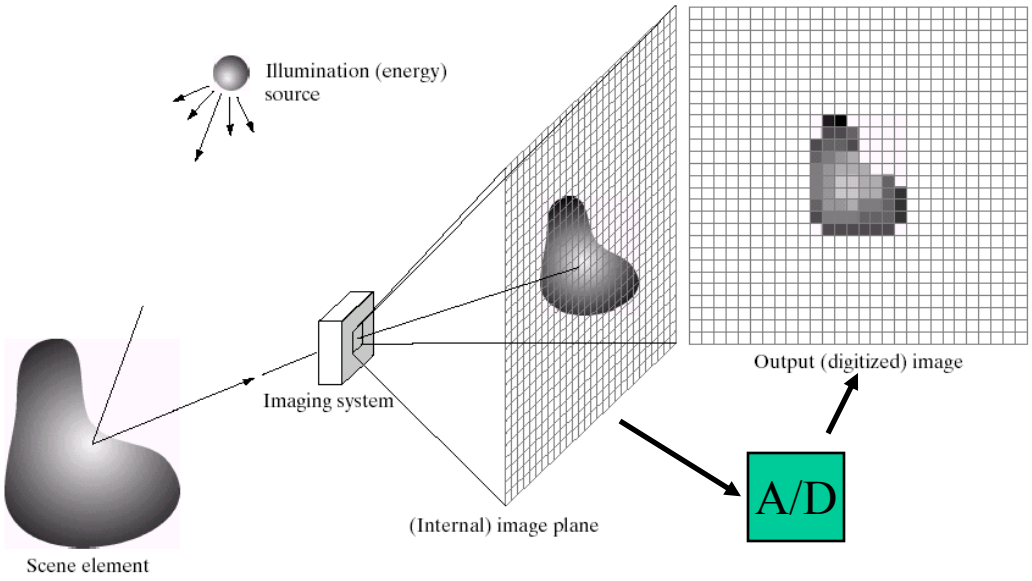
- Integration over time
  - **Exposure time**
    - ✓Shutter time
  - **Motion blur**
  - **Maximum charge**
    - ✓Saturation
    - ✓Blooming

Under exposed

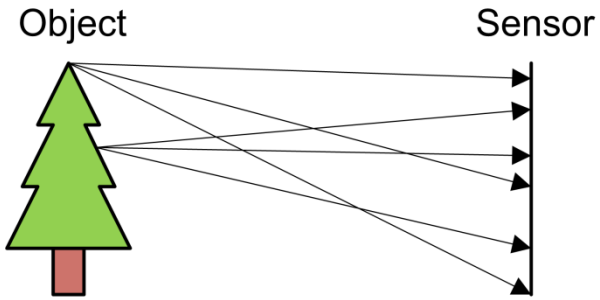
Motion blur

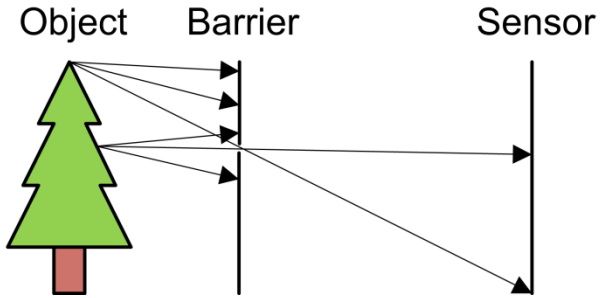
Image formation - the lens

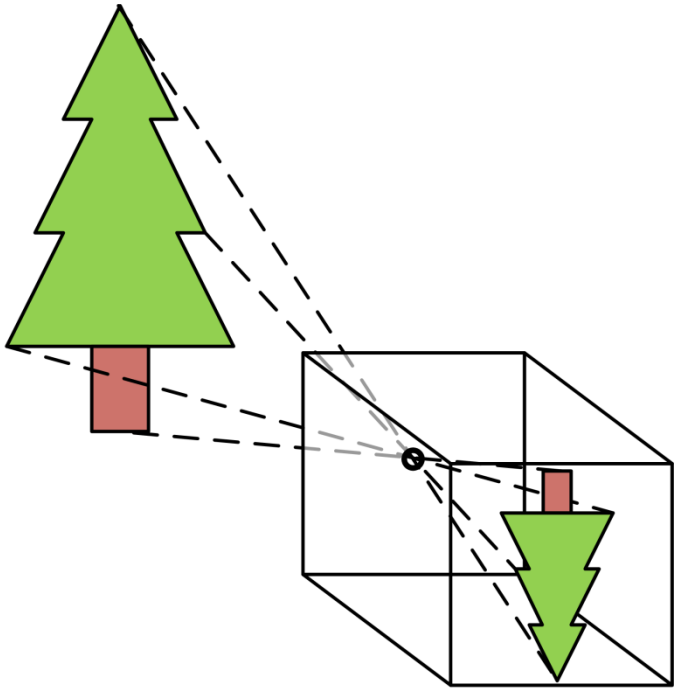




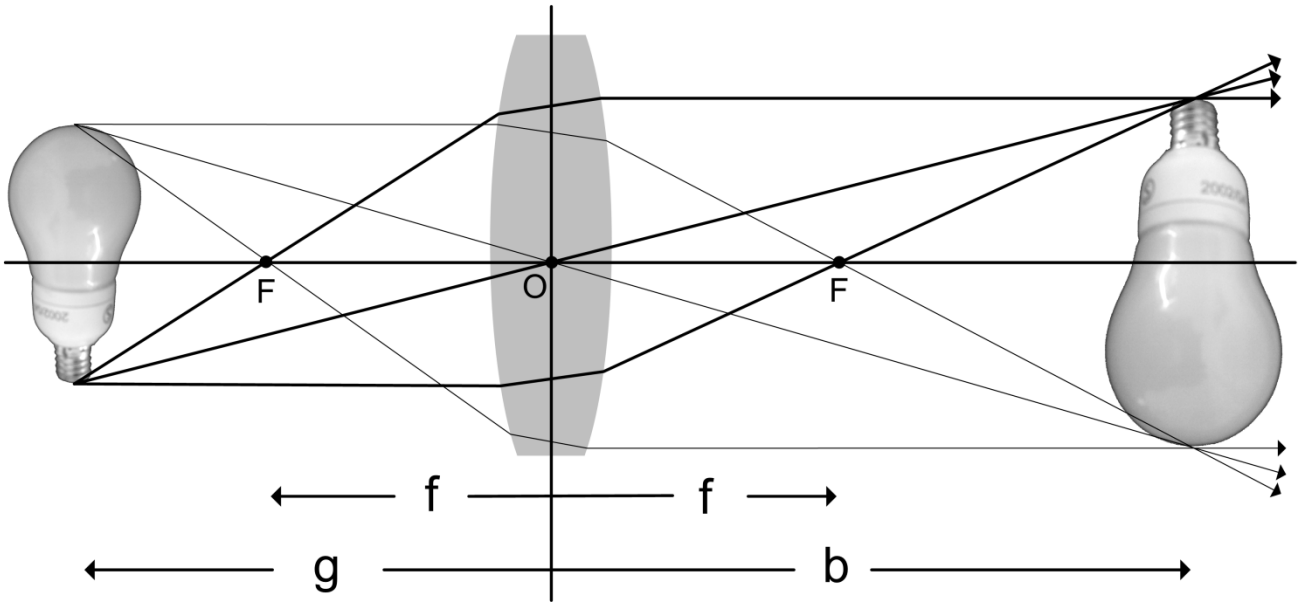
The lens





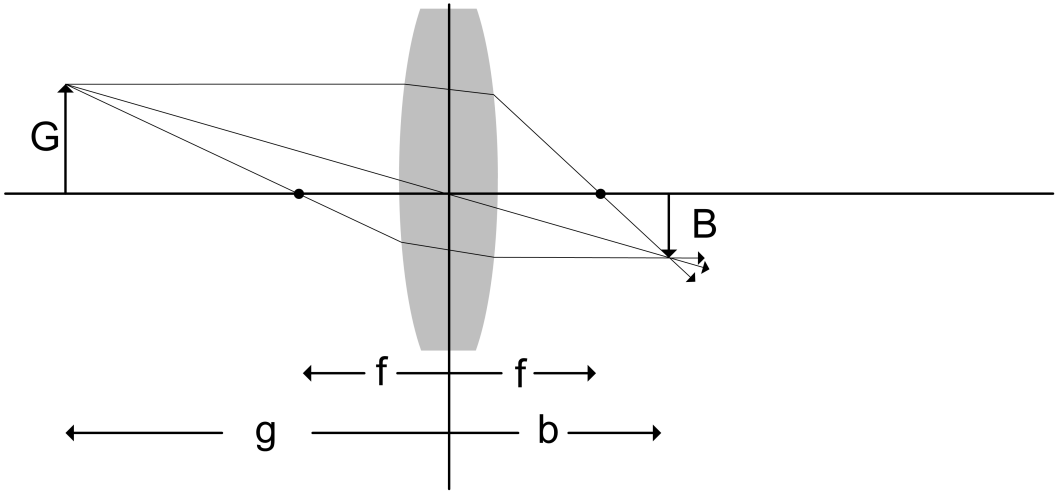


The lens



- A lens focuses a bundle of rays to one point
- Parallel rays pass through a focal point ***F*** at a distance ***f*** beyond the plane of the lens. ***f*** is the focal length
- ***O*** is the optical center
- ***F*** and ***O*** span the optical axis/principal axis

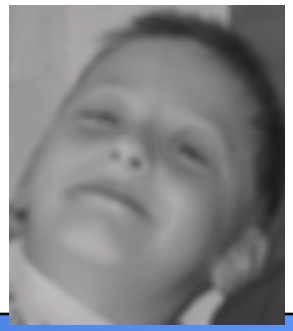
Focus



$$\frac{1}{g}+\frac{1}{b}=\frac{1}{f}$$

In focus

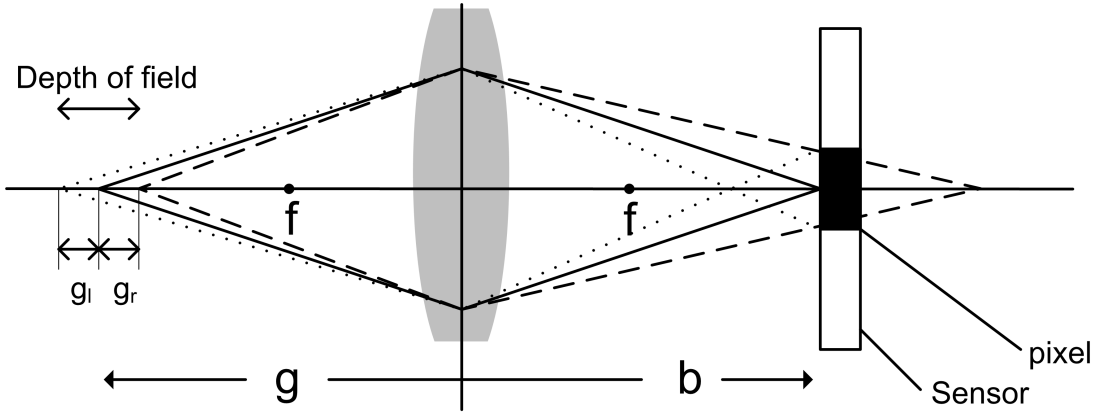
Not in focus

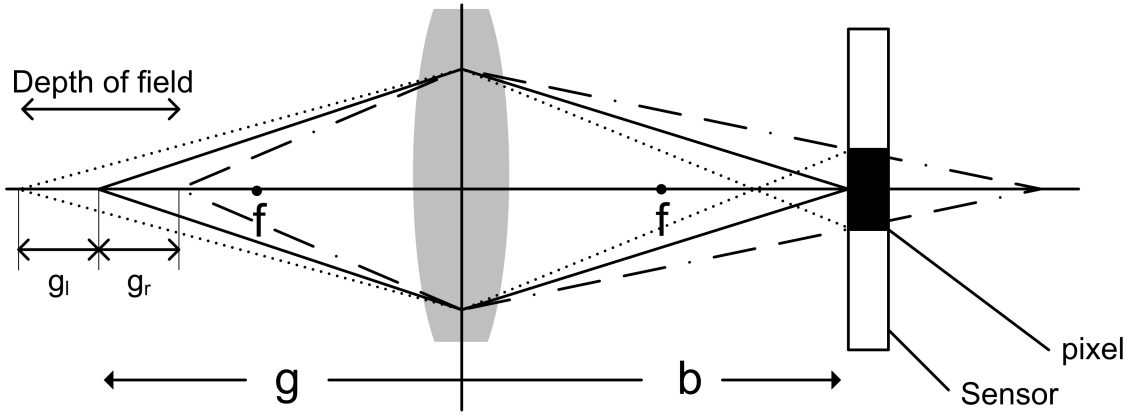


(vis på oh)

Focus and depth-of-field

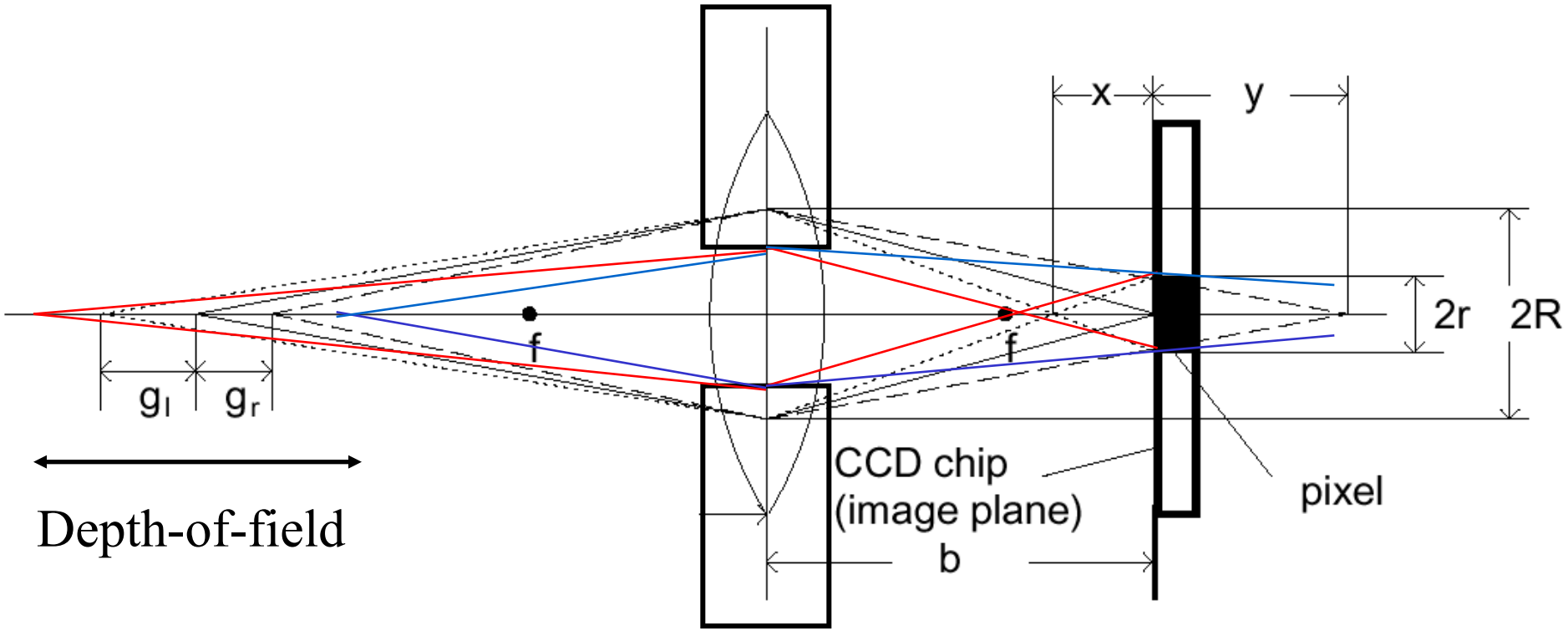
• Depth-of-field is the distance from the nearest to the farthest object in front of the camera that can be captured sharply in the result image, i.e., the blur does not exceed a certain value





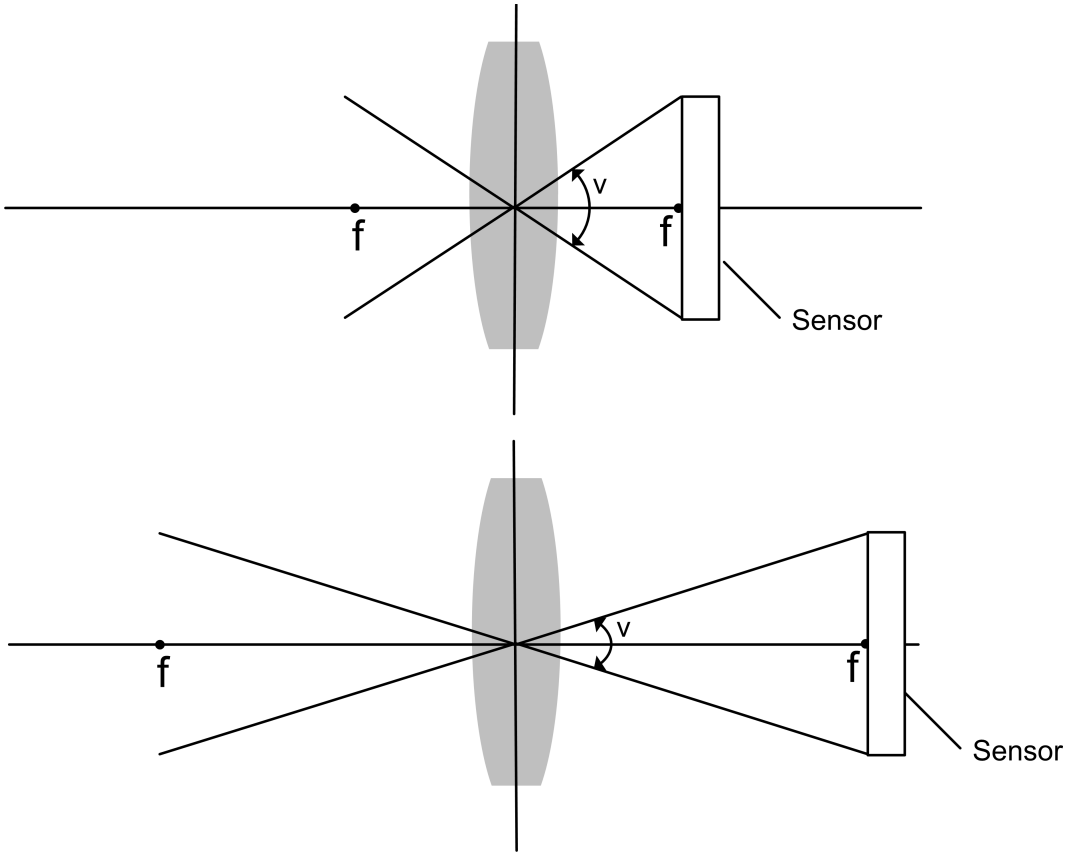
$$\frac{1}{g}+\frac{1}{b}=\frac{1}{f}$$

Aperture



- The smaller aperture, the longer the depth of field.
- **Downside**: smaller aperture ⇒ less light enters the camera
  ⇒ increase exposure time
  ⇒ risk of blur due to motion

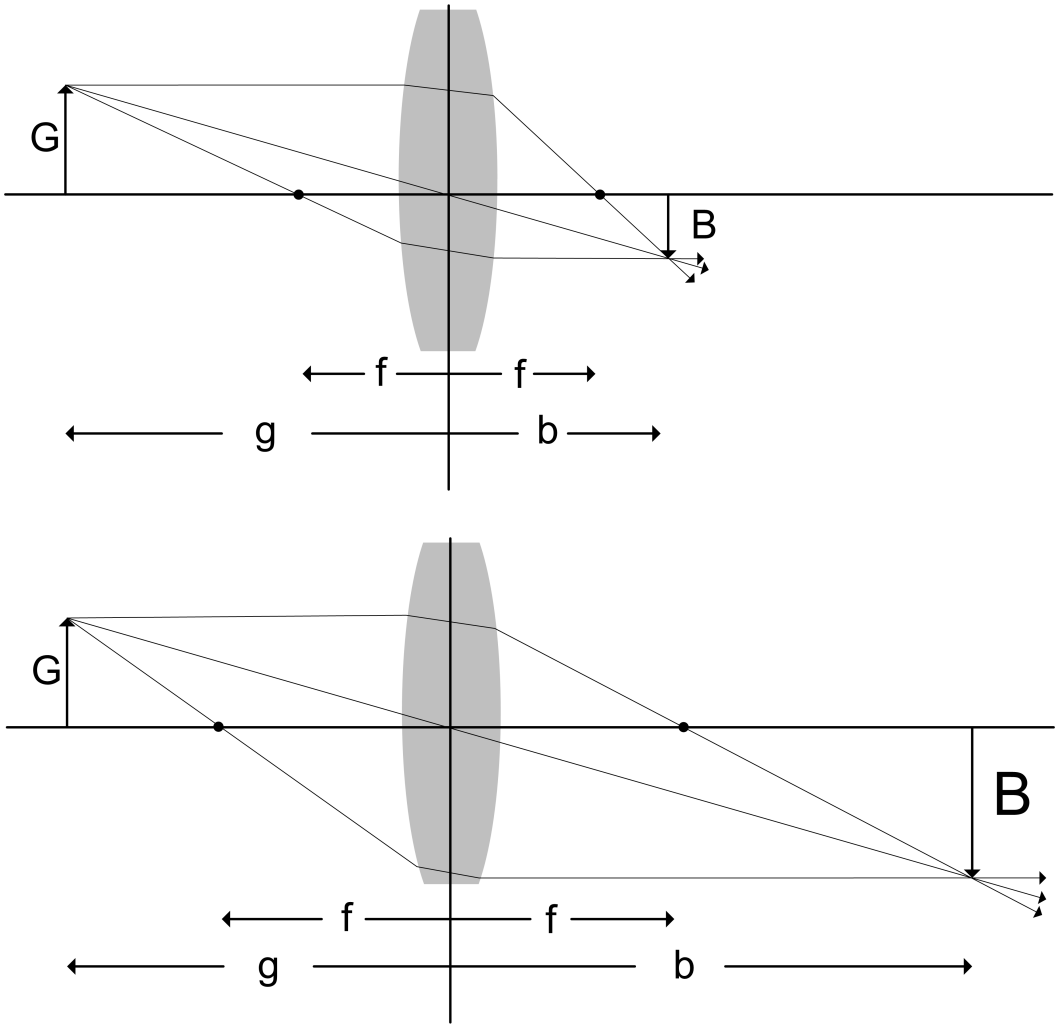
Field-of-view



- Field-of-view, v, depends on size of the sensor and focal length
- ”Fisheye” lens ⇒ small focal length and large field-of-view
- Horizontal FOV and Vertical FOV

Zoom

- Optical zoom
  - **The optics (lens) is changed ⇒ focal length, f, is changed**
- Digital zoom
  - **Interpolation**

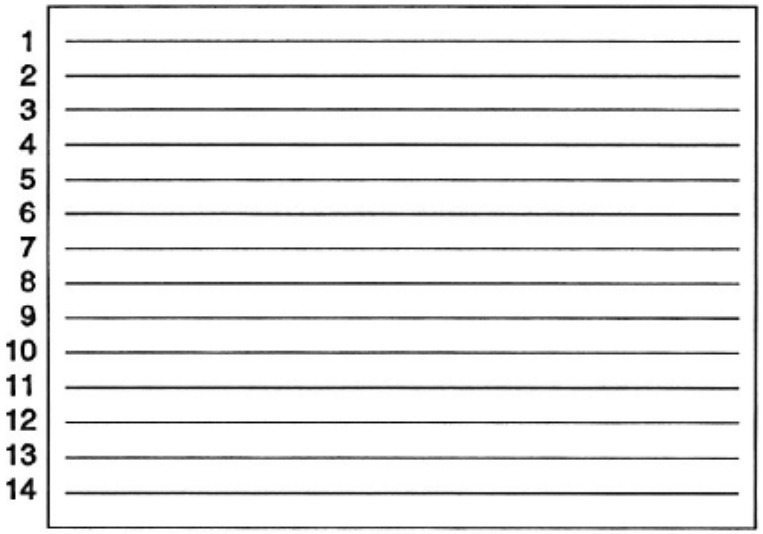


Zoom

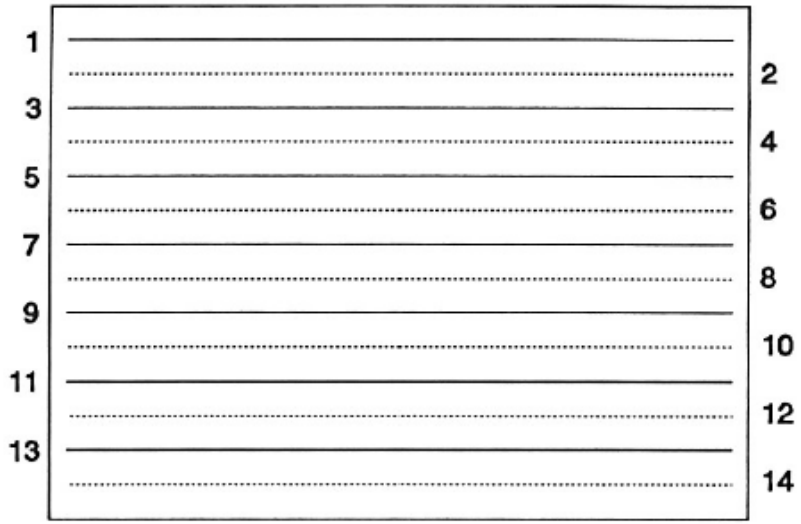
Digital Zoom ⟶

Optical Zoom ⟶

Progressive vs. Interlaced



Progressive

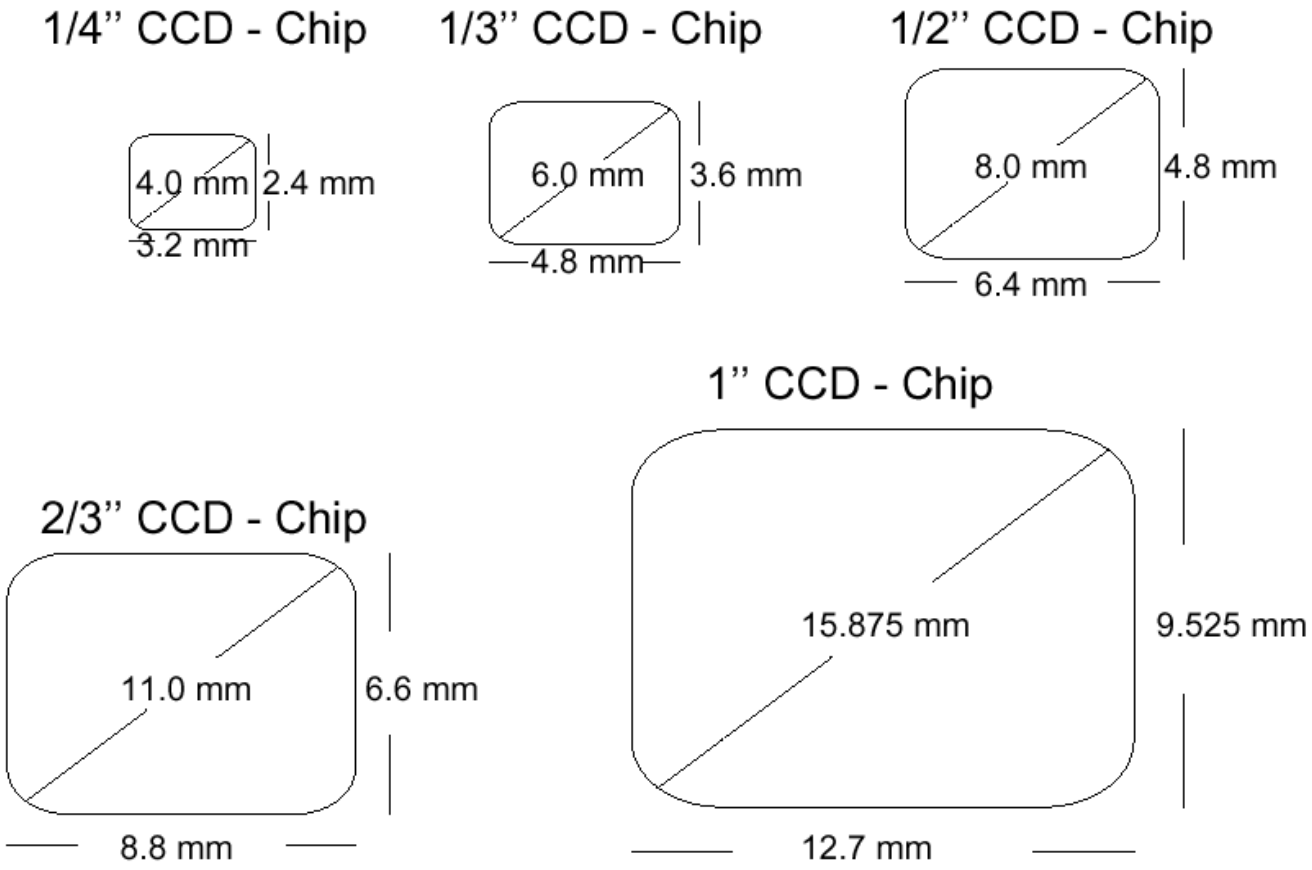


Interlaced

Sensor Chip Formats

Number of Pixels
from 500x500
to 5000x5000

Pixel size
from 4µm x 4 µm
to 16 µm x 16 µm



A good image…

- Issues to consider:
  - **Dist. to object**
  - **Motion of object**
  - **Zoom**
  - **Focus**
  - **Depth-of-fields**
  - **Focal length**
  - **Shutter**
  - **Field-of-view**
  - **Aperture (DK: blænde)**
  - **Sensor (size and type)**

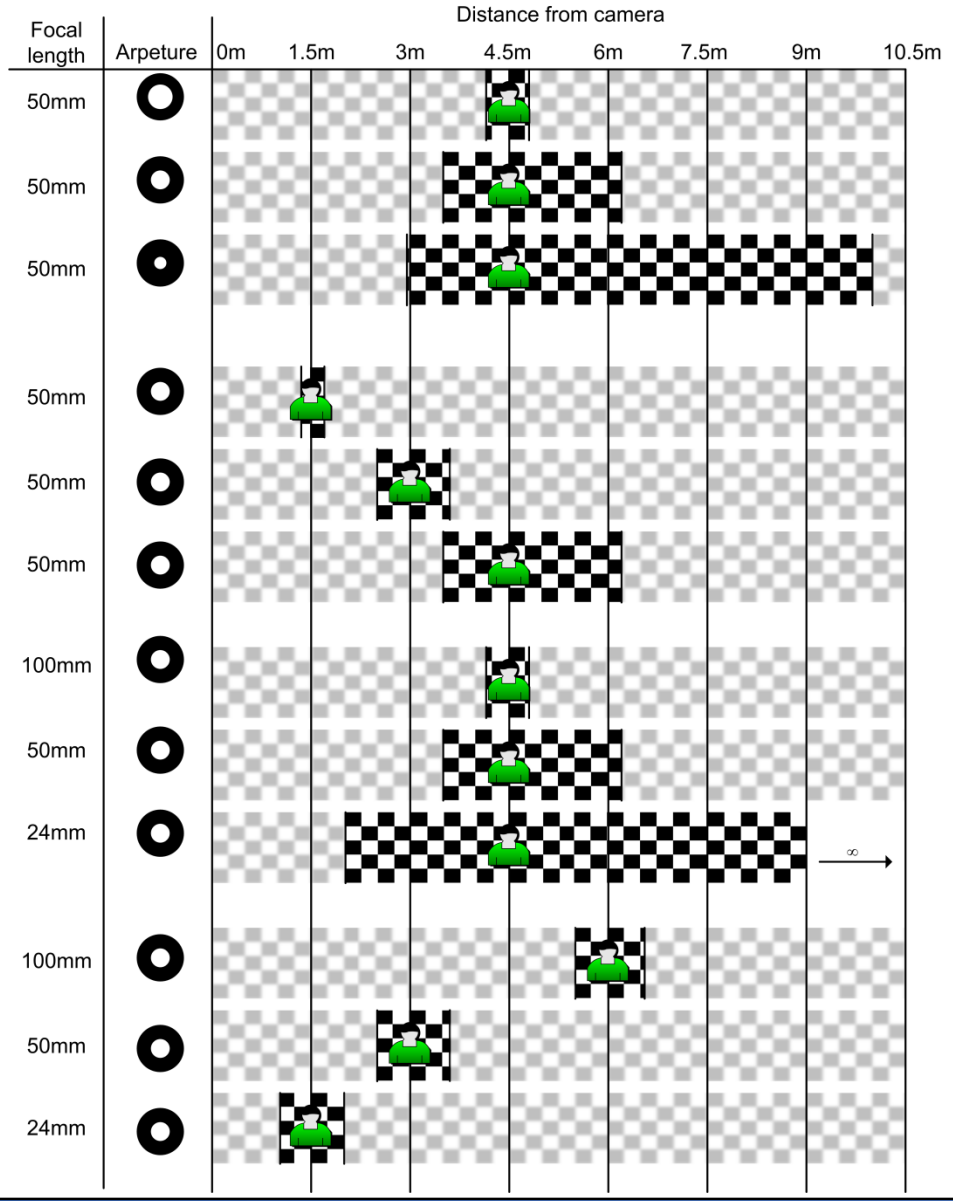


Image file types

- image.jpg, image.tif, image.gif, image.png, image.ppm, ….
- Raw:
  - **No data is lost**
  - **Header + data (234 235 32 21…)**
  - **For example: image.pgm**
  - **The file can be viewed**
- Lossless compression:
  - **No data is lost, but the file cannot be viewed**
  - **For example: image.gif**
- Lossy compression:
  - **Better compression**
  - **Some data is lost (optimized from the HVS' point of view)**
  - **The file cannot be viewed**
  - **For example: image.jpg**

Image file types

- Normally you don't care about the file type
  - **The application will take care of it for you:**
  - **For example: rotate**
    - ✓ Application
      - image.x => raw
      - Rotate the raw image
      - Rotated raw => rotated_image.x
- But to write your own programs from scratch the images need to be in the raw format (without a header)

Is there any tool/library for processing images?

- MATLAB
  - **Demonstrations**
    - ✓Image: Read, Write, Display, Simple Process
- OpenCV