2012 :15th SESSION of ESMP

Lecture presented in Archamps (Salève Building) by :

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Fundamental Aspects of Digital Imaging

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Comparison – Digitization versus Human Visual System

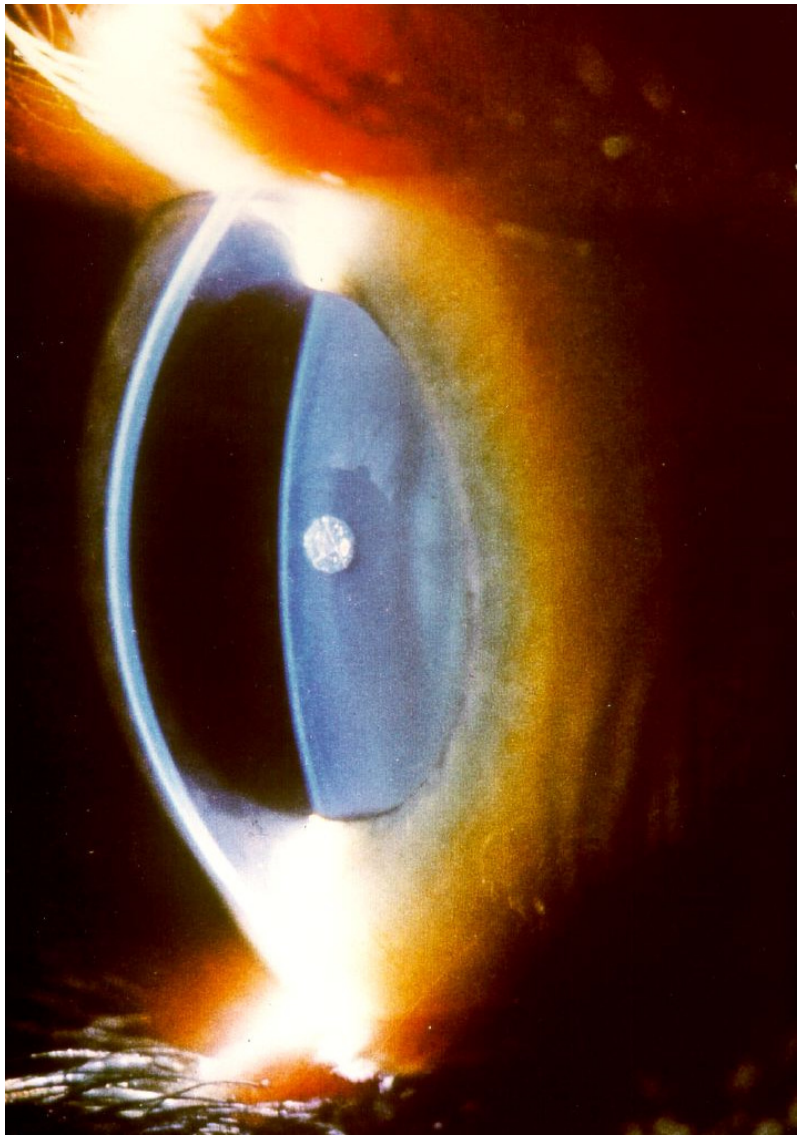
Transformation of an image

- Picture Elements → Receptive Fields
- Mean signal → Membrane Voltage

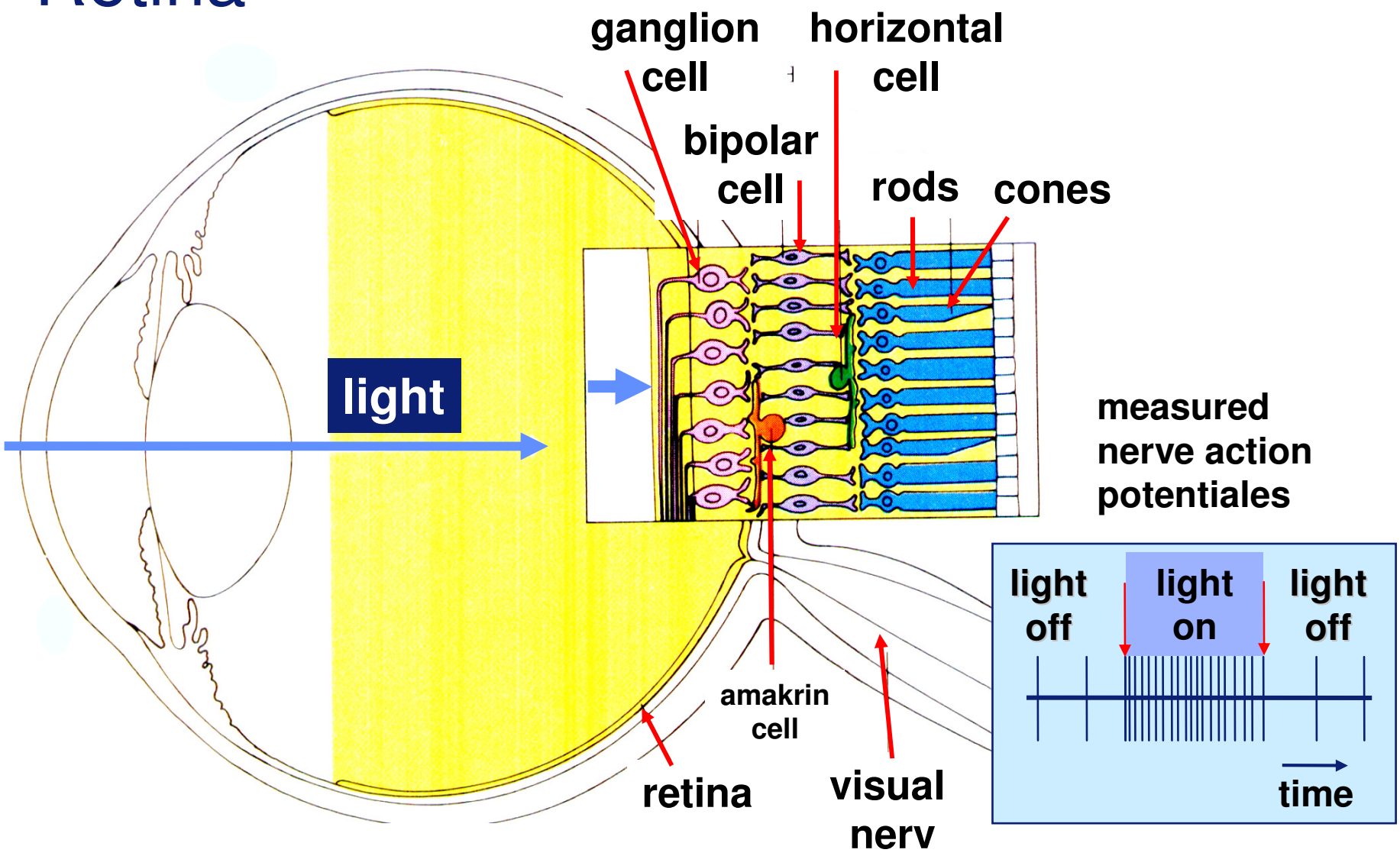
- Coding → Nerve Action Potentials

Parameters of the human visual system:

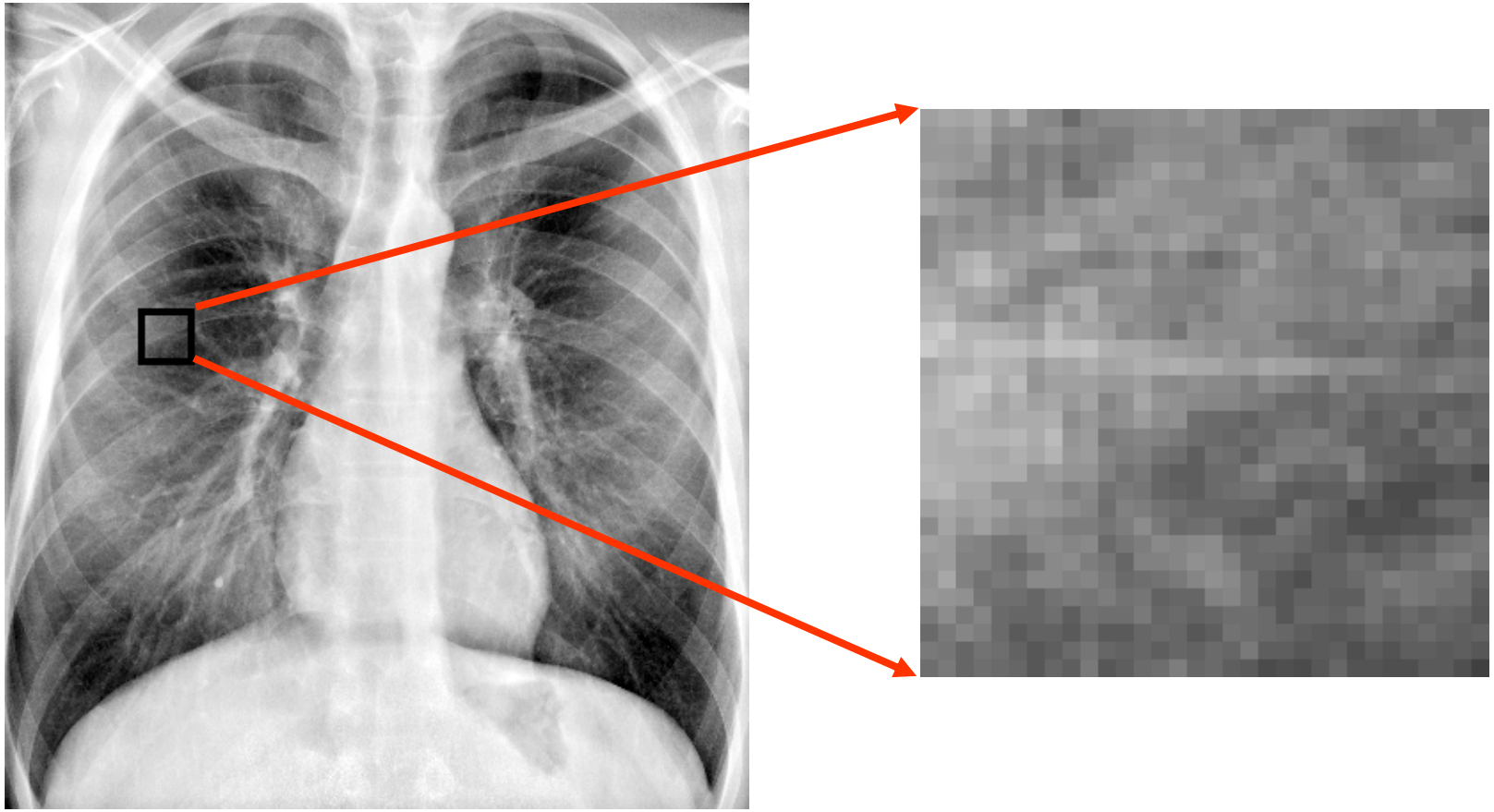
- Contrast Sensitivity: 1% Contrast
- Spatial Resolution: Visus 1



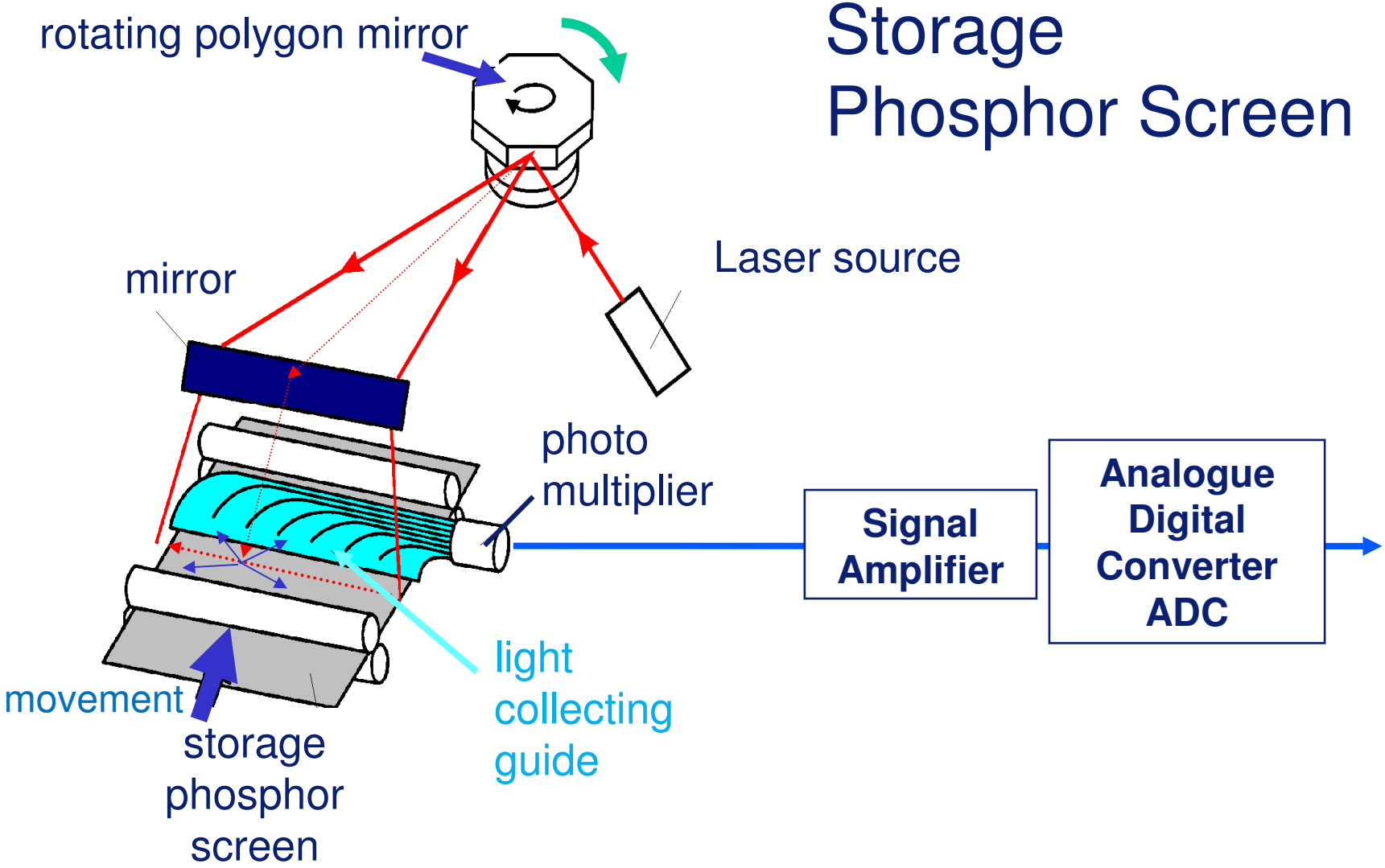
Retina


ganglion cell
horizontal cell
bipolar cell
rods
cones
light
measured nerve action potentiales
light off
light on
light off
time
amakrin cell
retina
visual nerv

Digitization of a Radiograph



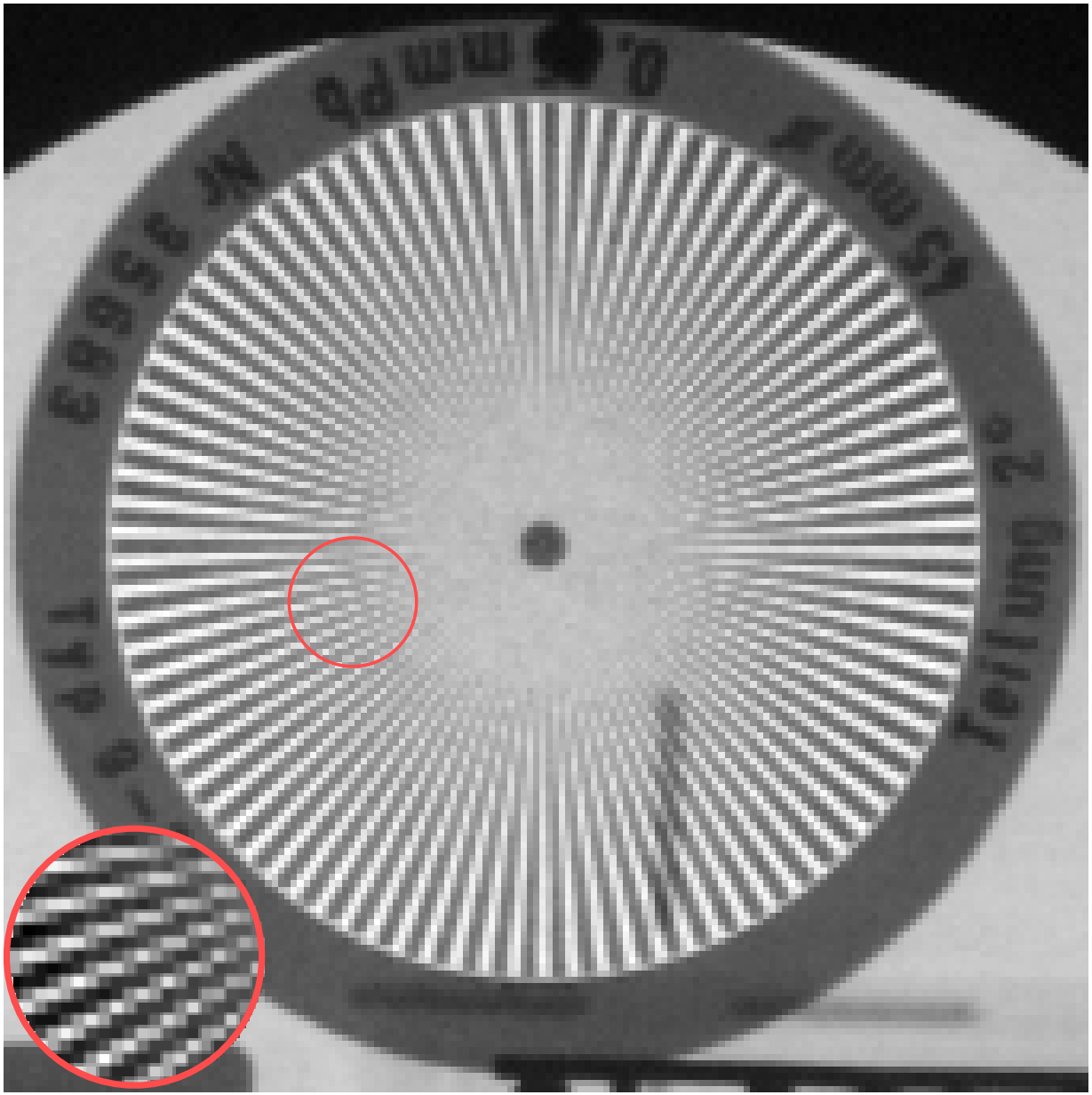
Digitization by Scanning



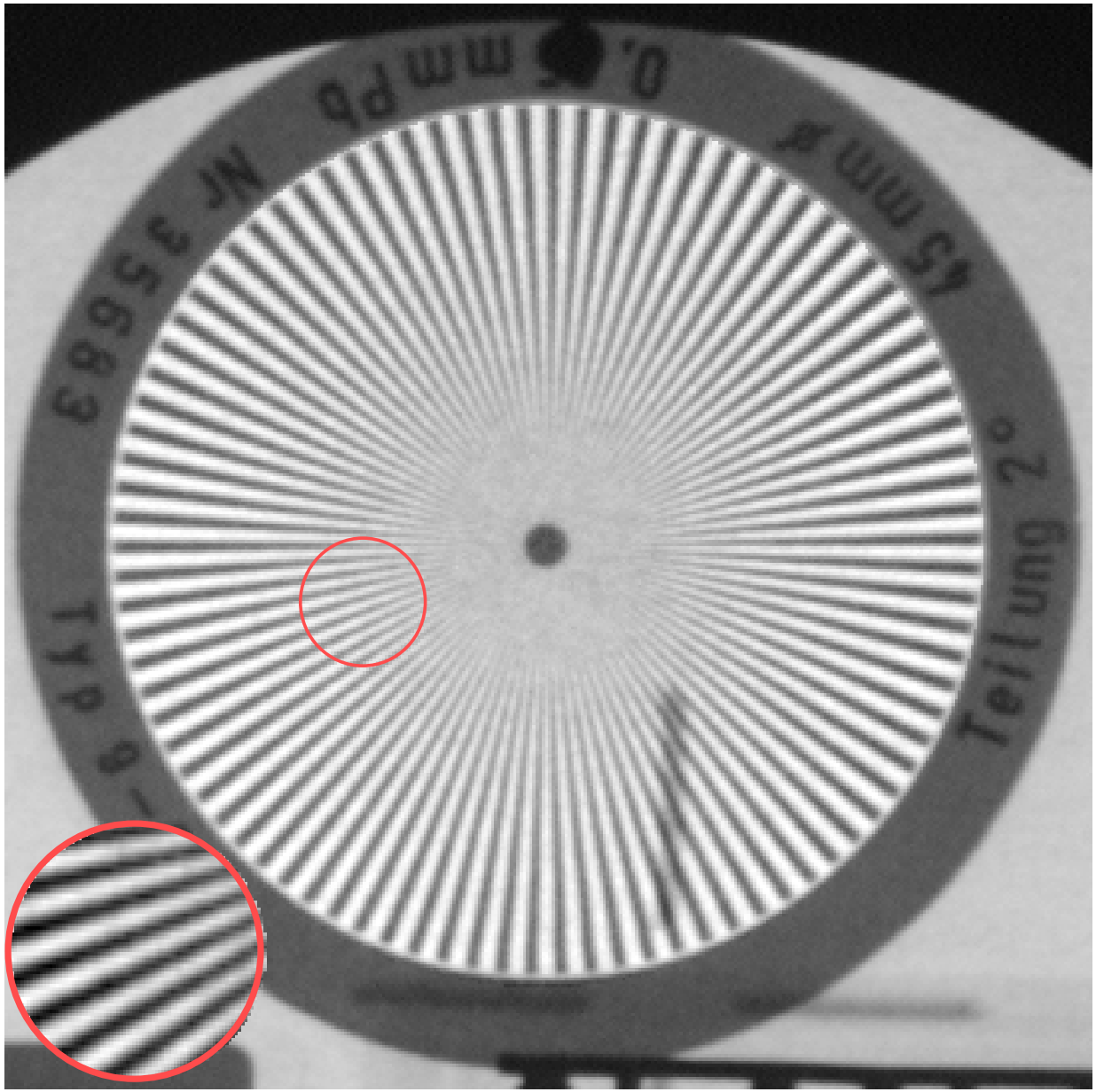
Transformation Steps towards a Digital Image

- **Pixelization (discretisation)** — **subdivision of the image to picture elements → pixels**
  registration of the mean signal value
- **Quantization** — **subdivision of the signal range to discrete signal levels → gray levels**
  mean signal value → signal level
- **Coding** — **transformation of signal level to binary digits → bits**

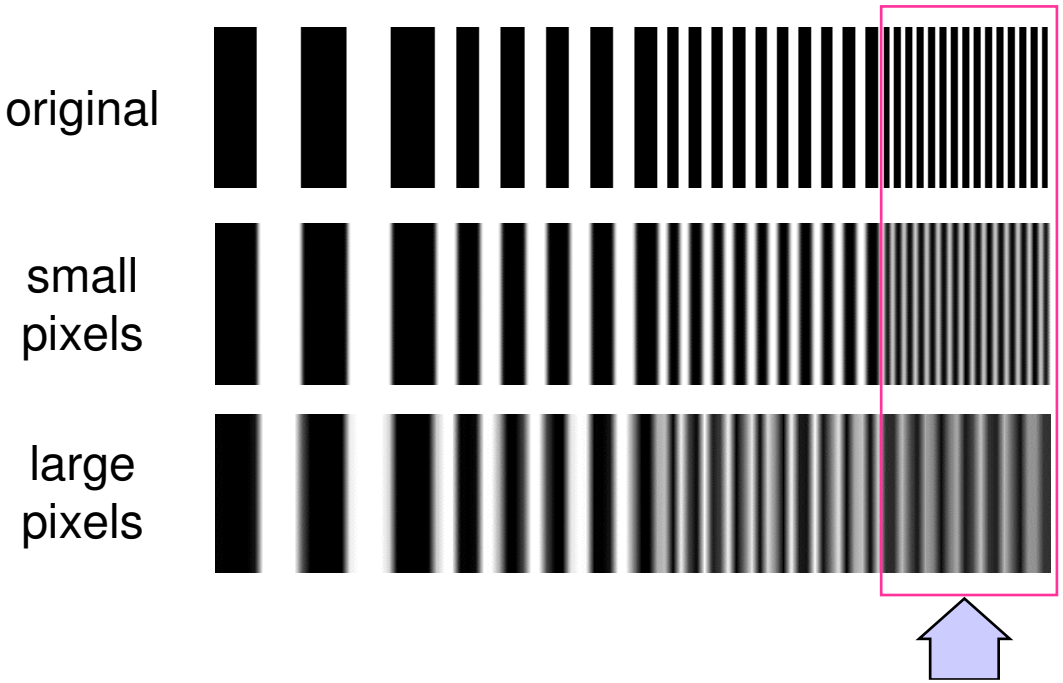
Is there a loss of information?



Aliasing


0.5 mm Pb
Nr 35683
Typ 8
45 mm
Teilung 2°

effect of Aliasing (pseudo structures)



structures, smaller than the pixel will be distorted by the imaging process.

limiting spatial frequency for pixel size a:

$f_N = 1/ 2a$

Pixel (mm)	f_N (lp/mm)
0.2	2.5
0.1	5.0
0.05	10.0

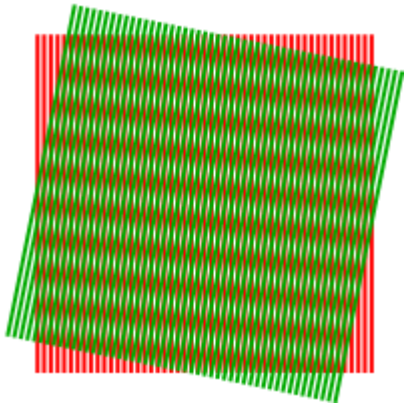
f_N = Nyquist frequency

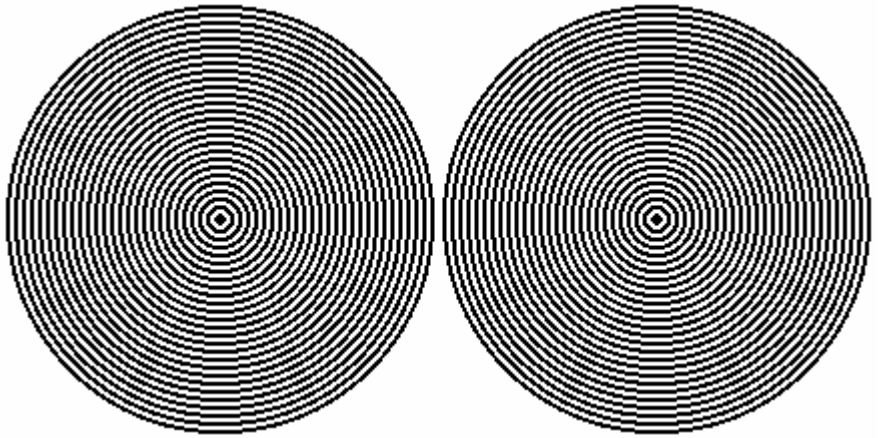
Moiré patterns

superposition of two grids

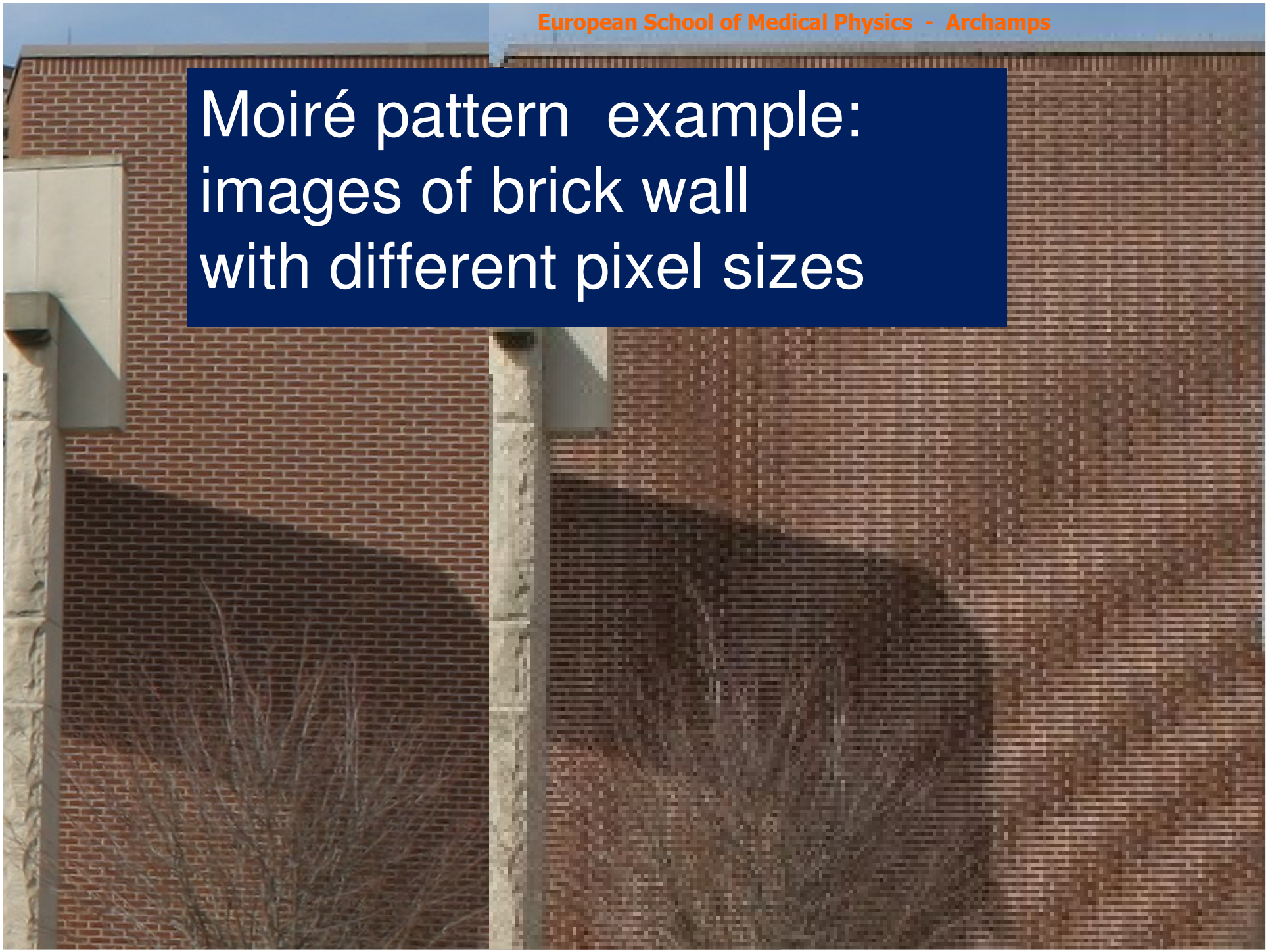
→ undesired artifact within images

- produced by various digital imaging and computer graphics techniques

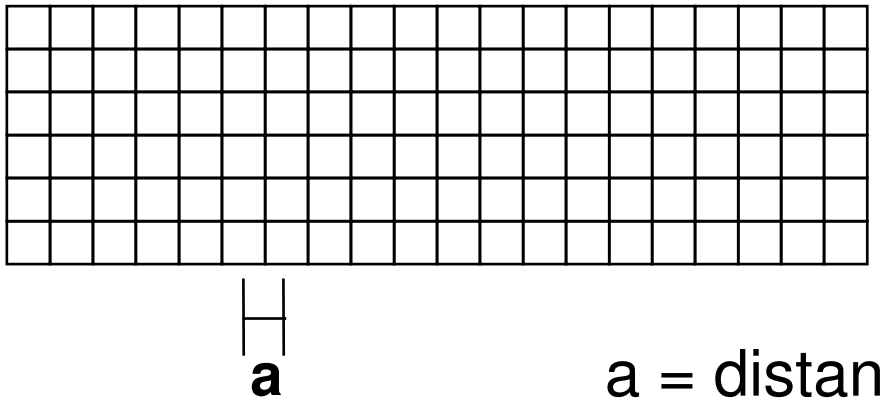




Moiré pattern example: images of brick wall with different pixel sizes



Definition of Sampling Frequency



Section of a digital image consisting of discrete pixels

a = distance between two pixel centers
(called: pixel pitch or pixel size)

Sampling Frequency $f_s = 1 / a$

= number of

pixels per unit of length
example: pixel size 200 µm

f_s 5 p

Sampling Theorem

Nyquist-Shannon Sampling Theorem

also WKS Whittaker-Kotelnikow S T

Definition of Nyquist frequency for a digital imaging system:

$$f_{Nyquist} = \frac{f_s}{2}$$

called:
limiting spatial frequency

There is no loss of information by sampling an image, if

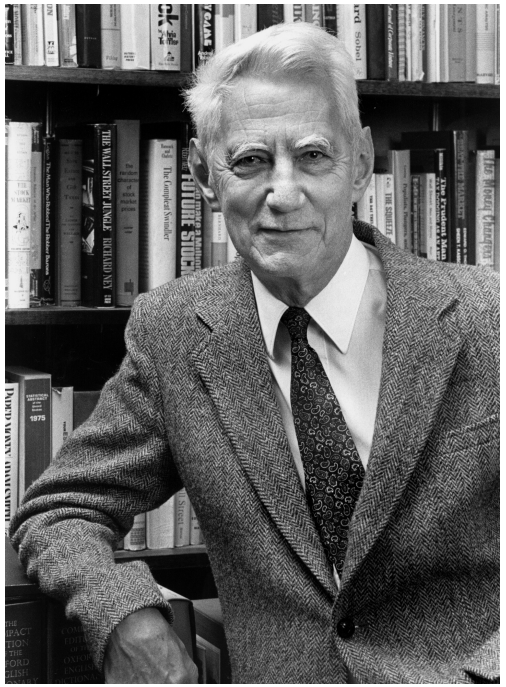
Nyquist frequency >
highest spatial frequency component of the signal

Historical background

Claude Elwood Shannon

* 30.4.1916 Petoskey, Michigan,

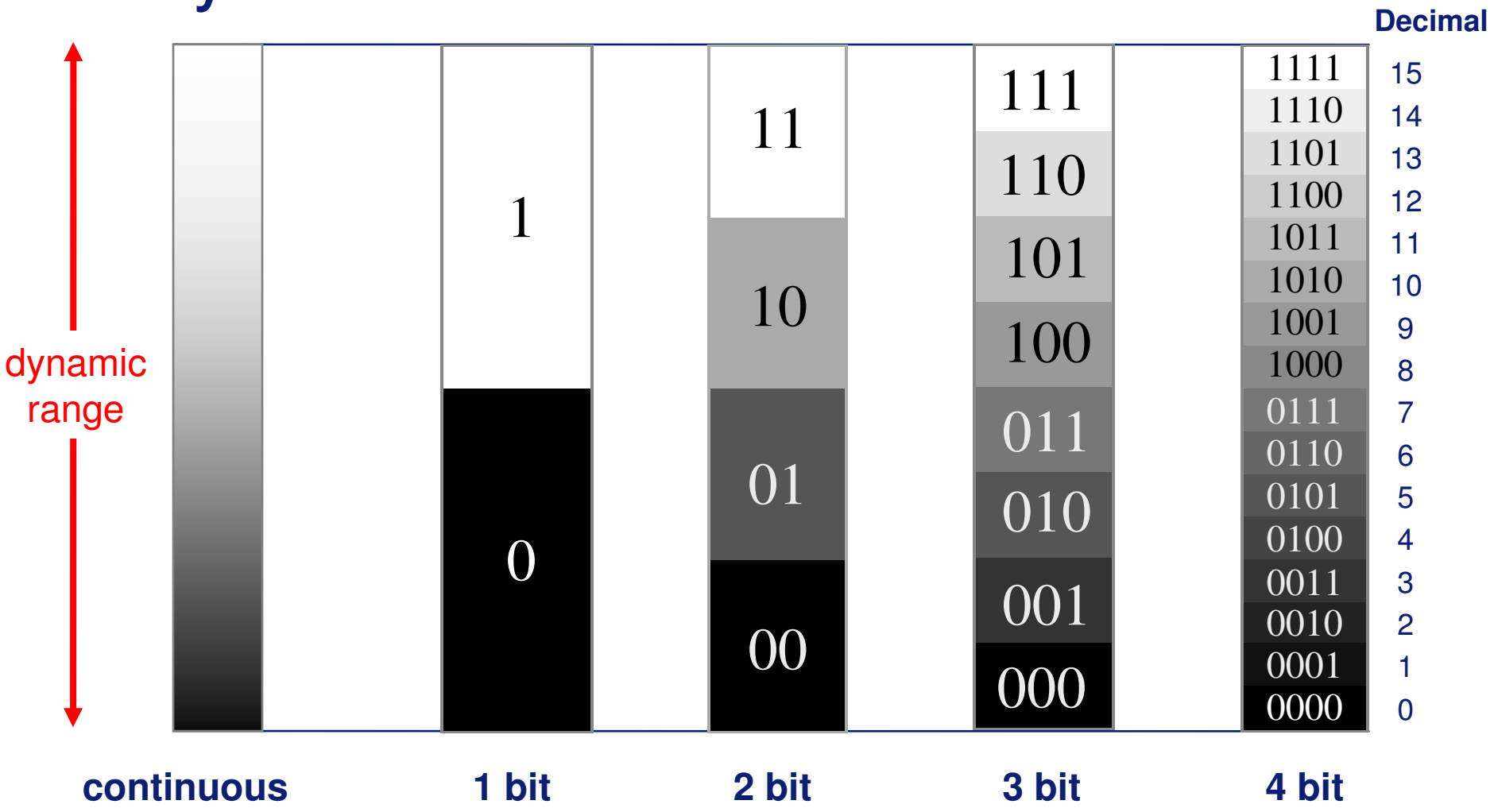
† 24.2.2001 Medford, Massachusetts



American engineer + mathematician

founder of information theory (1948)

Grey Scales



abbreviations bit = binary digit, 1 Byte = 8 bit

Pixel values of a picture element (Pixel)

number n of possible pixel values (grey values)
= range of values

$$n = 2^{\text{bits (per Pixel)}}$$

example:

8 bit	256 pixel values
10 bit	1024 pixel values
12 bit	4096 pixel values

Historical background

Leibniz, Gottfried Wilhelm,

* 1.7.1646 Leipzig,

† 14.11.1716 Hannover

philosopher, mathematician

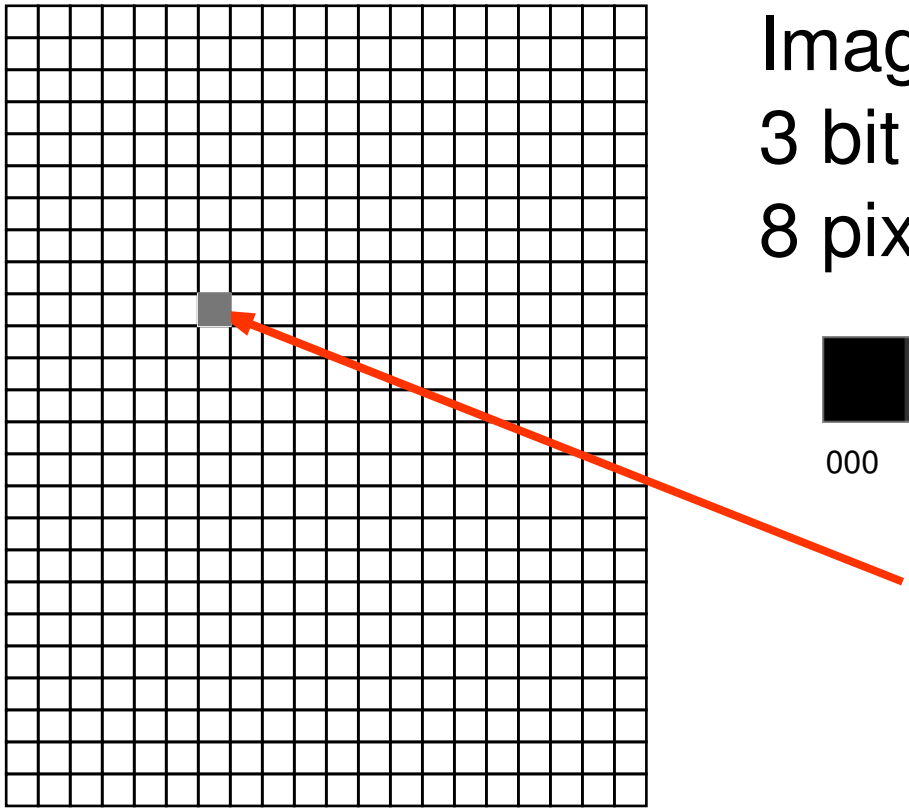
....general scientist

Representation of numbers using

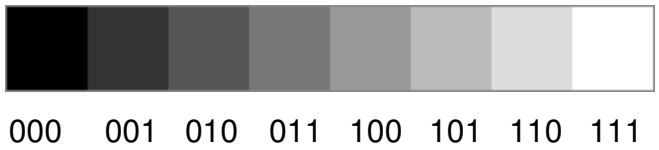
two values

Dual System

Matrix of an image

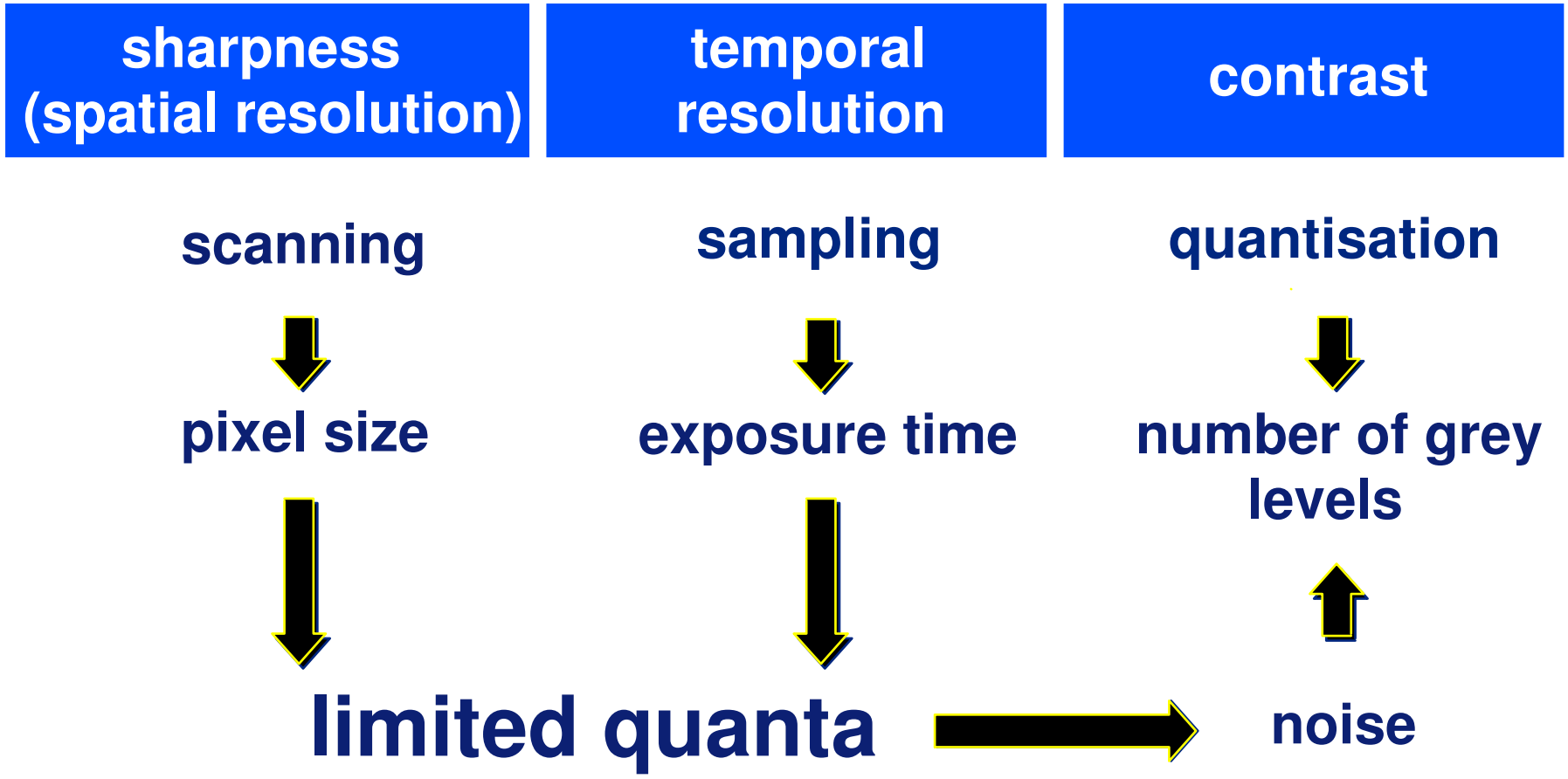


basic example:
Image Matrix 20 x 25 Pixels,
3 bit representing
8 pixel values



Picture Element, pixel
with pixel value 011

Quality of Digital Images



Aims of Digital Imaging

- Instant image
- Standardized + compact storage
- Image Enhancement by Processing
- no loss of images
- the right information
  - at the right place (networking)
  - at the right time
- fast retrieval in large data bases