Div. Ingeniería de Sistemas y Automática

Universidad Miguel Hernández

CAPTURING IMAGES

fachhochschule stralsund

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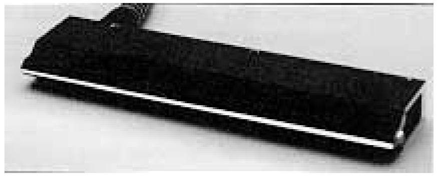
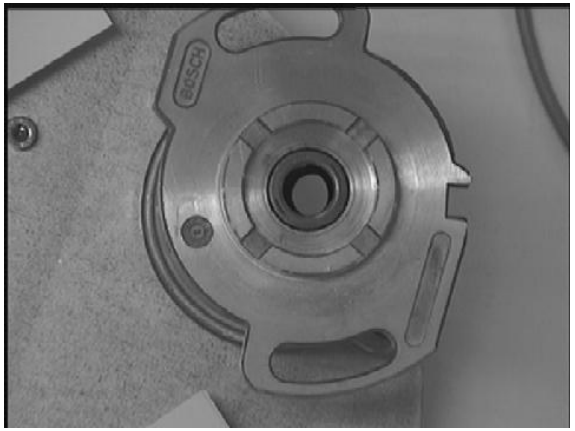
General outline in acquisition

Lights



Reflected light

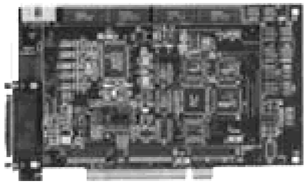


Scene

Camera

Analog Signal

Digitizer
Frame grabber



Computer

2D matrix of gray
levels or color

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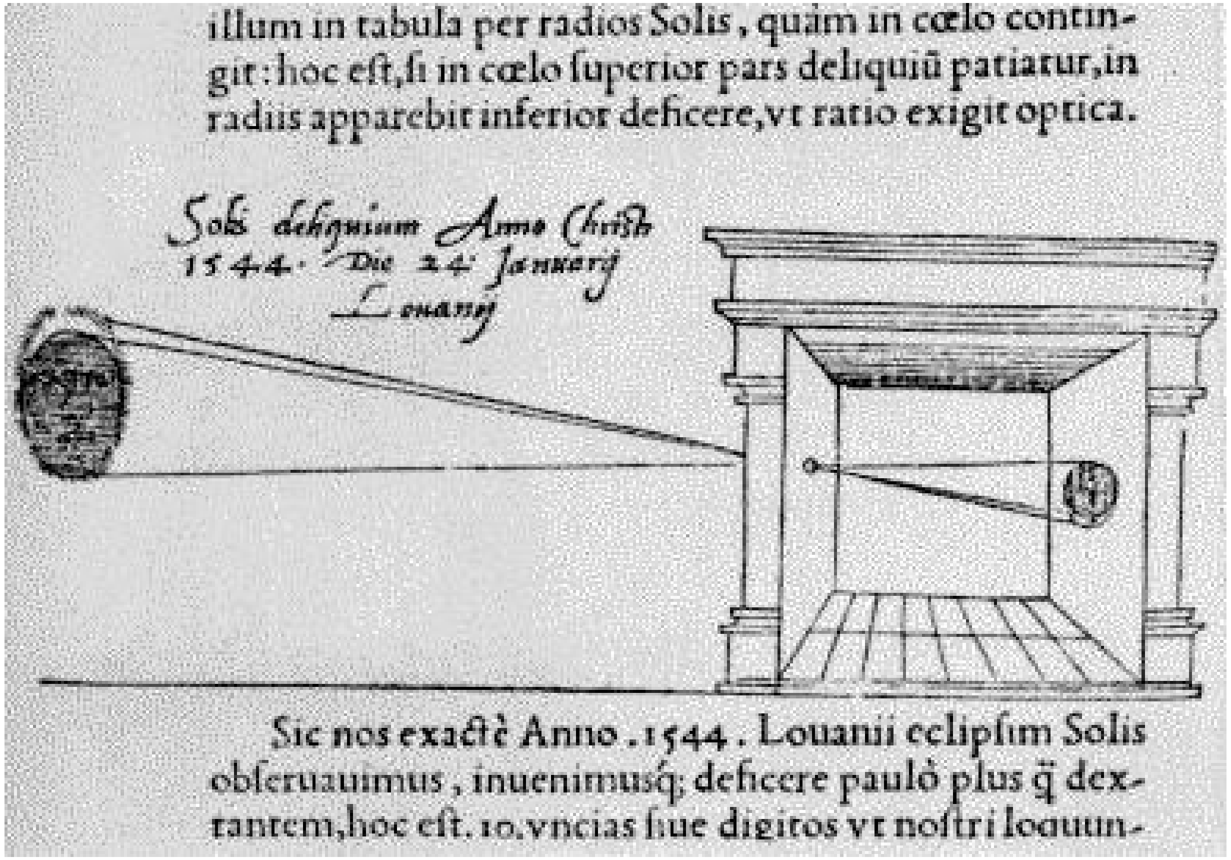
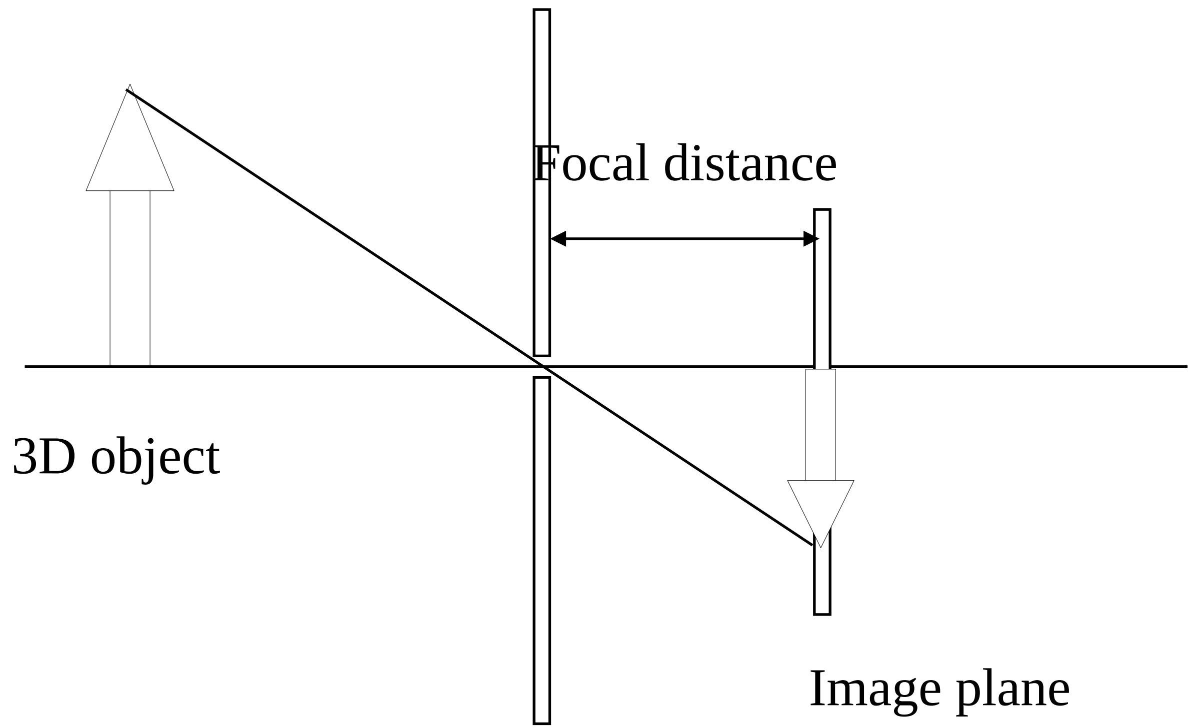
How is the luminical information of the scene projected into the image sensor?

Pin-hole camera

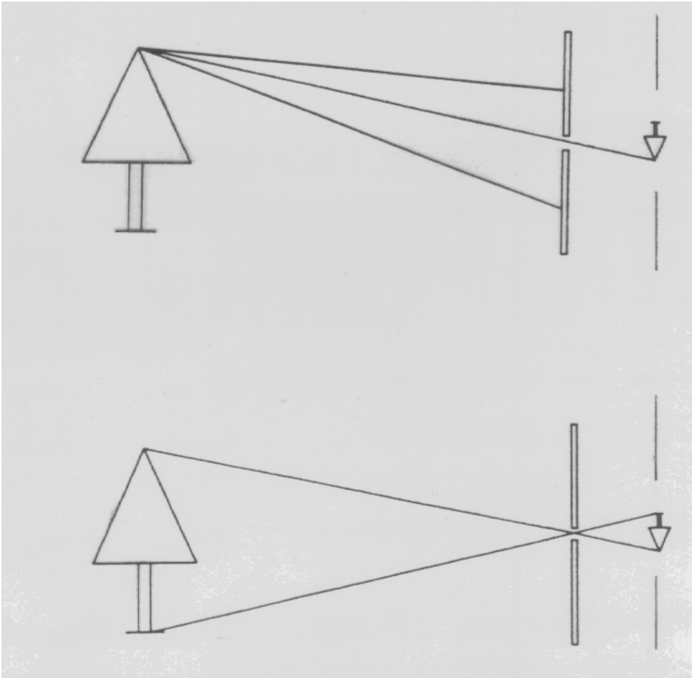
- Leonardo da Vinci (1452-1519) describes image formation using this kind of cameras (camera obscura).
- The camera is basically constituted by a dark room with a tiny hole through the wall.

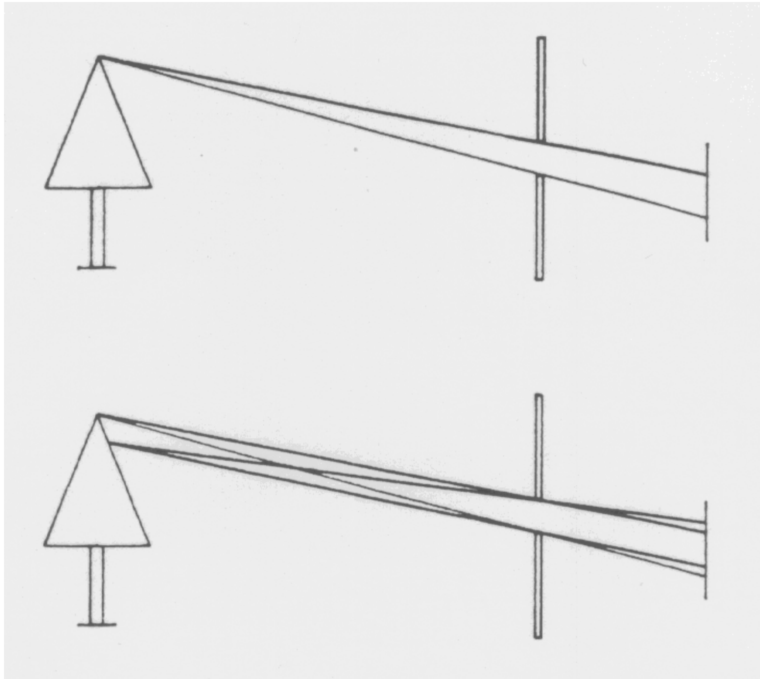


- Pin-hole model



- Ideal Pin-hole vs. Real Pin-hole

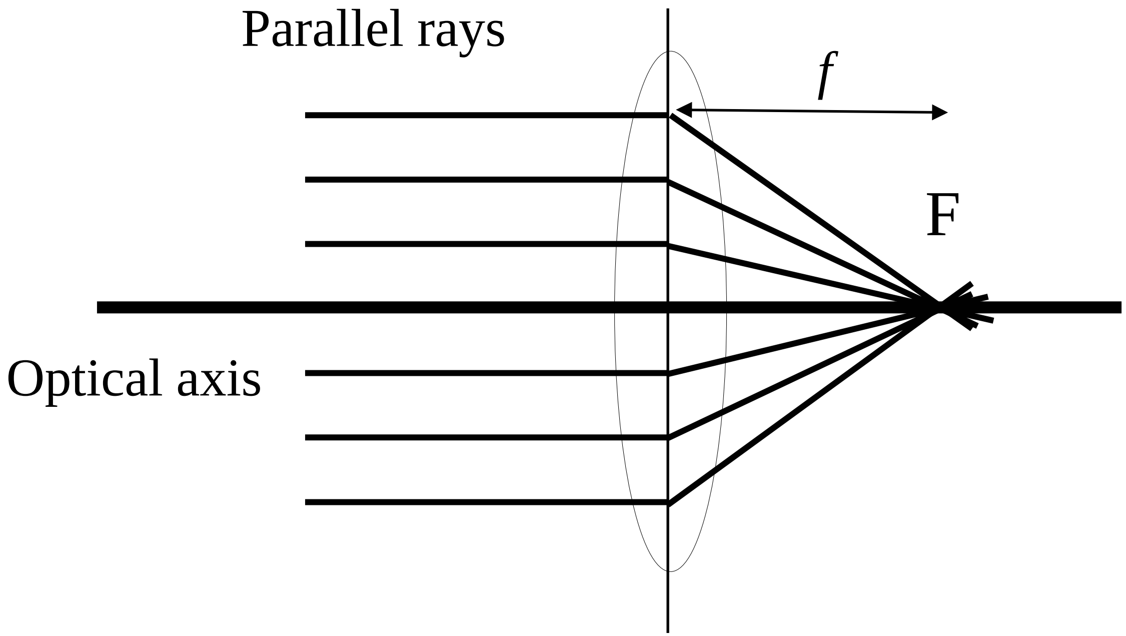




• If we can achieve an ideal differential hole, then each point in space projects to a single point in the image plane.

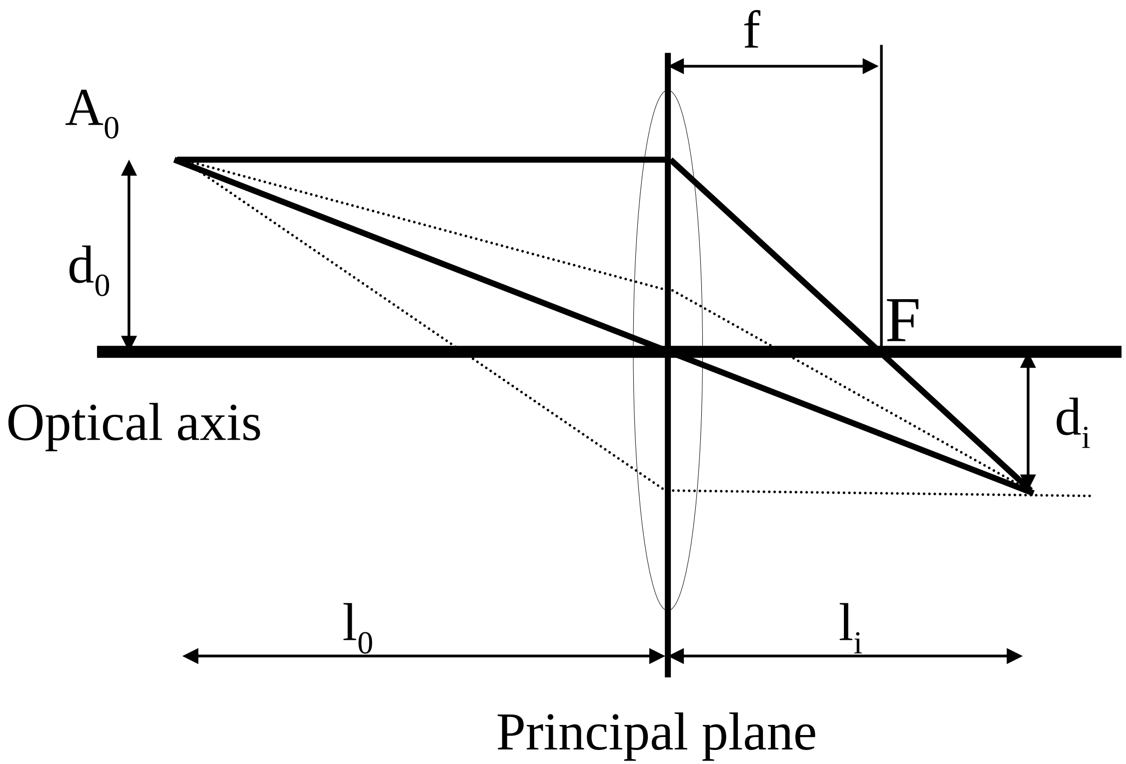
• However, in practice, if the hole is very thin, then no light will be able to stimulate the image sensor. On the other hand, if the hole is bigger, then it will produce blurred images.

- Thin lens model:
  - Rays parallel to the optical axis go through the focal point F on the other side.
  - The distance f is called focal distance.



Optics: Thin lens model

- Image formation



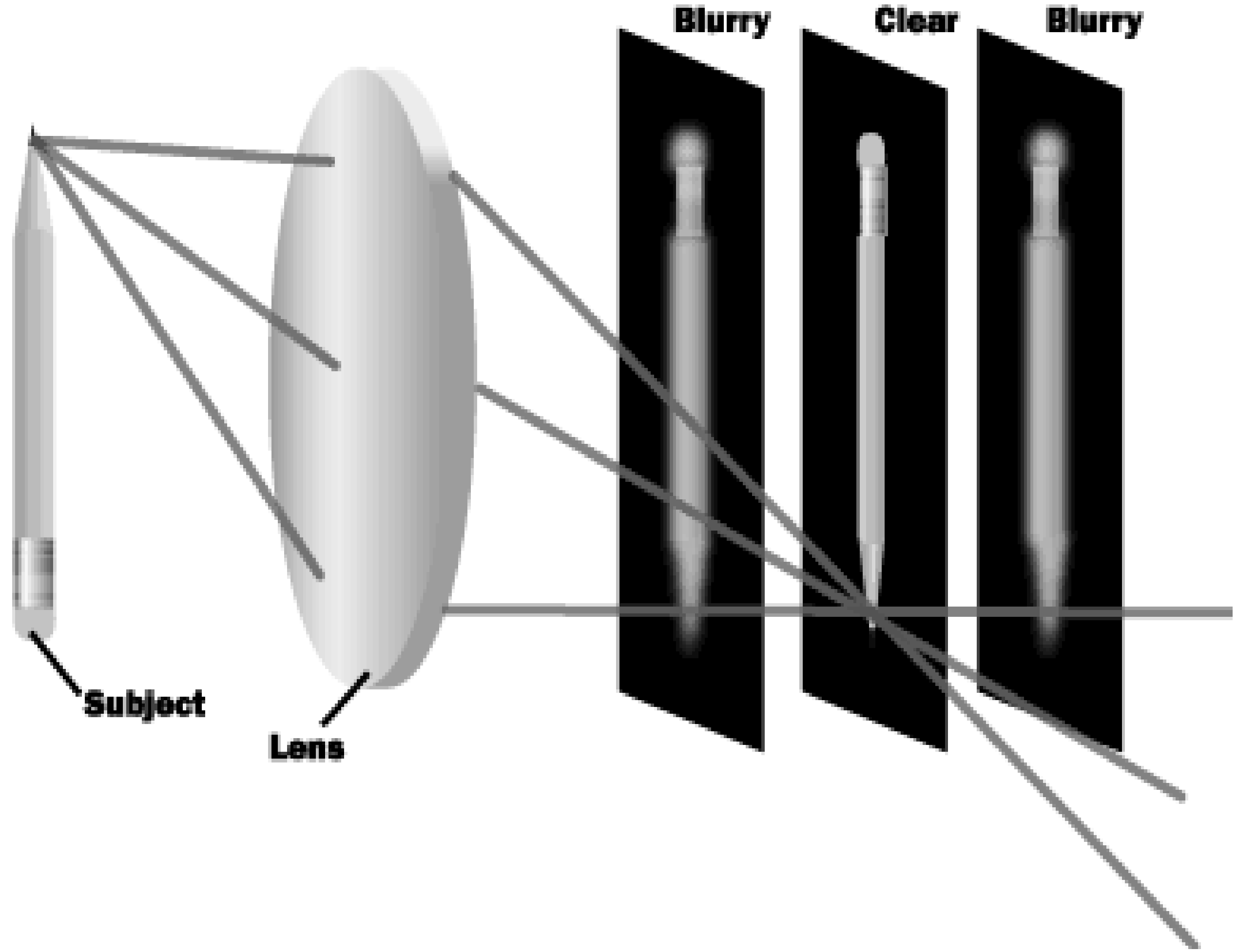
Note: It produces the same projection as in the pin-hole case.

- Fundamental equation of thin lenses
  - From the prior image we can easily prove that:

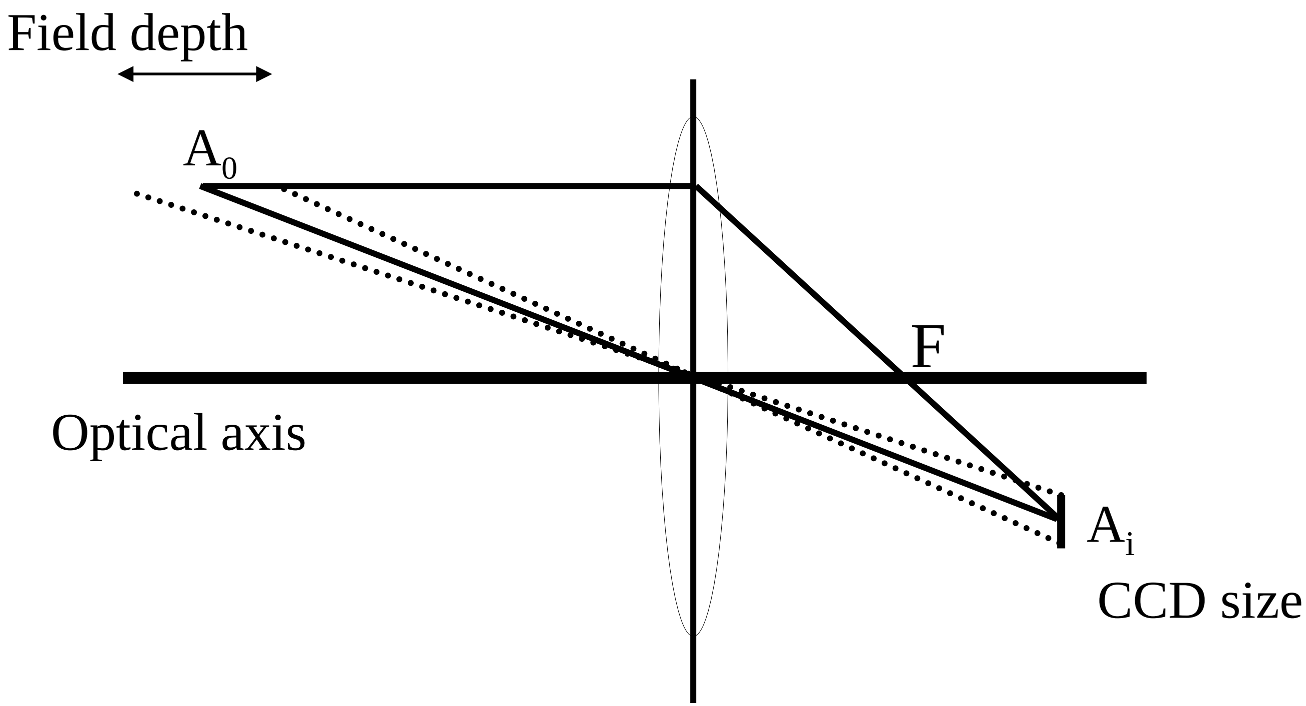
$$\frac{1}{f} = \frac{1}{l_0} + \frac{1}{l_i}$$

  - f depends on the properties of the lens which is being used.
  - l_i is called focusing distance. Can be changed in normal cameras to produce sharp images.
  - If our optics possesses zoom, then f can be varied.

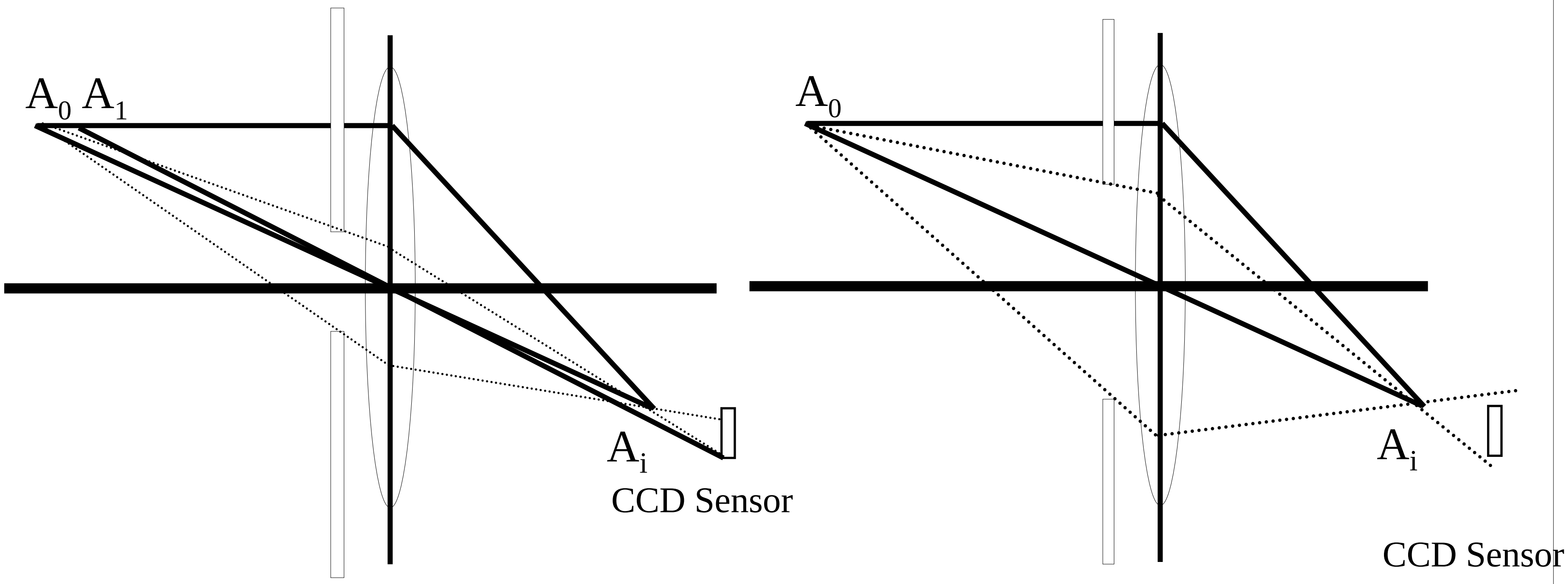
- Effects due to the variation of focusing distance



- Depth of field:
  - Depth of field: It is determined by the area that appears to be focused on the image plane.
  - It depends on: Sensors resolution, iris and focusing distance l_i.



- Iris opening:
  - It controls how much light receives the sensor (CCD, film), so that the image .
  - Depth of field is modified: The bigger the opening, the shorter the depth of field.



Óptica


CANON LENS FD 50mm 1:1.8 S.C.
CANON LENS MADE IN JAPAN
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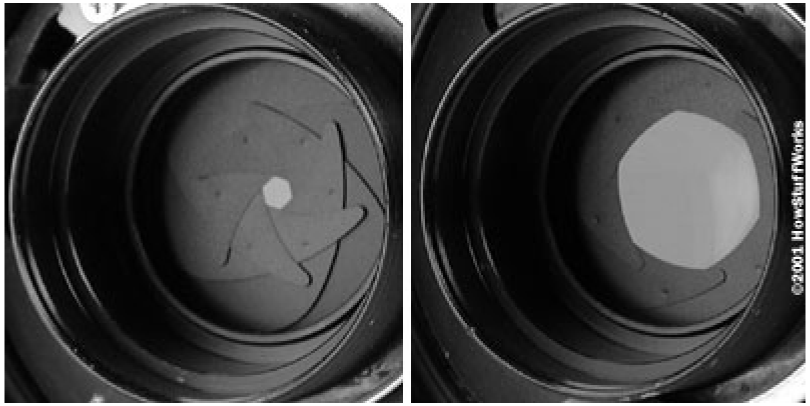
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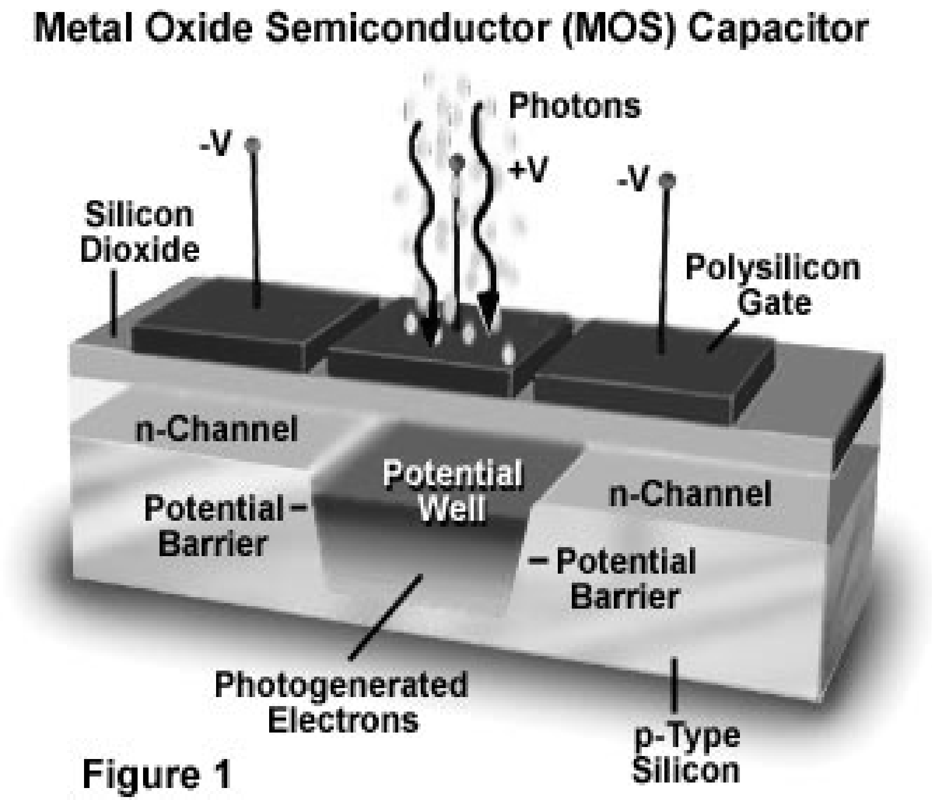
- ✓ Optics
- Sensors
- Image transmission
- Digitizers
- Quantization and sampling

- Camera types
  - Tube cameras (obsolete)
  - Solid state cameras (silicon):
    - CCD Sensors (*Charge Coupled Device*)
    - CMOS Sensors *(Complementary Metal-Oxide Semiconductor)*
    - CCD Color Sensors

CCD/MOS

- MOS capacitor
  - Photosensitive element. Charge acquired depends on the number of photons which reach the element.
  - CCD devices are arrays of this basic element.



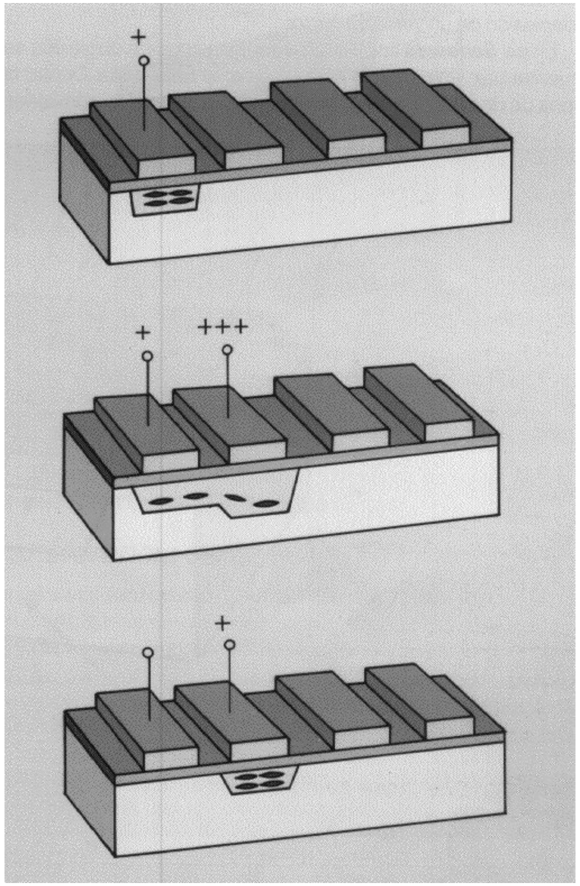
- MOS capacitor
  - Elements:
    - Electrodes (gates).
    - Isolating layer made of silicon oxide.
    - n-type silicon layer.
    - p-type silicon layer.
  - A potential well (potential barrier) is formed by applying a voltage to the MOS capacitor.
  - Photons that incide into silicon generate electrons which are trapped in the potential well.
  - Stored charge is proportional to light intensity and exposure time.

- CCD devices
  - They use photosensitive elements arranged in a matrix.
  - Charge is shifted along the device in order to form an analog signal.
  - Different solutions:
    - Interline transfer CCDs (ILT)
    - Full frame CCDs
    - Frame transfer CCDs

- CMOS devices
  - Each pixel owns the electronic needed to transfer luminical information. Each pixel can be accesed like RAM memory.

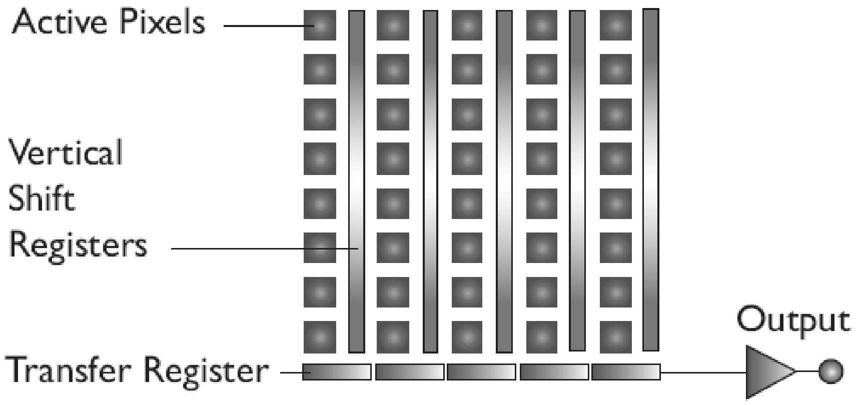
CCD devices

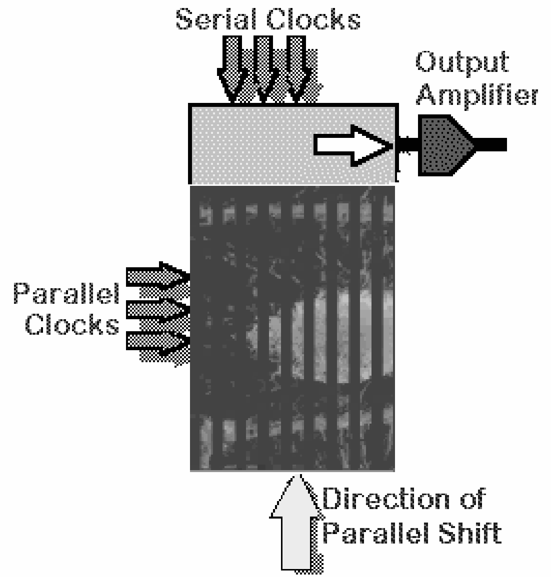
- Charge can be shifted along the sensor by aplying a difference of potential to the gates.
- Finally, a circuit converts charge to voltage.



- Basic concepts:
  - Fill factor:
    - Defines the area in the sensor that is trully sensitive to light. a la luz.
    - Ideally it should be the 100%.
    - Shift registers and others can reduce it up to a 30%.
  - Well capacity:
    - It measures the quantity of charge that can be stored in each pixel. In consequence, it defines its working range.
    - It is in close relation with pixel dimensions.
  - Integration time:
    - It is the exposure time that is required to excite the CCD elements.
    - It depends on the scene brightness.
  - Acquisition time:
    - Time needed to transfer the information gathered by the CCD elements.
    - It depends on the number of pixels in the sensor.

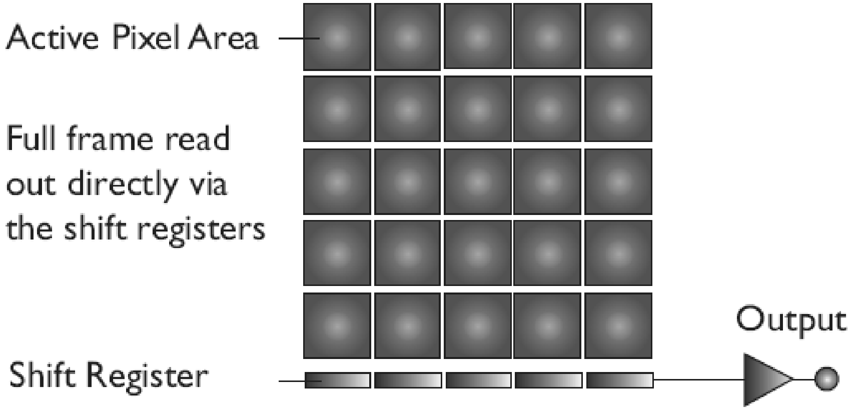
- Interline Transfer CCDs
  - It is the most frequent solution.
  - They use shift registers, which are light shielded between lines of active pixels. Those registers transfer the image data.
  - They are typically very fast: While image data is transmitted, the next image can be acquired.

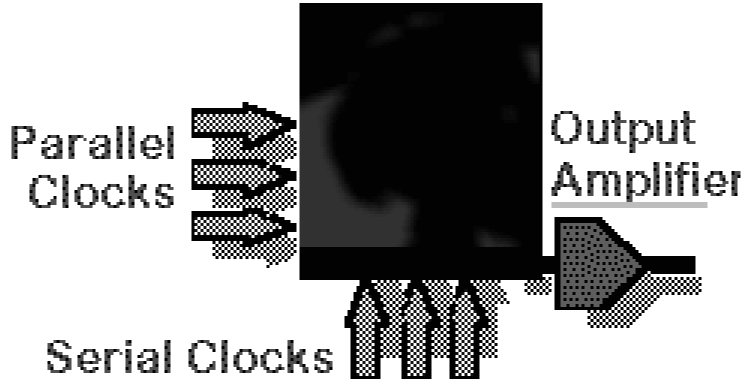




Full Frame CCDs

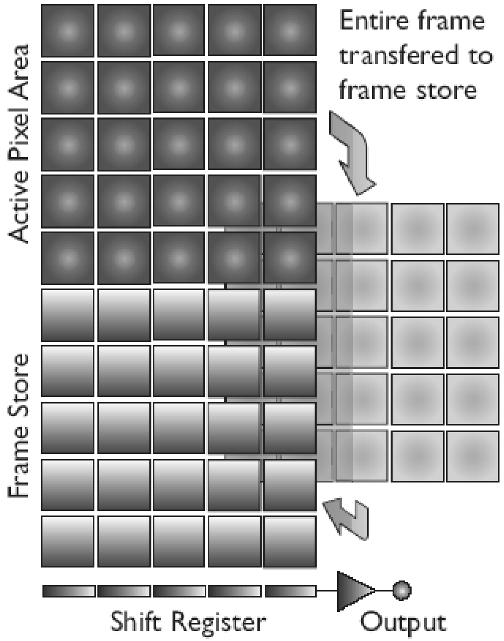
- Full frame CCDs
  - The imaging area is the same as the storage area.
  - This arrangement does not allow for electronic shuttering. In order to work properly, it needs a strobe light or a external shutter.
  - Charge is shifted sequentially along the sensor.
  - Its main advantage is a high pixel fill factor.

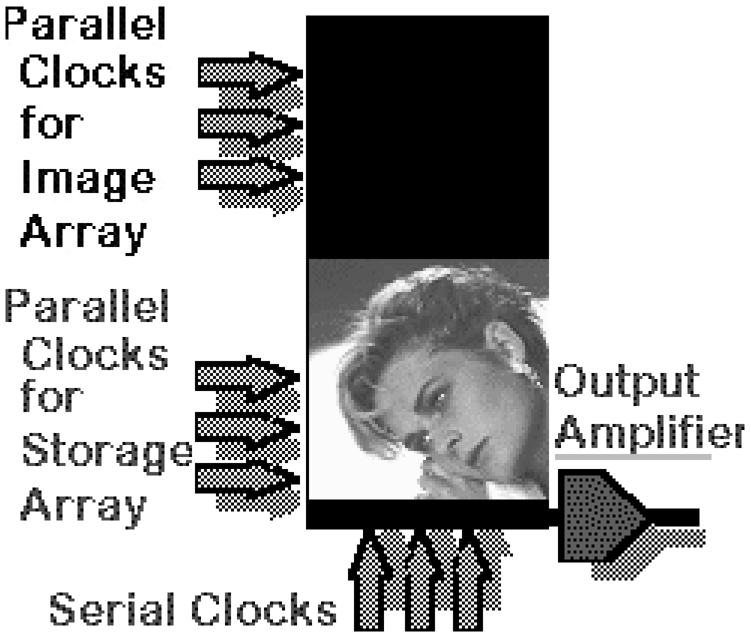




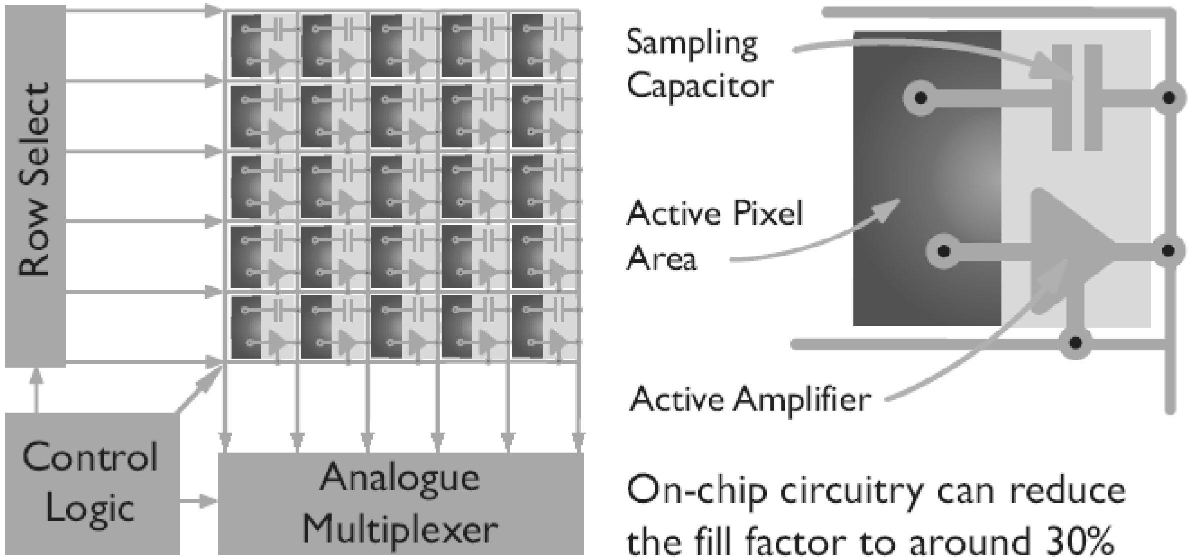
Frame Transfer CCDs

- Frame transfer CCDs
  - Frame transfer have a dedicated storage area which is separated from the active pixel area.
  - Once acquired, image is quickly transfered to the storage memory.
  - There is no need of external shutter.





- CMOS devices
  - Each pixel owns its own electronic for charge-voltage conversion.
  - There is no need for external shutter (electronic shutter).
  - They are by far much faster than CCD devices.

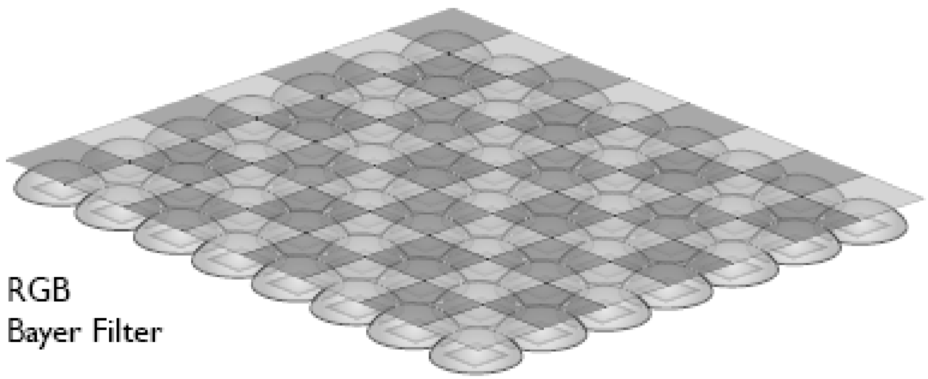


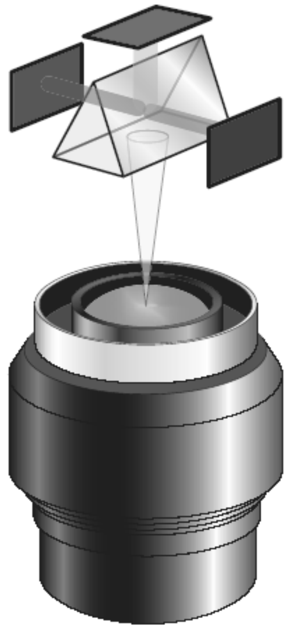
Comparing CCD/CMOS

- CMOS sensors are more sensitive to noise. On the other hand, CCD devices generate typically low noise images.
- Fill factor is typically low in CMOS sensors.
- CMOS devices have little power consumption. In contrast, CCD devices require up to 100 times more power.
- CMOS devices are typically cheaper than CCDs.

Color sensors

- CCD or CMOS sensors respond to monochromatic light. We find two different techniques in order to capture color information:
    - Triple CCD: This scheme uses a beam splitter. Each separated beam is then filtered to obtain three spectral components. Expensive. Used in applications requiring great precision (microscopy).
    - Single CCD and a RGB filter: It uses a tessellated filter. Interpolation is used to find each of the 3 fundamental colors (RGB). Frequently used in consumer cameras.





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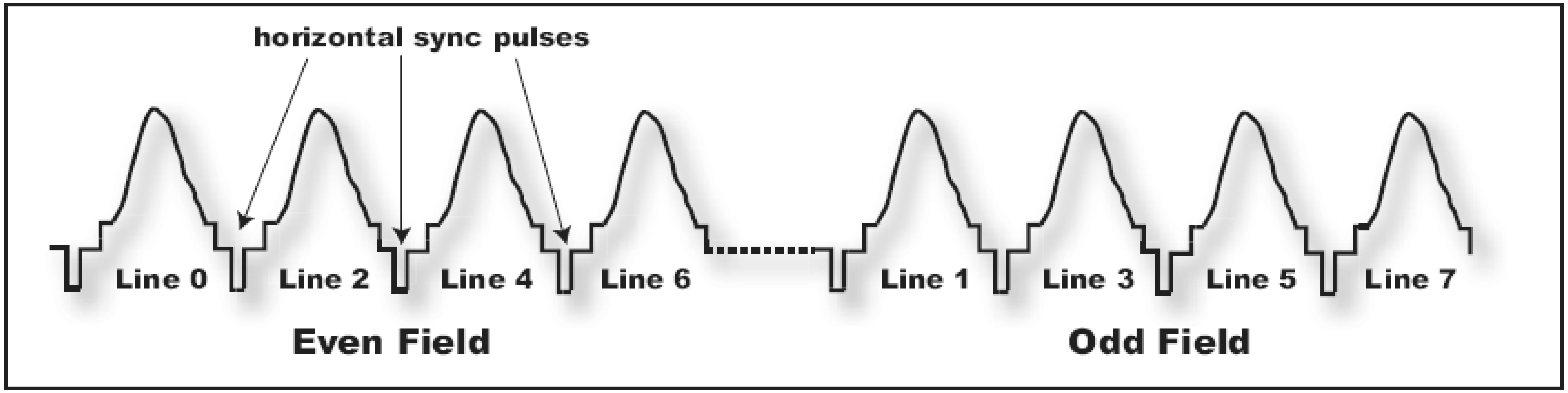
- Video signal is analog
    - The shape of the video signal is conditioned to the early broadcast of commercial TV (limited bandwidth).

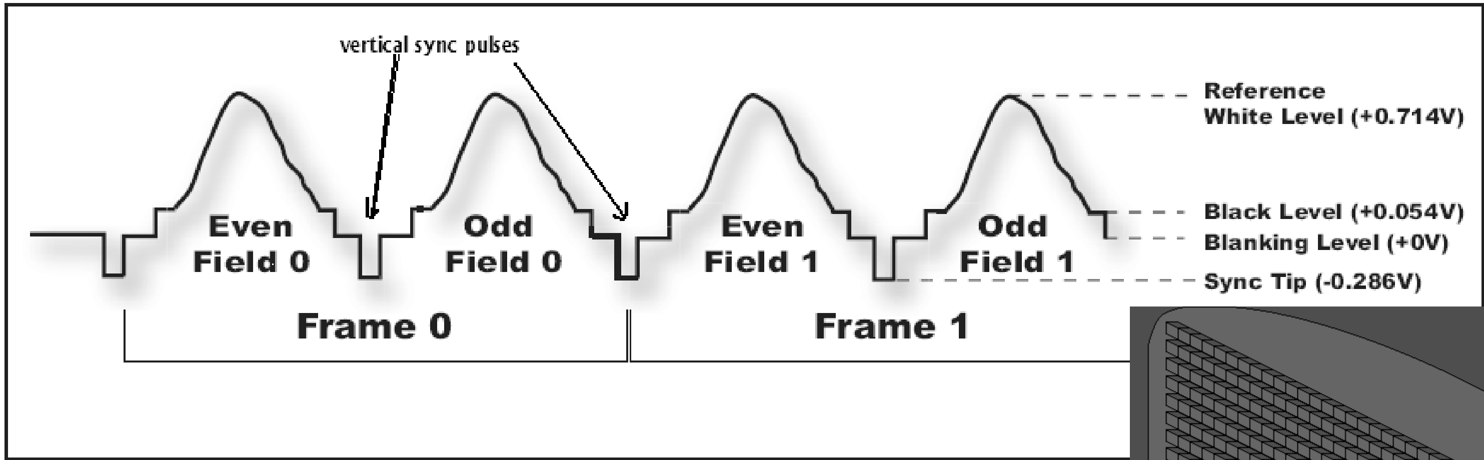
Video standards

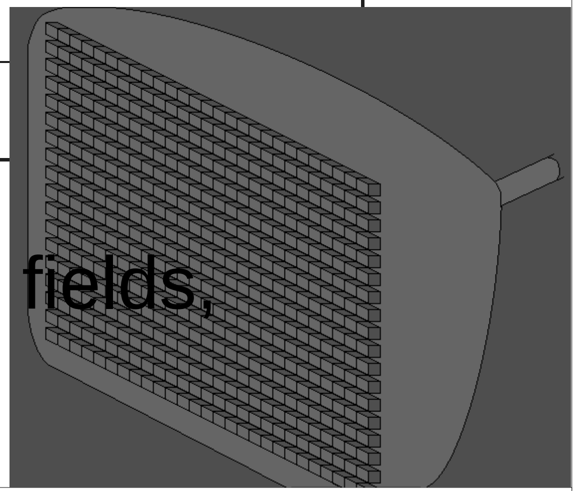
- Monochromatic standards
  - RS-170A, RS-330 and RS-343: EEUU, Canada and Japan.
  - CCIR: Monochromatic standar in Europe.
- Color standards
  - NTSC: EEUU, Canada and Japan.
  - PAL: Europe
  - SECAM: France and old URSS.

Video standards: Example

- RS-170A.
  - Monochromatic
  - Interlaced. First, even lines are transmitted, then odd lines are transmitted.
  - It gathers information of:
    - Brightness
    - Timing
  - 525 lines
  - 30 images/second (*frames*/s), 60 *field*/s
  - Voltage range: -0.286V a +0.714V
  - White→ +0.714V
  - Black→ +0.054V

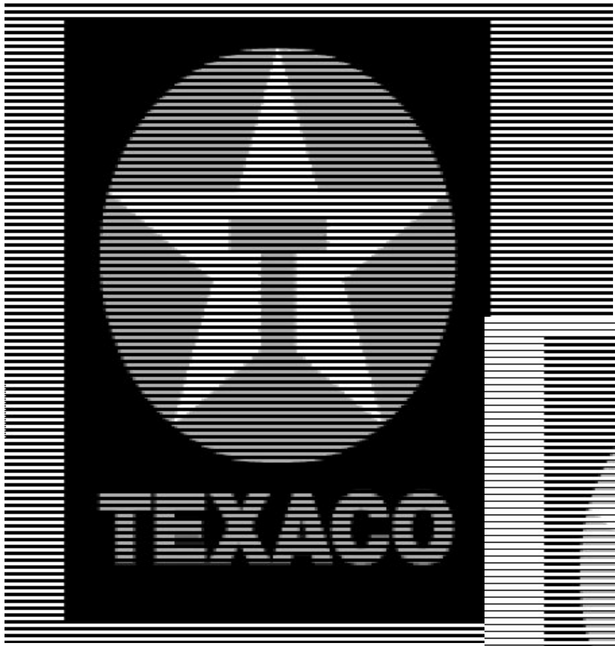






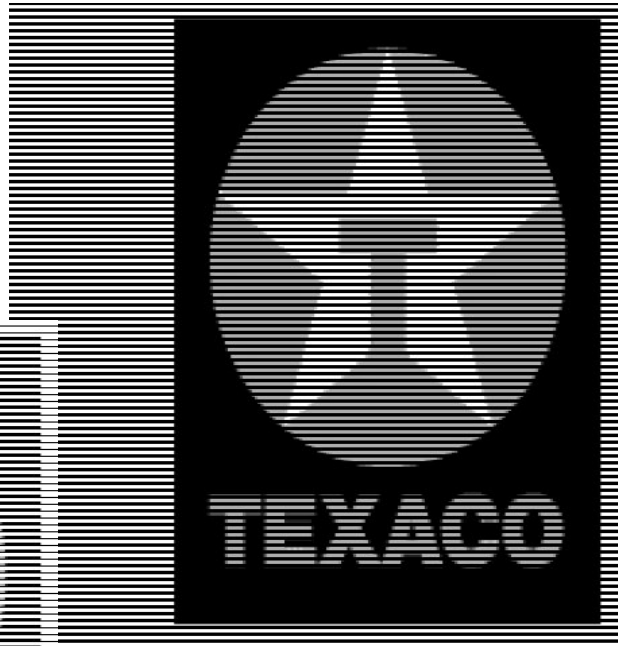
- On TV. Human vision integrates both fields, resulting in a single image.

- Problems with movement



Even field

Complete image
(frame)



Odd field

Digital video signal

- Digital video signal:
  - Transmission is digital. TTL o RS-422 differential.
  - Improves image transmission. No external noise is added.
  - Different standards:
    - Camera Link
    - IEEE1394
    - USB (general data transmission)

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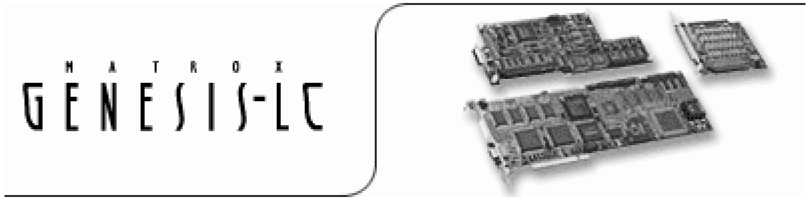
- ✓ Image transmission
- Digitizers
- Quantization and sampling

Digitizers

- Main purpose:
  - To convert the analog signal to a discrete 2D matrix which can be stored in our computer.
- Some:
  - MATROX
  - NATIONAL INSTRUMENTS
  - IMAGING TECHNOLOGY
  - DATACUBE
  - ...



- How to select one?:
  - Are you capturing…?
    - PAL, NTSC….
    - B/W or Color, digital video input
    - # of channels to be captured
  - ISA or PCI bus
  - Processing capabilities on-board
  - Libraries (I.e. MIL: *Matrox Imaging Libraries*)
  - ...

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Quantization and sampling

- Digitizers effectuate basically two processes: Quantization and spatial sampling.
- Quantization defines how many bits are needed to encode each gray level.
- Spatial sampling refers to the number of pixels that form the image.

- Spatial sampling

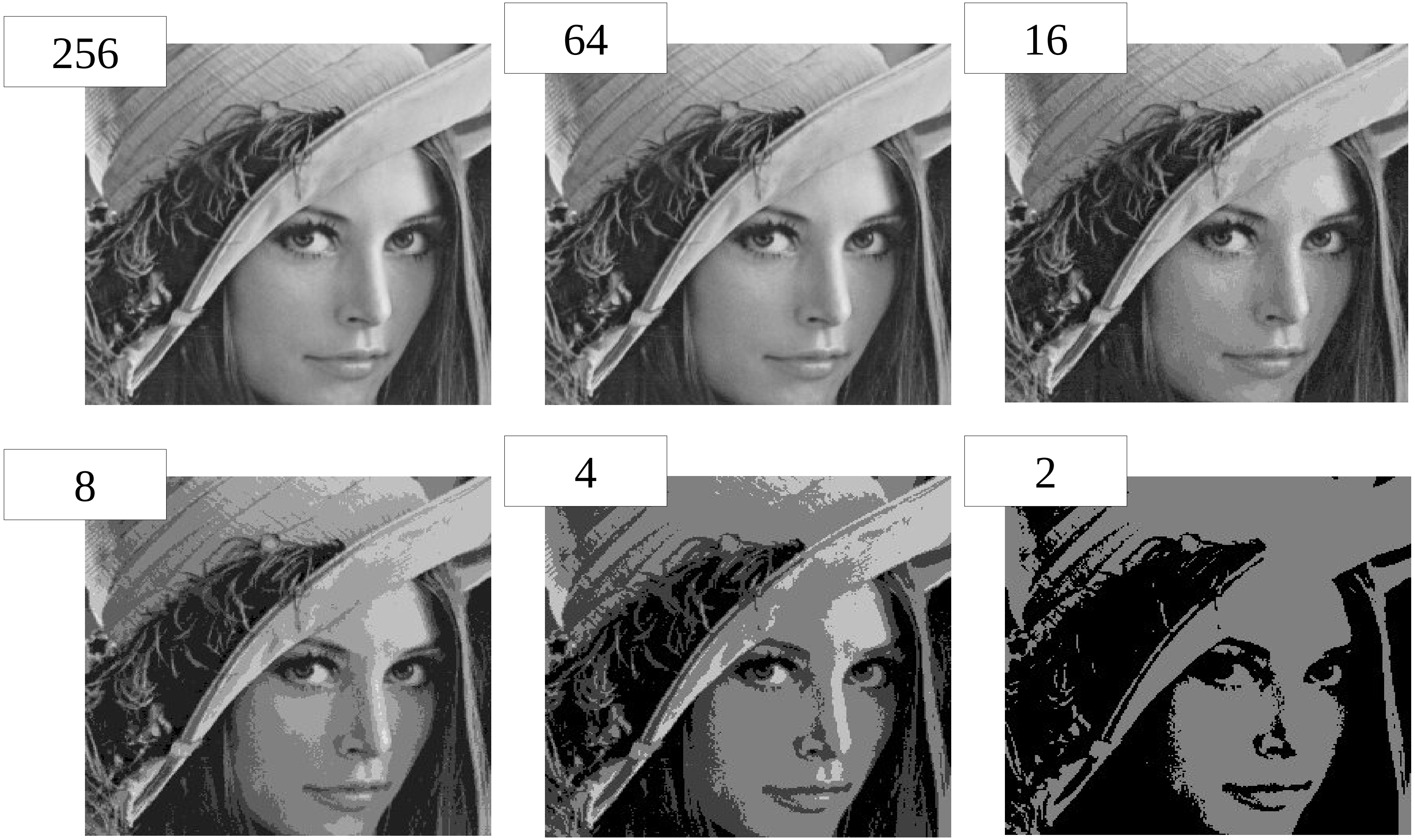

Original


2 points


4 points


8 points

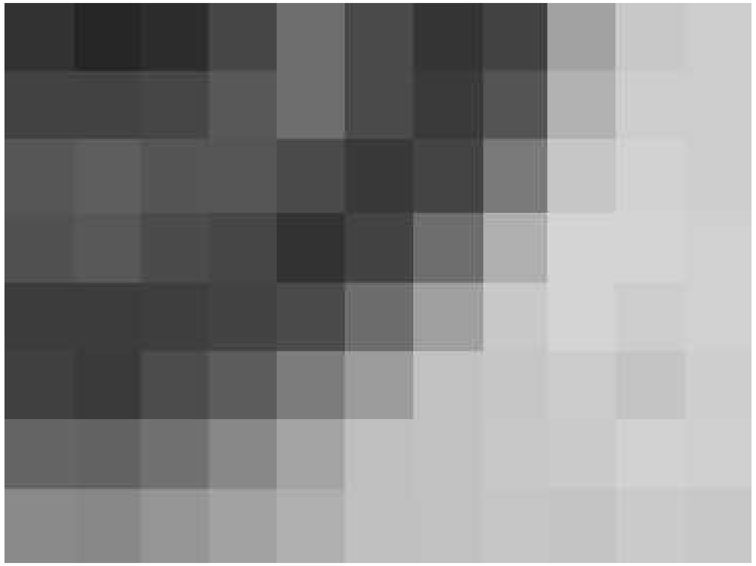
- Quantification (how many bits to encode each pixel)



Sampling and digitizing

- 2D Matrix

Image with 256 gray levels



50	38	44	70	110	74	52	66	162	200	206
66	66	70	88	110	74	58	84	178	206	206
86	94	84	86	74	56	68	122	198	210	206
80	88	74	70	50	66	110	176	212	212	210
60	60	62	66	74	108	160	200	212	206	210
64	58	76	92	124	156	194	198	204	196	206
100	98	112	136	164	192	194	200	202	210	208
138	136	150	162	176	192	194	198	196	202	200