Image Analysis

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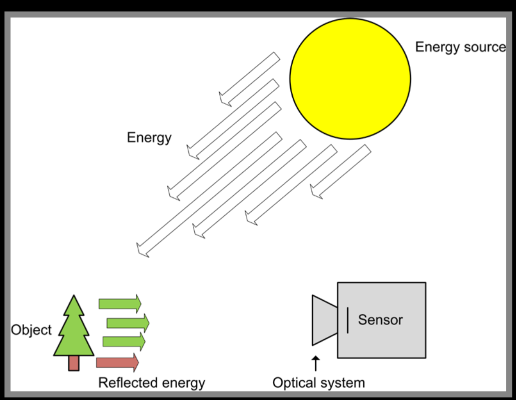
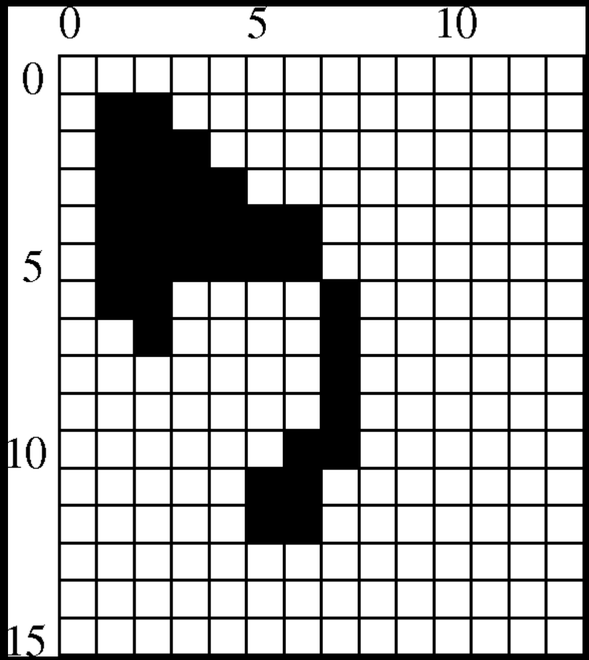
DTU Compute

http://courses.compute.dtu.dk/02502

Lecture 2

- Image acquisition, compression and storage





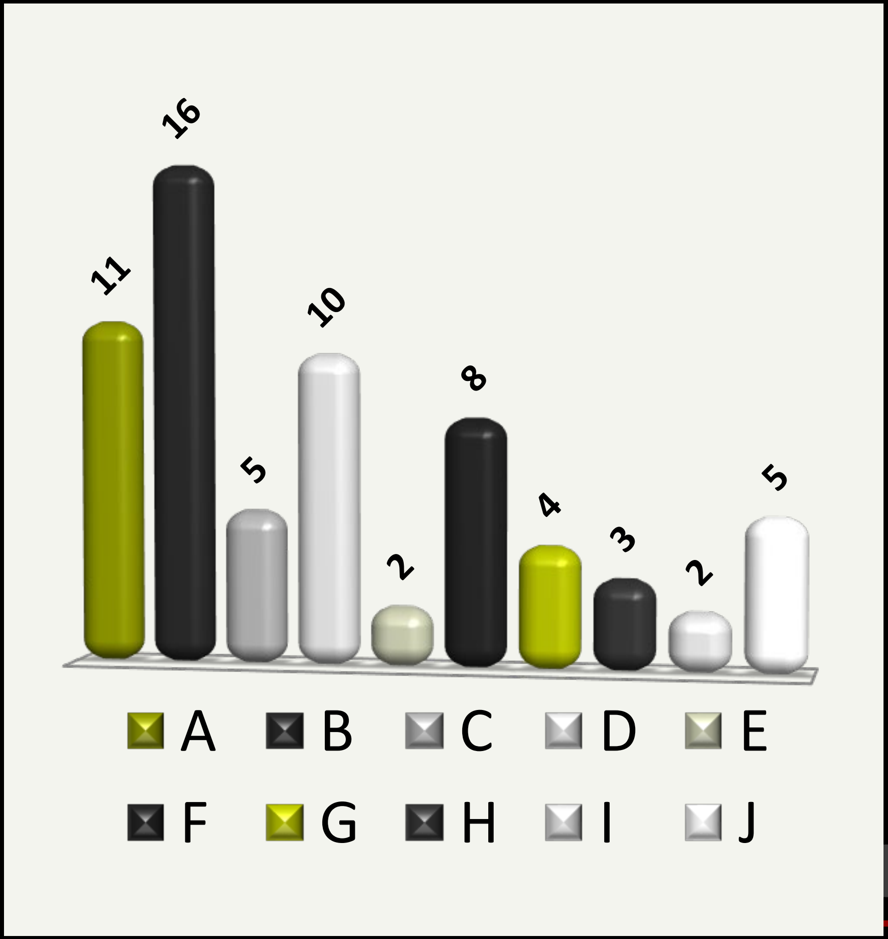
Testing learning objectives!

Last week: Click mix

Today: Clickers

What is your favourite candy

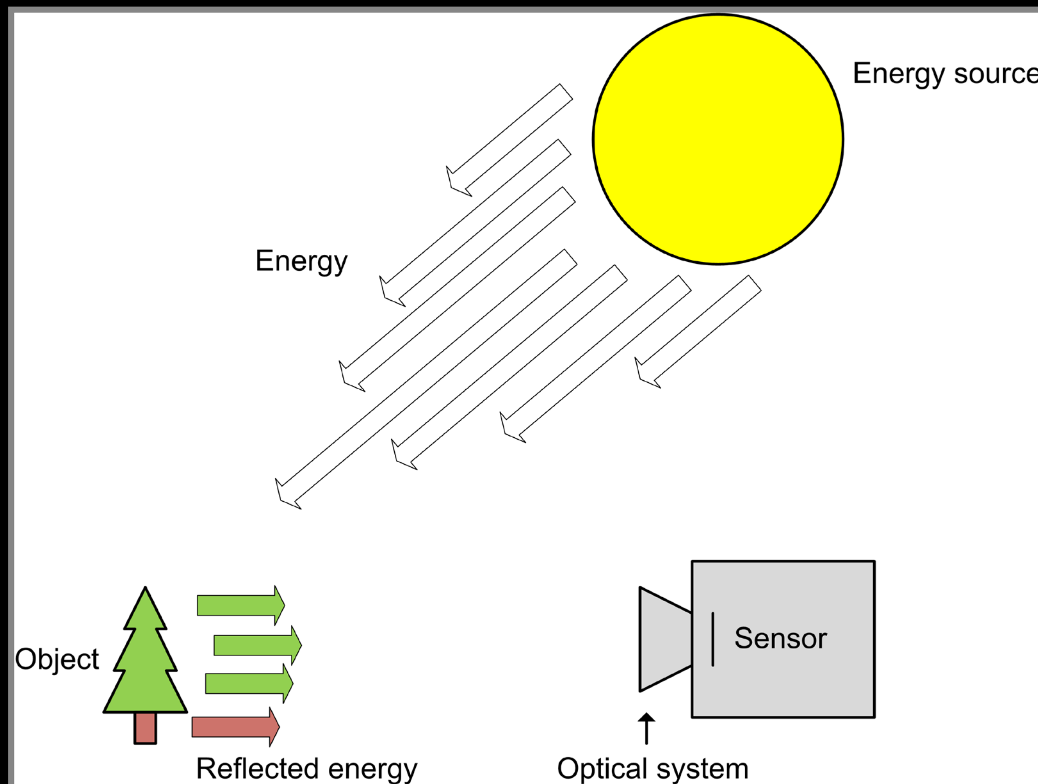
A) Matadormix
B) Click mix
C) Lossepladsen
D) Grandma's secret pills
E) Bridge blanding
F) Carrot and cucumber
G) Piratos
H) Lakrisal
I) Vingummibamser
J) Candy ?



Today – What can you do after today?

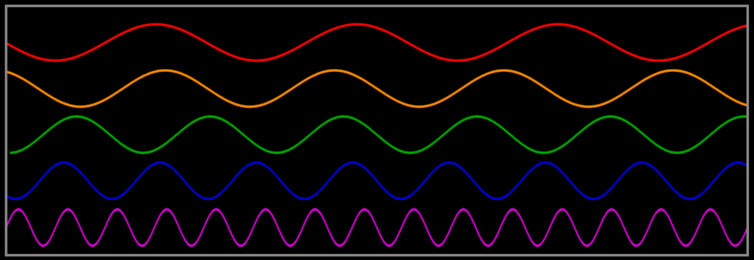
- Explain where visible light is in the electromagnetic spectrum
- Describe the pin hole camera
- Describe the properties of a thin-lens including focal-length, the optical center, and the focal point
- Estimate the focal length of a thin lens
- Compute the optimal placement of a CCD chip using the thin lens equation
- Describe depth-of-field
- Compute the field-of-view of a camera
- Explain the simple CCD model
- Compute the run-length code of a grayscale image
- Compute the chain coding of a binary image
- Compute the run length coding of a binary image
- Compute the compression ratio
- Describe the difference between a lossless and a lossy image format
- Decide if a given image should be stored using a lossless or a lossy image format

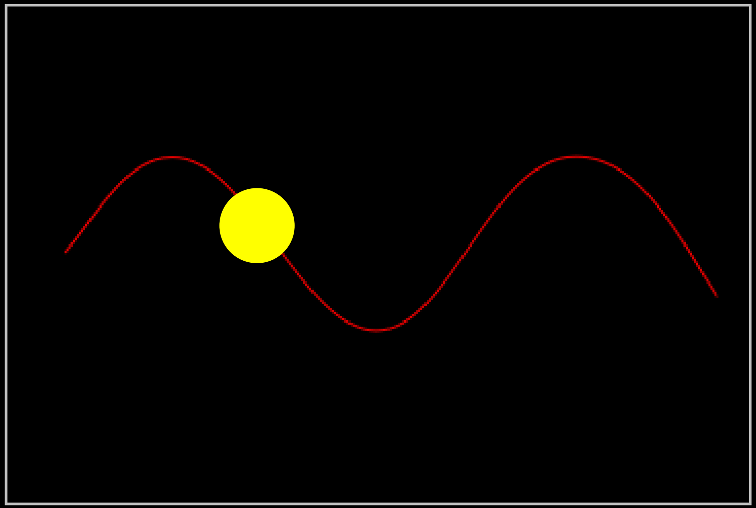
How is an image created?



This is just one way! Other methods will be described later in the course.

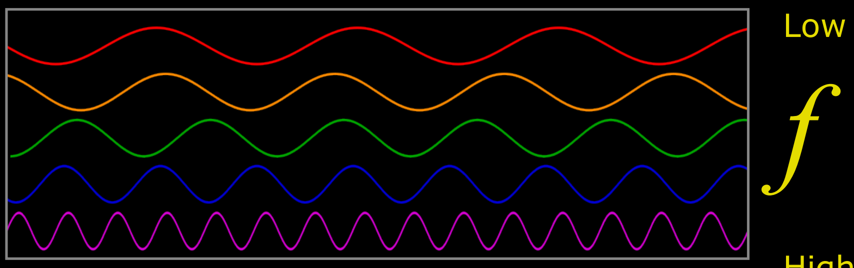
What is light?



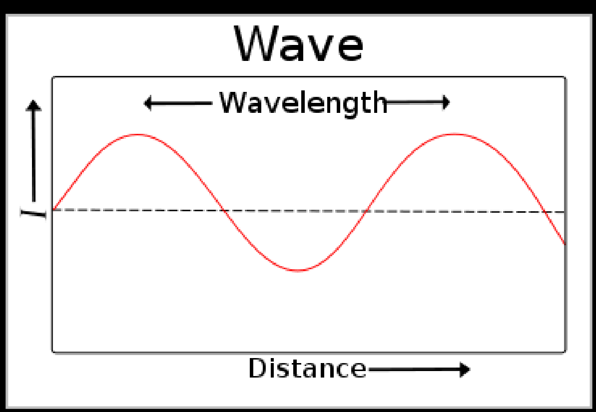


- Can be seen as electromagnetic waves
- Or as a photon
  - Mass less fundamental particle

Light as a wave



$$\lambda = \frac{c}{f}$$



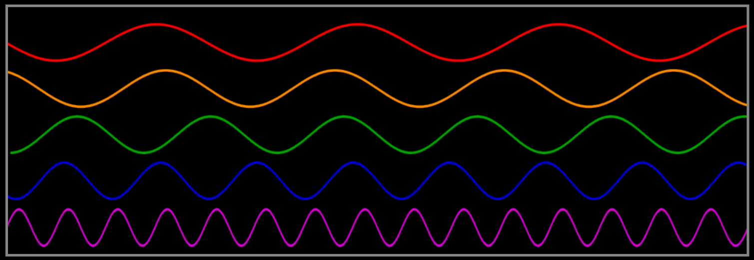
- It has a frequency f
  - Measured in Hertz [Hz]
- It has a wavelength λ (lambda)
  - Measured in meters [m]
- It has a speed
  - “The speed of light” c

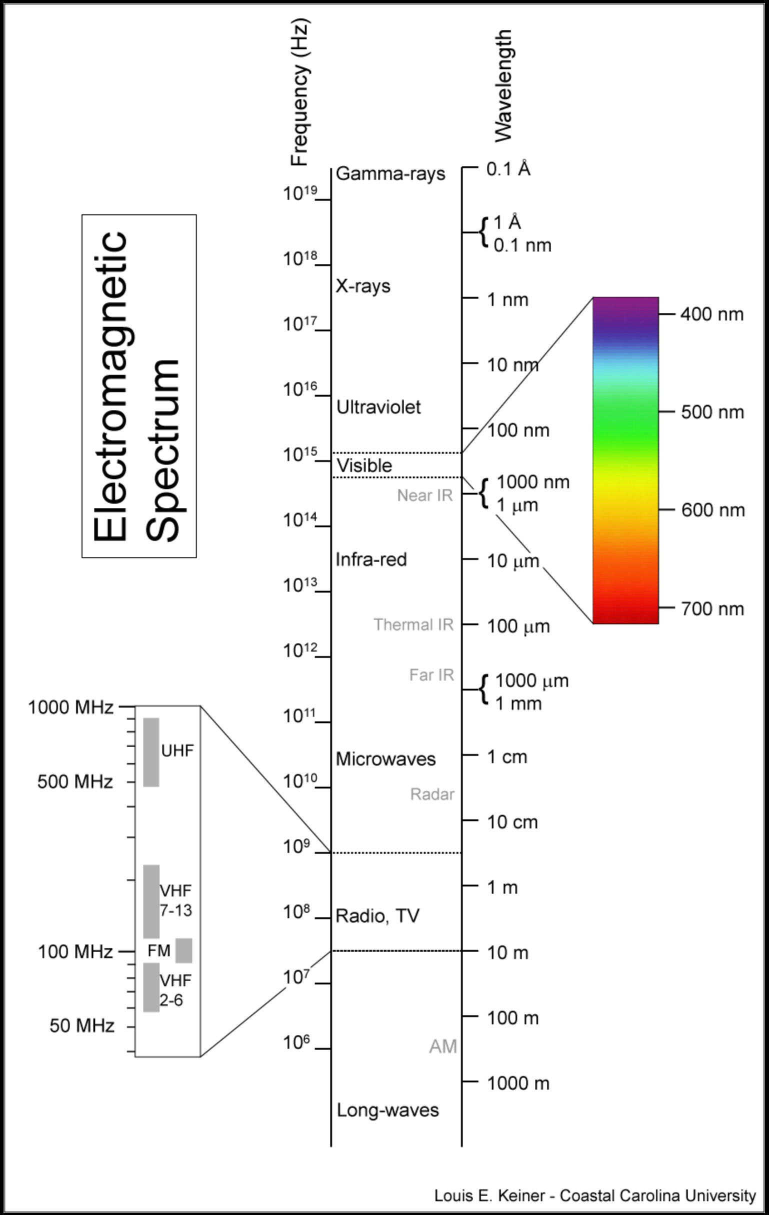
- High frequency -> short waves
- Low frequency -> long waves

Energy of light

$$E = h \cdot f$$

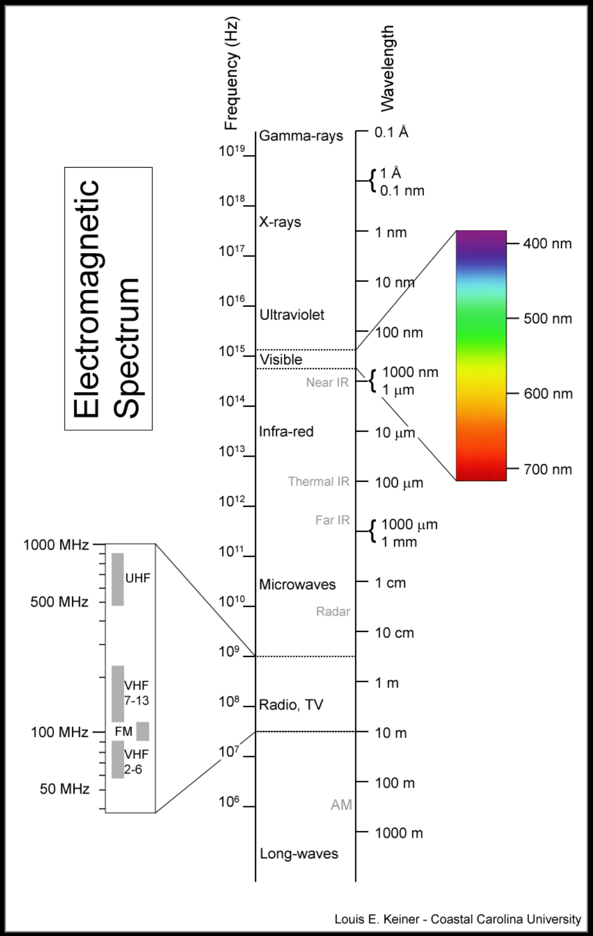
- Light has energy
  - You can feel it in the sun!
- Planck's constant h
- High frequency -> high energy
- Long waves -> low energy



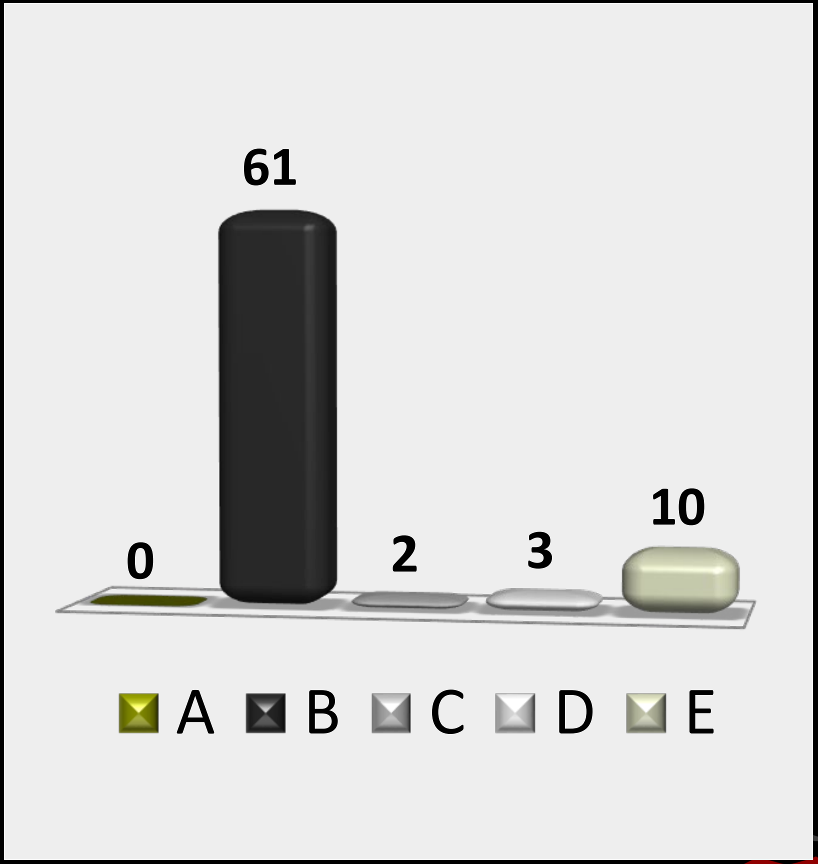


- Electromagnetic spectrum
  - Range of all frequencies
- Wavelengths
  - 1 μm = 1 micrometer = 0.001 mm
  - 1 nm = 1 nanometer = 0.0000001mm

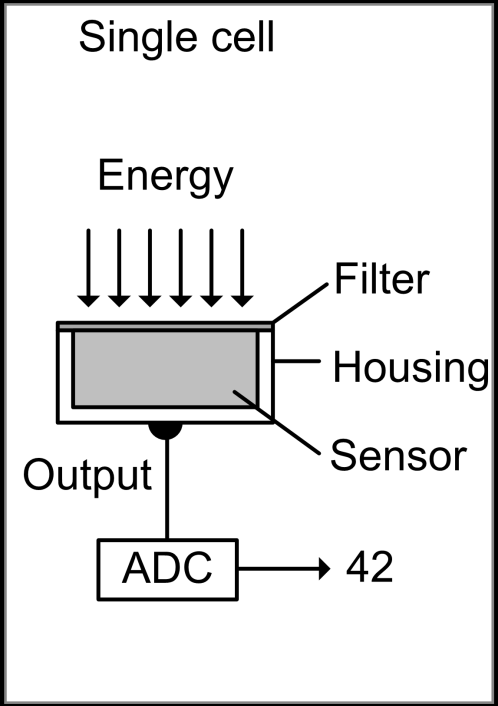
What has the most energy?

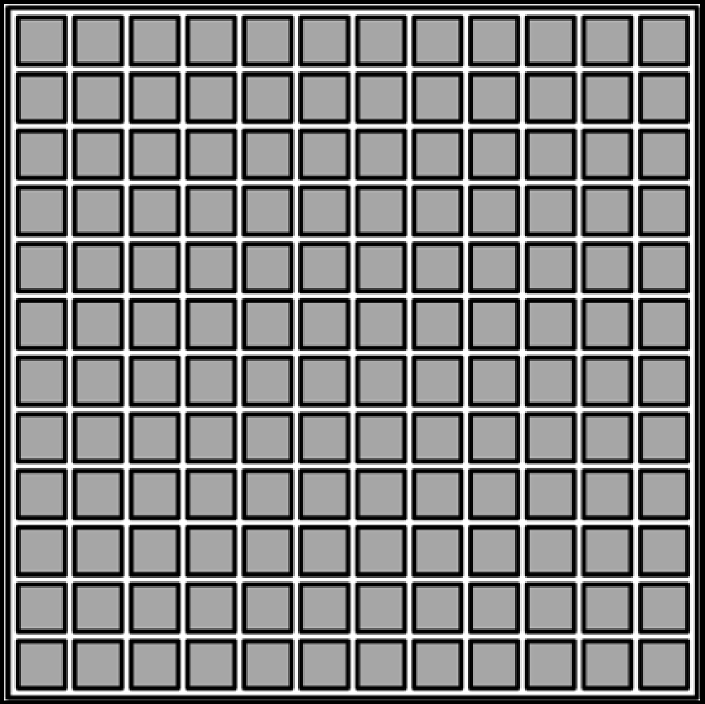


A) Radio
B) X-rays
C) Red light
D) Microwave
E) Ultraviolet



How do light become a digital image?



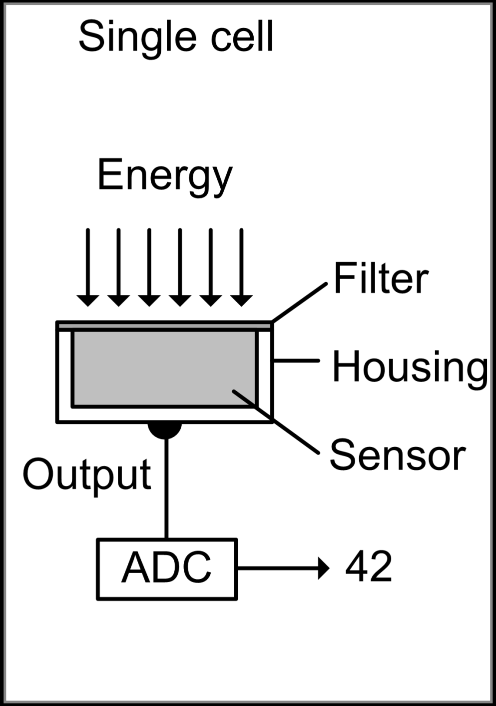


Charged coupled device

(CCD-chip)

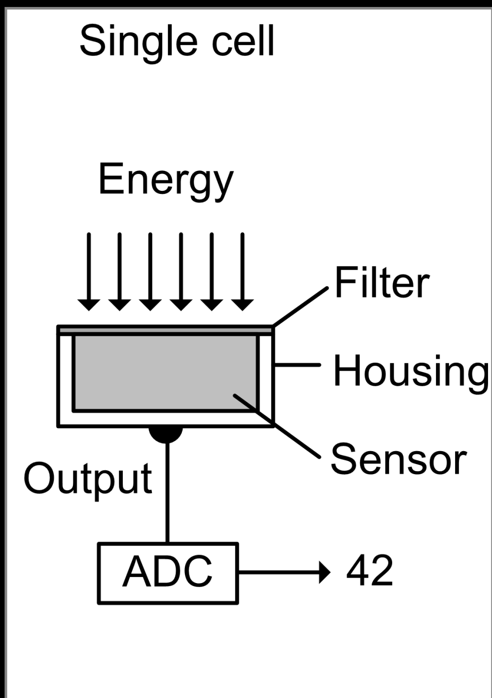
The digital film!

The CCD cell



- The cell can be seen as a well that collects energy
- It collect energy for a limited time
  - Exposure time
  - Integration time
  - Shutter

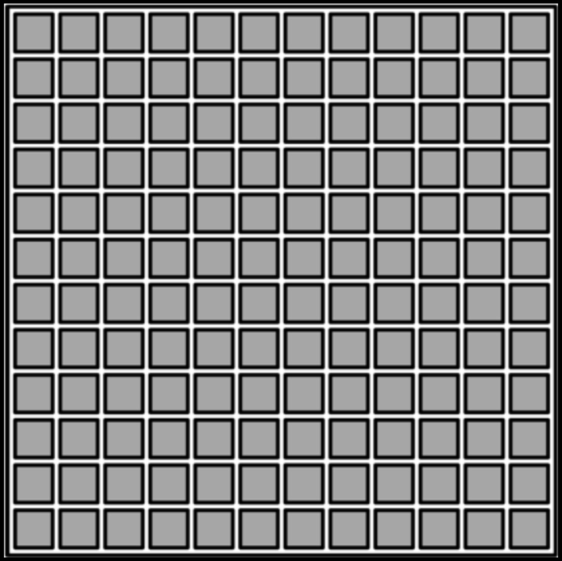
The CCD cell - conversion



- Energy transformed to a digital number
  - Analog-to-Digital converter (ADC)
- Takes a an “analog signal” and converts it to a digital signal

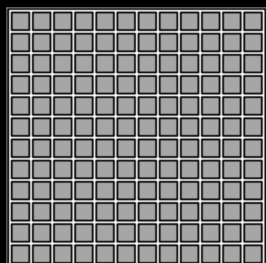
CCD and images

- Surprise! 1 CCD cell = 1 pixel
  - Only for grayscale images
  - More complex for RGB images
- 10 MPixel camera
  - 10 millions analog to digital conversions for one image!



What is the size of a single CCD cell?

5.3 mm



7.2 mm

2048 x 1536 pixels

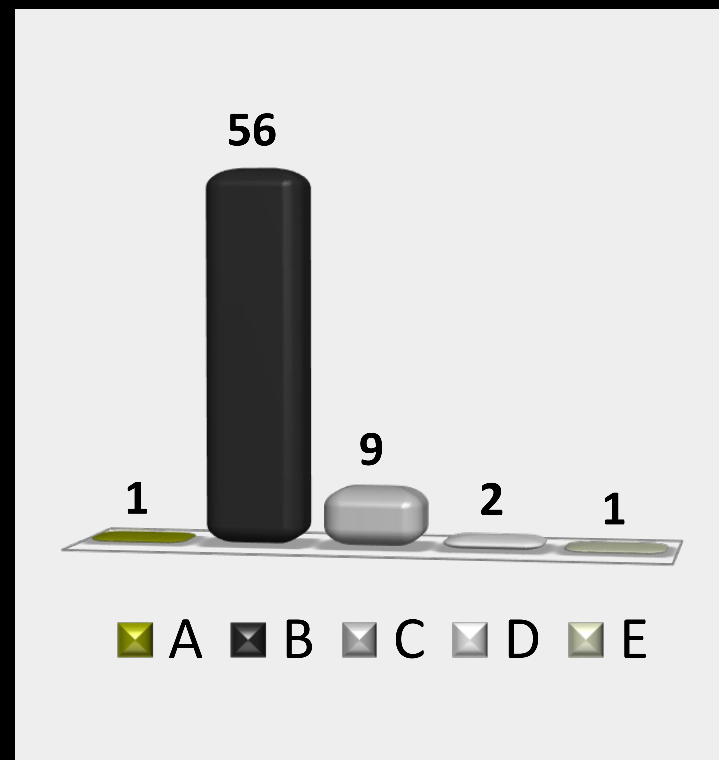
A) 1 x 1 milimeter

B) 3.5 x 3.5 micrometer

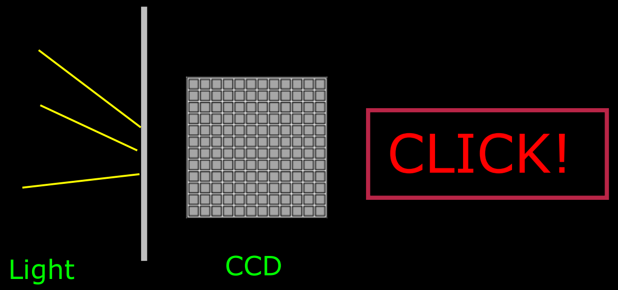
C) 0.002 x 0.002 milimeter

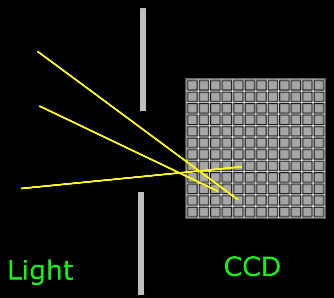
D) 5.6 x 5.6 micrometer

E) 0.4 x 0.4 milimeter

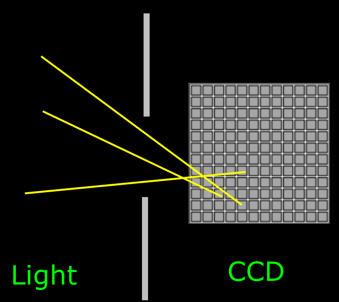


What happens when you press the button?

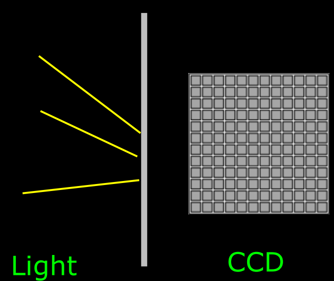




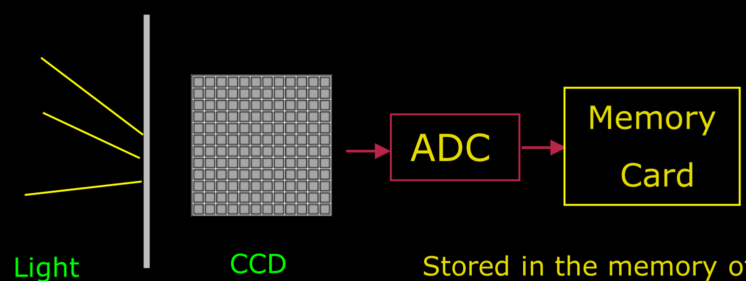
The shutter opens and the CCD is hit by light



CCD is integrating



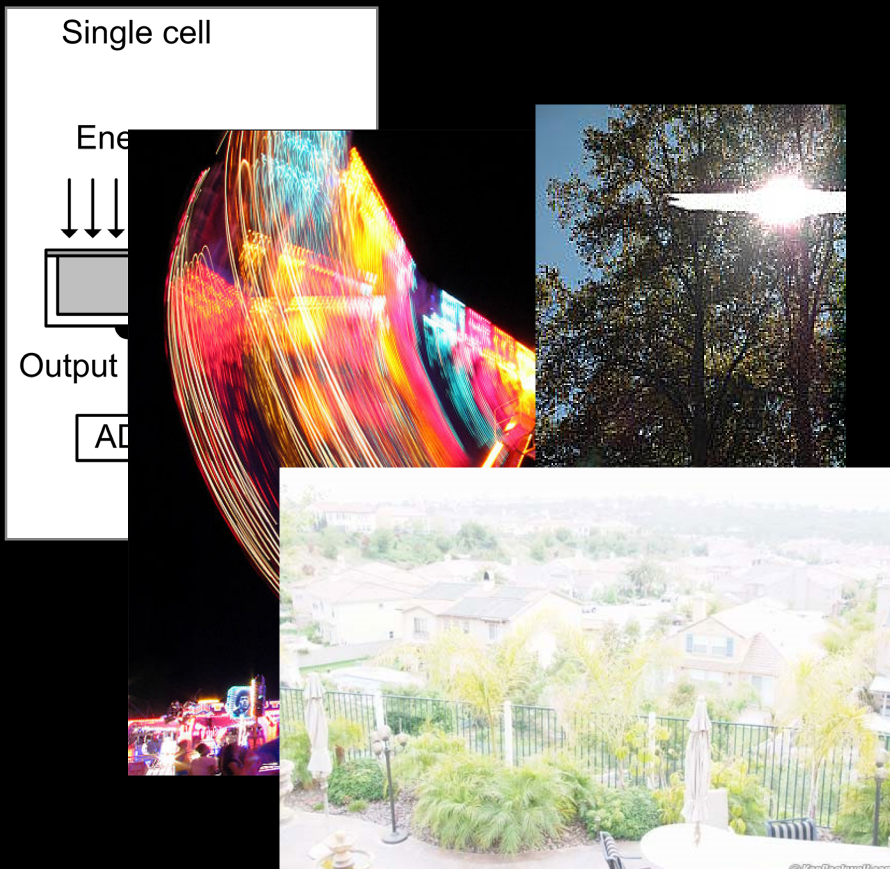
Shutter closes



The collected energies are transferred and converted to digital values

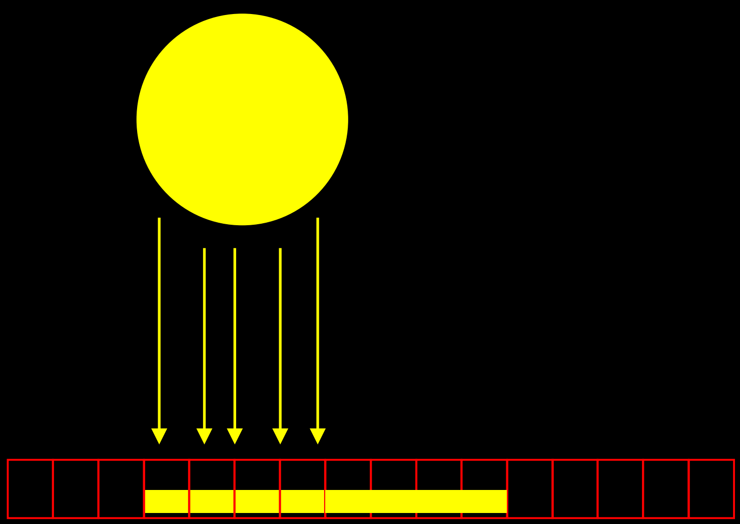
Stored in the memory of the camera

Question: Integration time



- What happens if we integrate over long time?
  - Motion blur
  - Over-exposure (the well is overrunning)
  - Blooming
- Short integration time
  - Noise
  - Lack of contrast

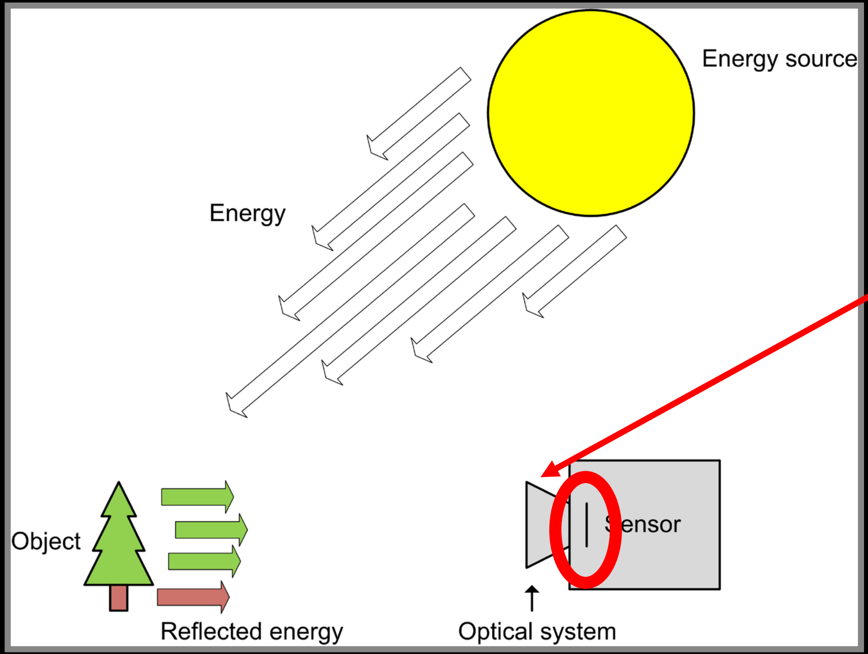
Motion blur



- Causes blurring of the moving object

The bigger picture

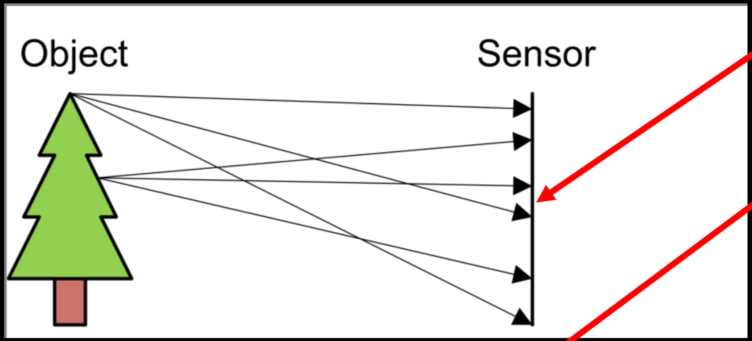
- A camera is more than a CCD!
- The CCD is the sensor!
- There is also “an optical system”



Optical system
(lenses)

Optical system

- How do we get an image on the CCD?
- Light follows a straight line
- Light that hit one spot reflects in many directions

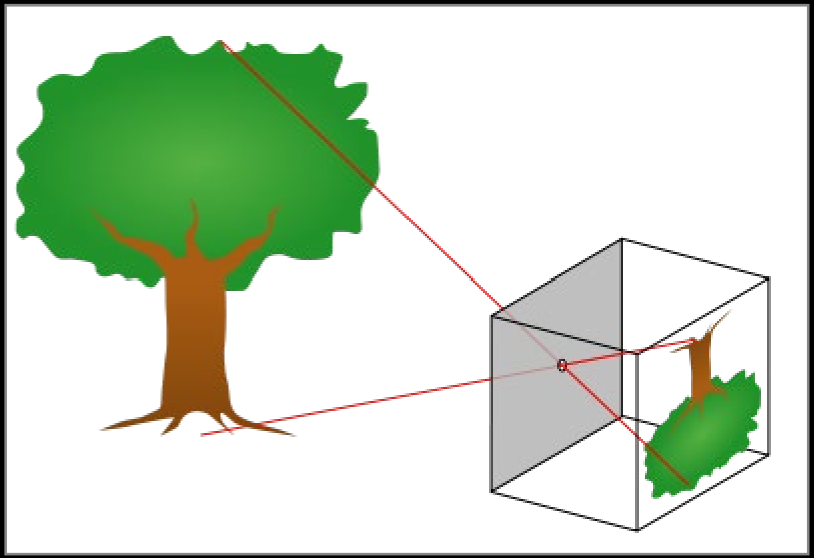


Same point hit by rays from all over the object

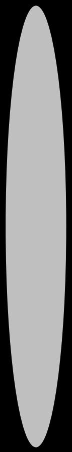
Barrier with tiny hole

nera

Pinhole camera



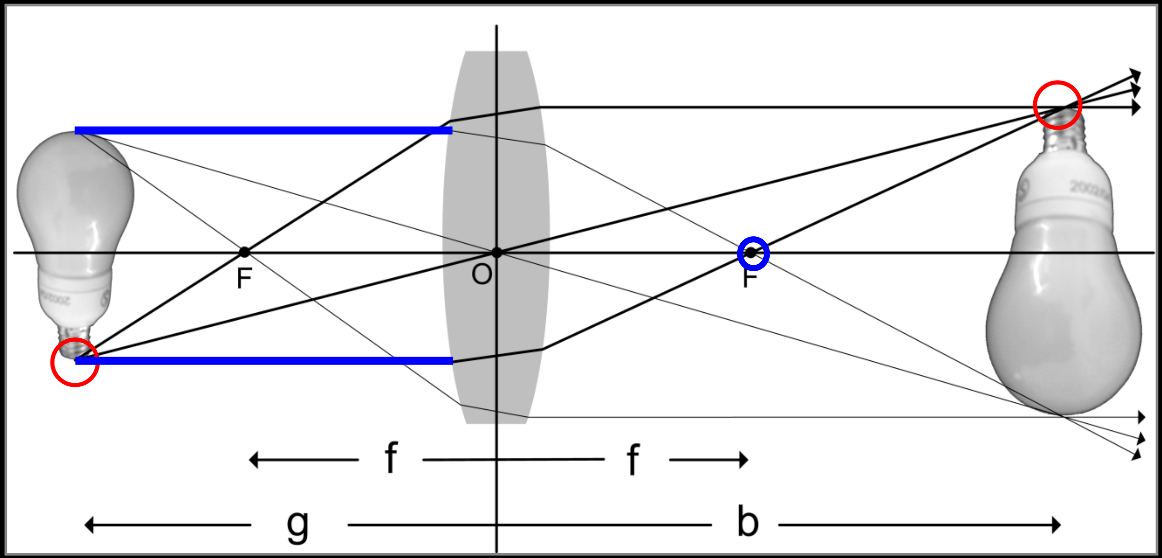
- Light coming through the tiny hole – any problems?
  - Very little light!
- How do we get more light inside the camera?
  - While keeping the focus?



A 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 centre. F and O span the optical axis

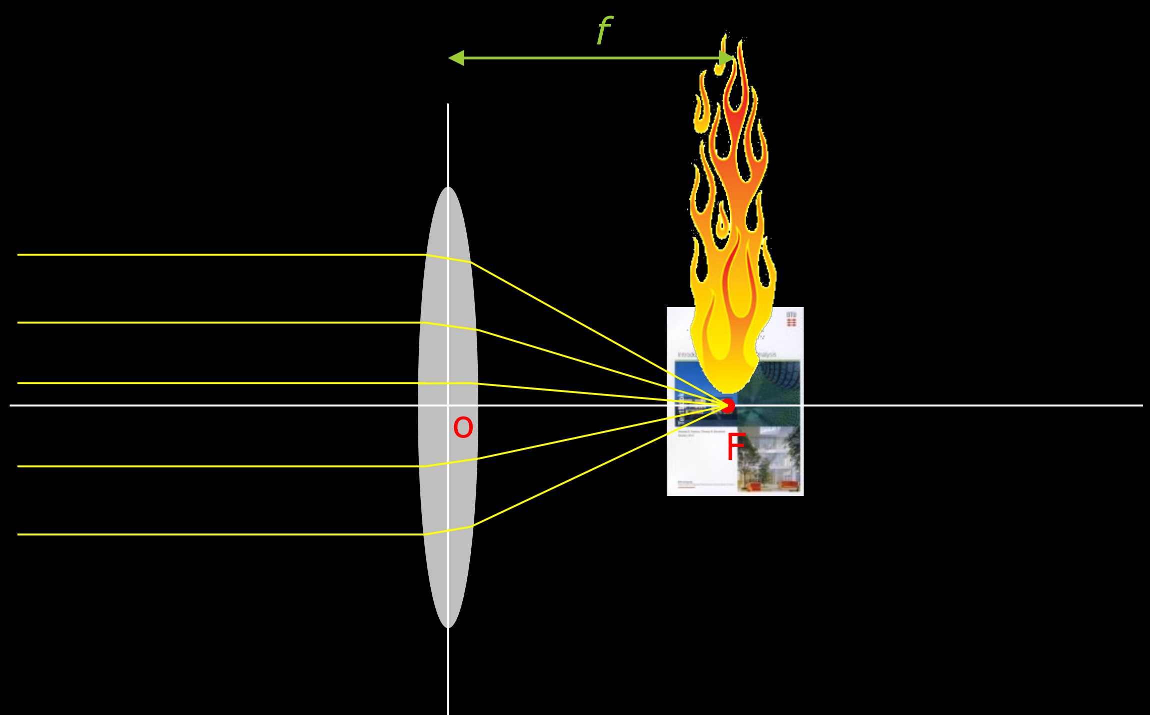


World

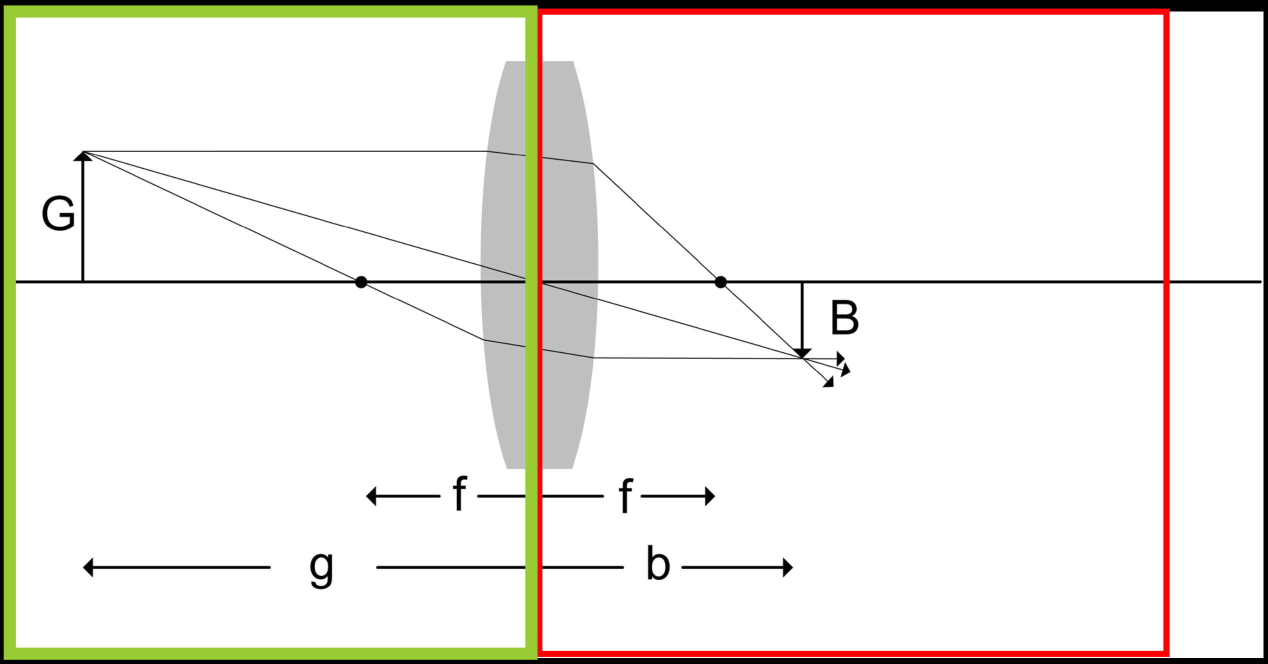
Inside camera

Focal point – focal length

- Light coming from “really far away” can be seen as parallel rays
- Rays intersect at the focal point
- Distance from optical centre O to focal point F is called *focal length f*



Where do non-parallel rays meet?



World

Camera

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

Thin lens equation

or

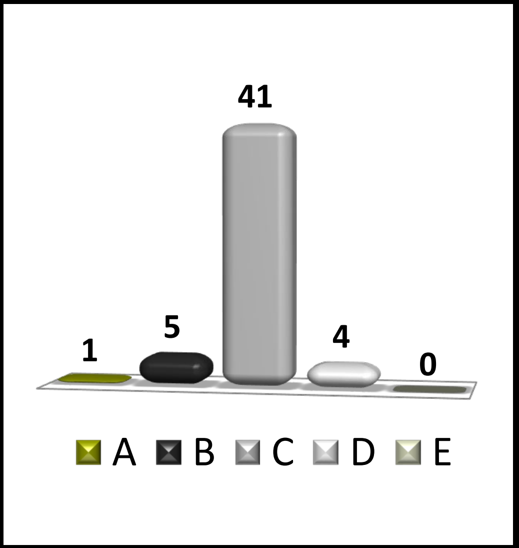
Gauss' lens equation

g – distance to object

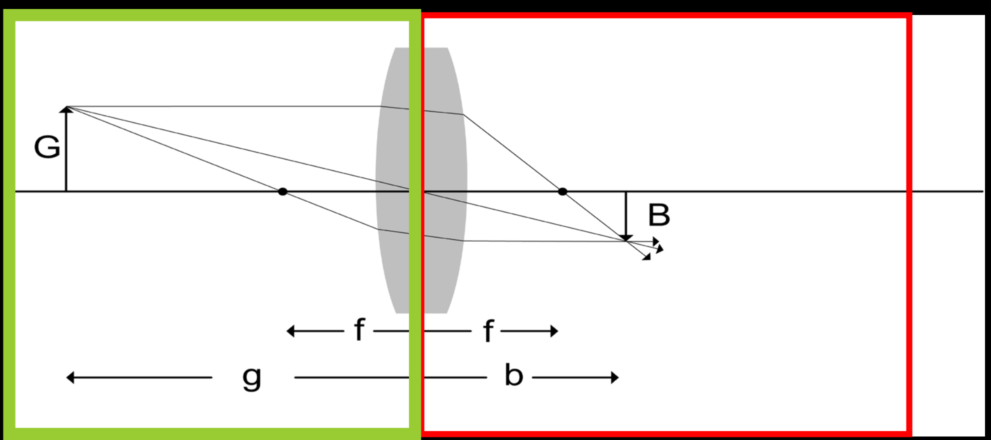
b – distance to intersection

Where do the rays meet

- Camera with focal length of 5 mm
- Rasmus is standing 3 meters away
- Where do the rays meet in the camera? (b)



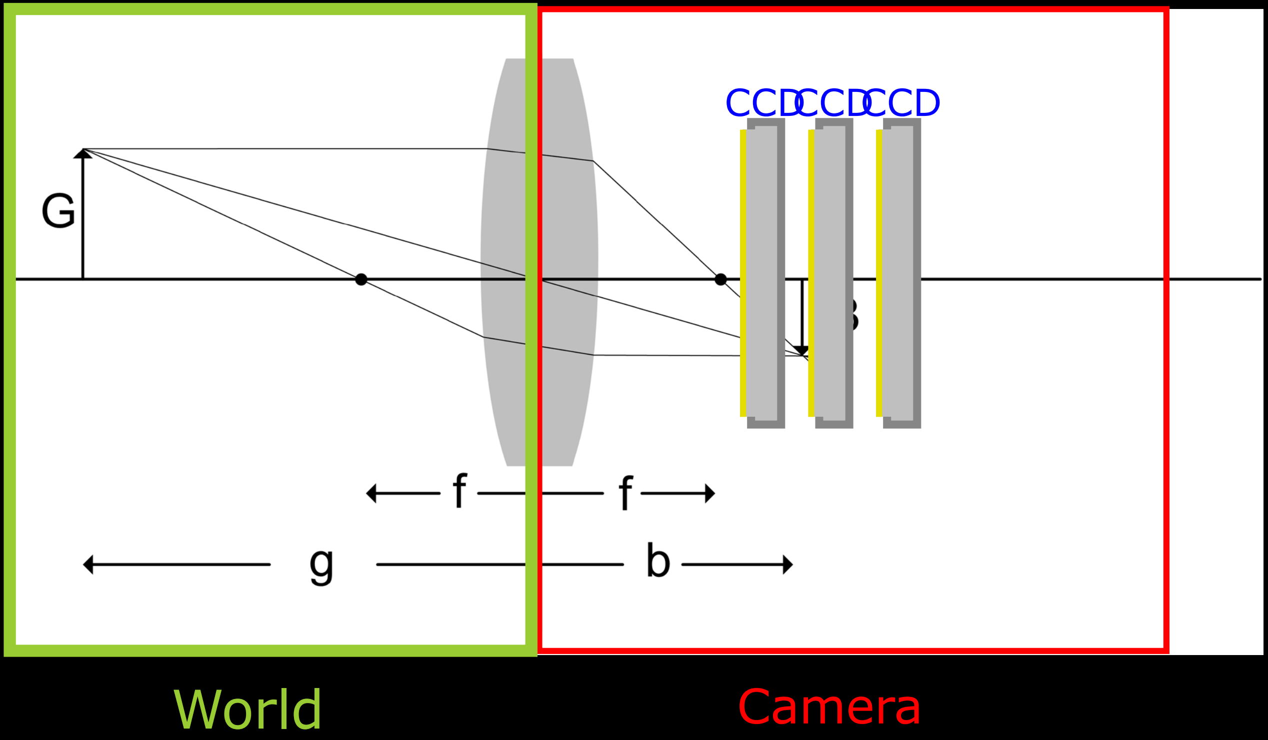
A) b = 1 mm
B) b = 4 mm
C) b = 5 mm
D) b= 6 mm
E) b = 7 mm



World Camera

Focus or not to focus?

How do we make focused images? Placing the CCD right

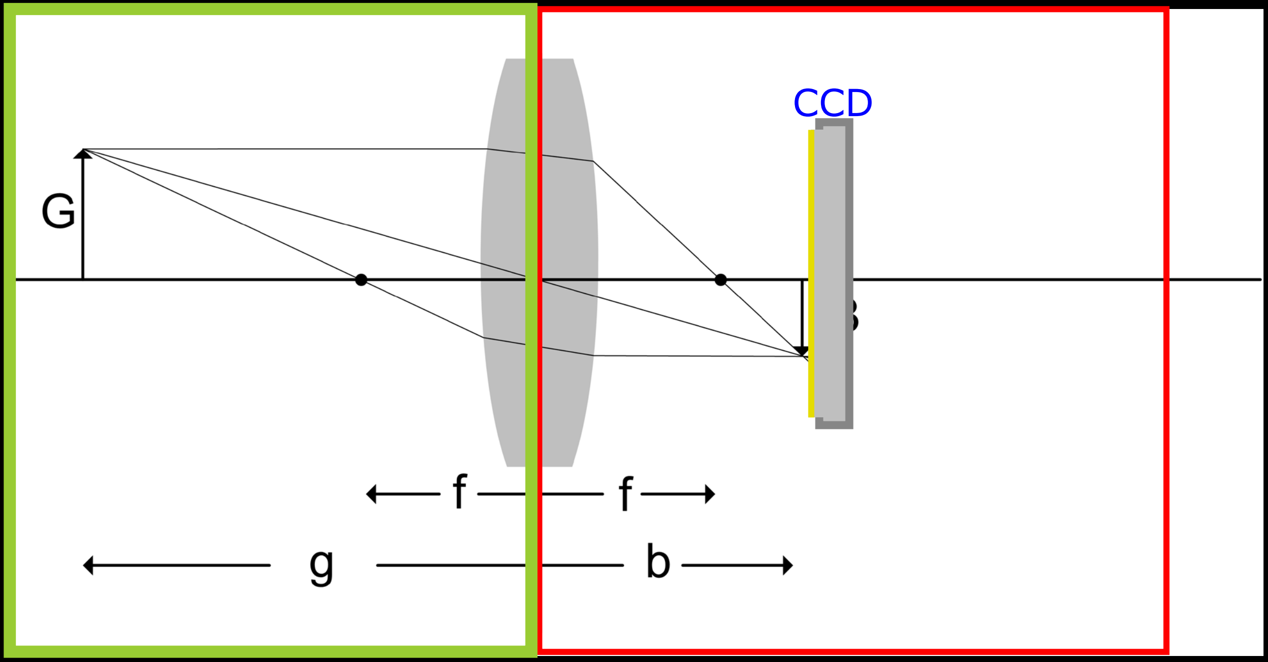


CCD should be placed at b!

g – distance to object

b – distance to intersection

Focusing



World

Camera

g – distance to object

b – distance to intersection

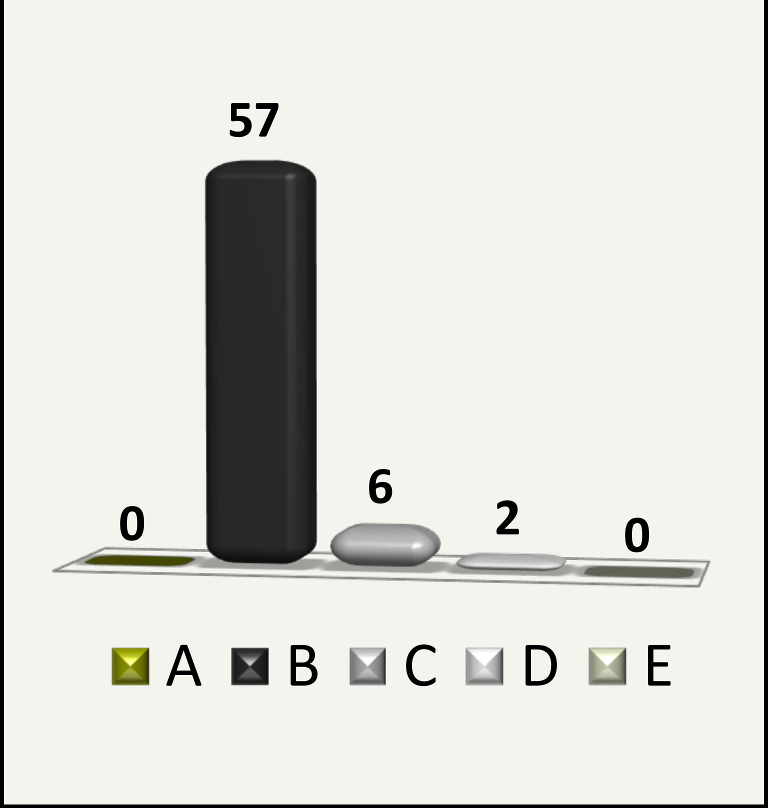
- We move the camera
- Distance to object (g) changes
- f is fixed
- b changes
- Move CCD to b
  - Focusing

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

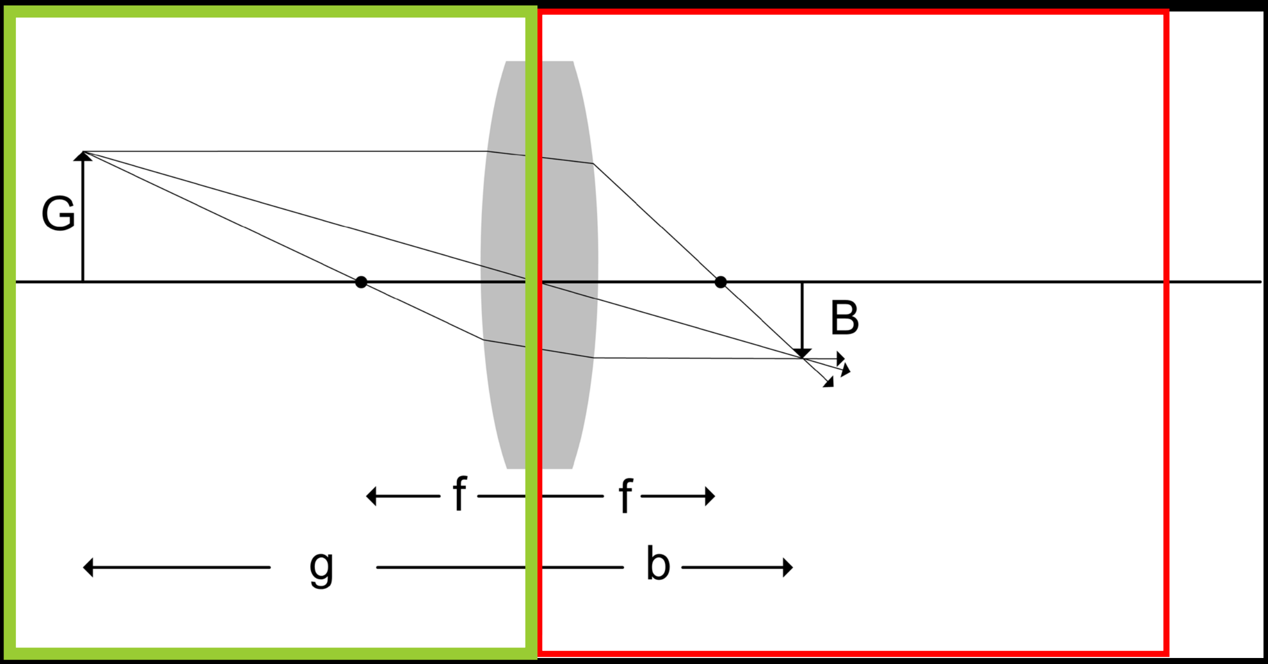
Focal Length

You got a new camera with a simple lens. You would like to determine the focal length of the lens. The distance from the CCD chip to the lens is 61 mm. The camera can take a sharp image of a car standing 3.66 meter from the camera. What is the focal length?

A) 58.5 mm
B) 60.0 mm
C) 61.5 mm
D) 62.5 mm
E) 63 mm



Object size



World

Camera

What is the size of an object on the CCD?

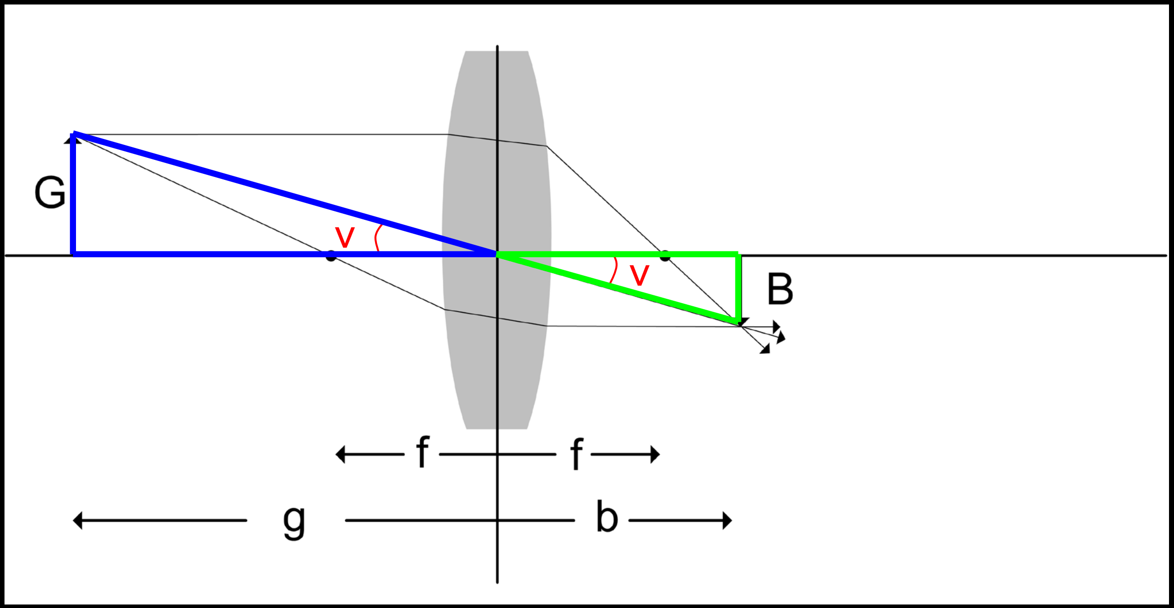
g – distance to object

b – distance to intersection

G – Object height

B – object height on CCD

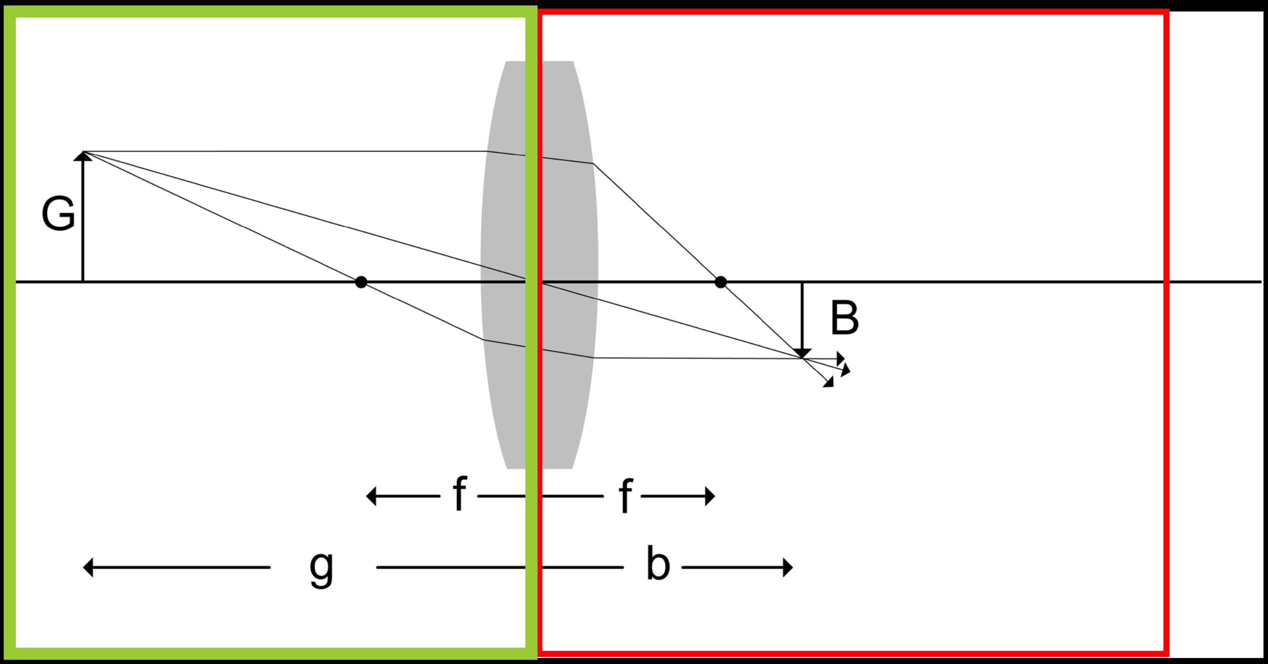
An important relation!



- Two triangles
- One with side length g and one with b
- B and G are related! – how?
- Hint - tangens

$$\frac{b}{B} = \frac{g}{G}$$

An important relation!



$$\frac{b}{B} = \frac{g}{G}$$

World

g – distance to object

G – Object height

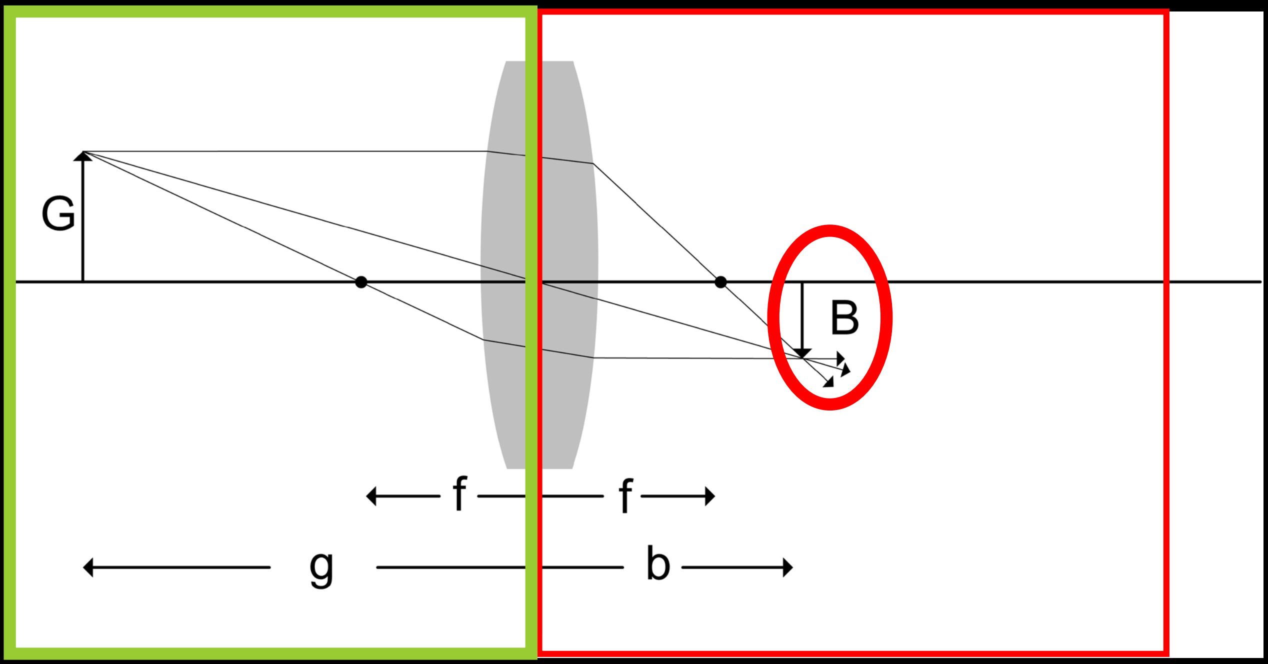
Camera

b – distance to intersection

B – object height on CCD

How do we Zoom ?

We want to make B larger! How?



World

Camera

g – distance to object

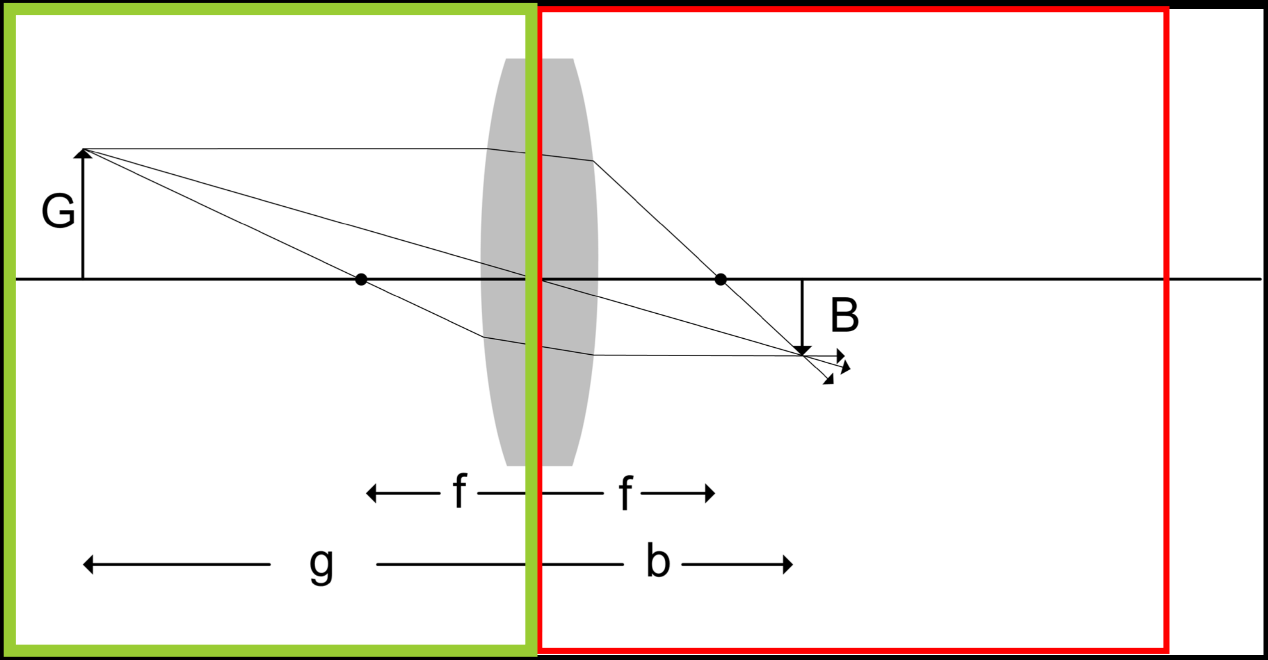
b – distance to intersection

G – Object height

B – object height on CCD

Zoom

We want to make B larger! How?



$$\frac{b}{B} = \frac{g}{G}$$

$$B = b\frac{G}{g}$$

Fixed

World

g – distance to object

G – Object height

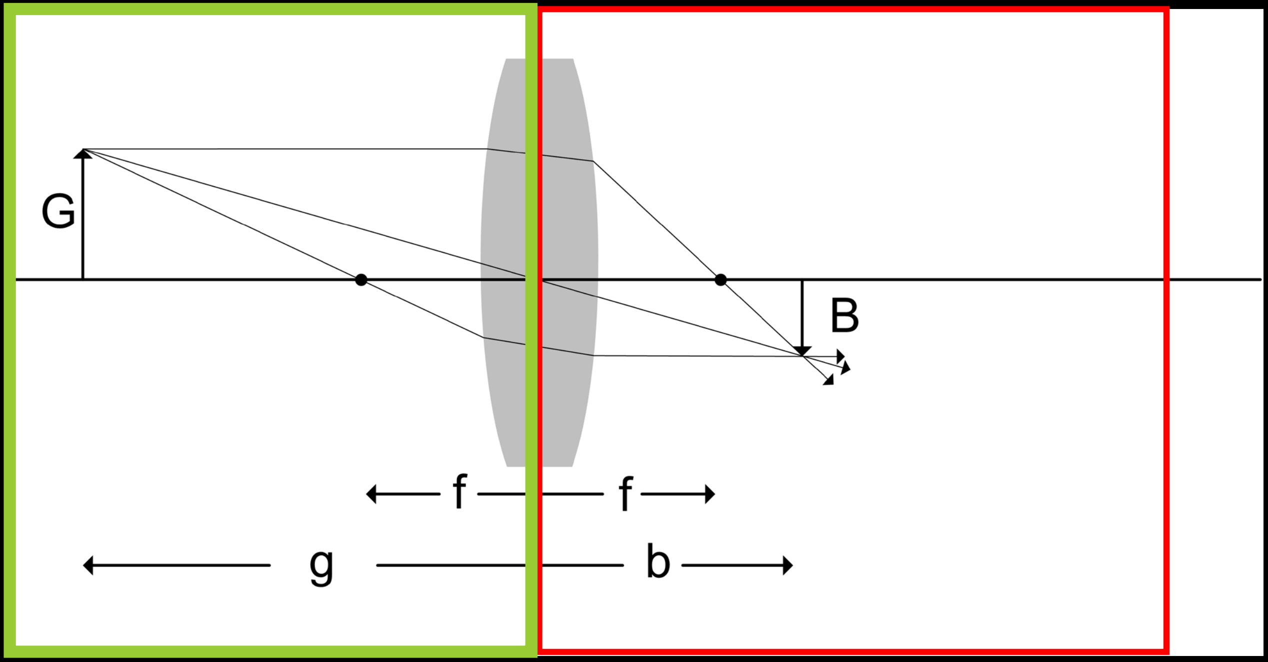
Camera

b – distance to intersection

B – object height on CCD

Zoom

We want to make B larger – changing b!



$$B = b\frac{G}{g}$$

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

constant

To change B we change the focal length!

World

g – distance to object

G – Object height

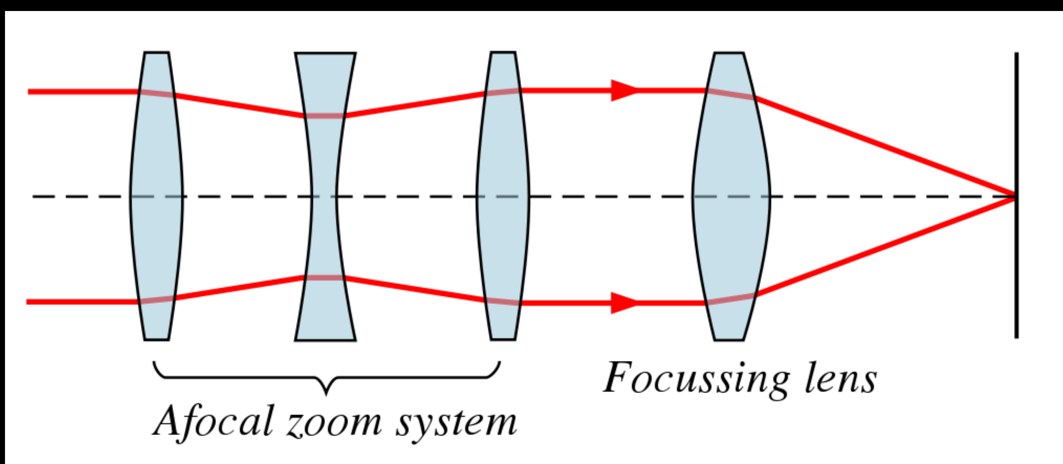
Camera

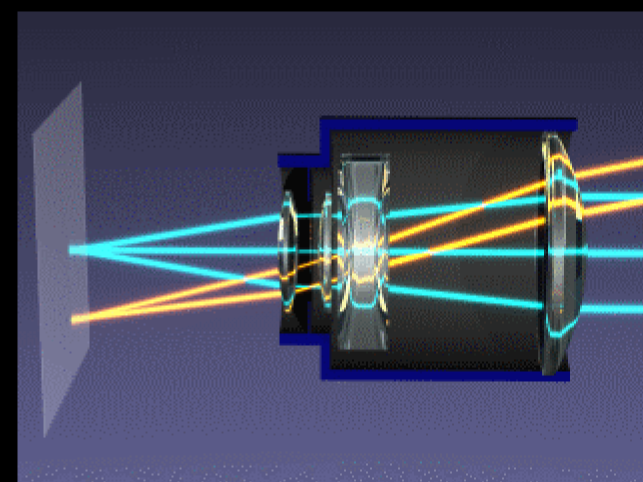
b – distance to intersection

B – object height on CCD

Changing the focal length?

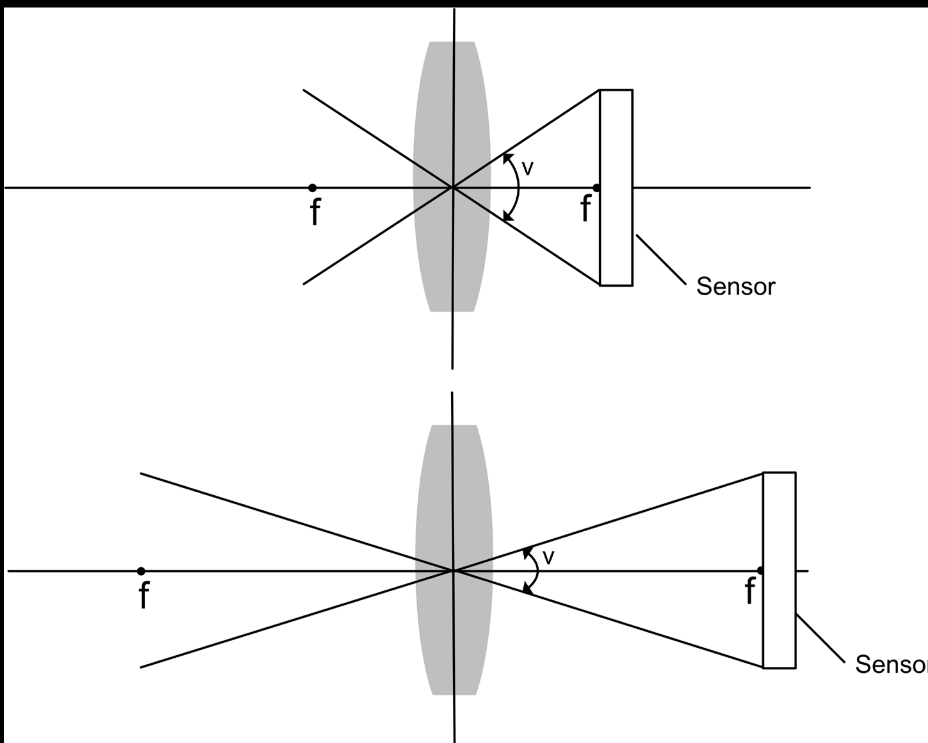
- Not possible on a simple lens
- Need a “zoom lens”
- Several lenses together





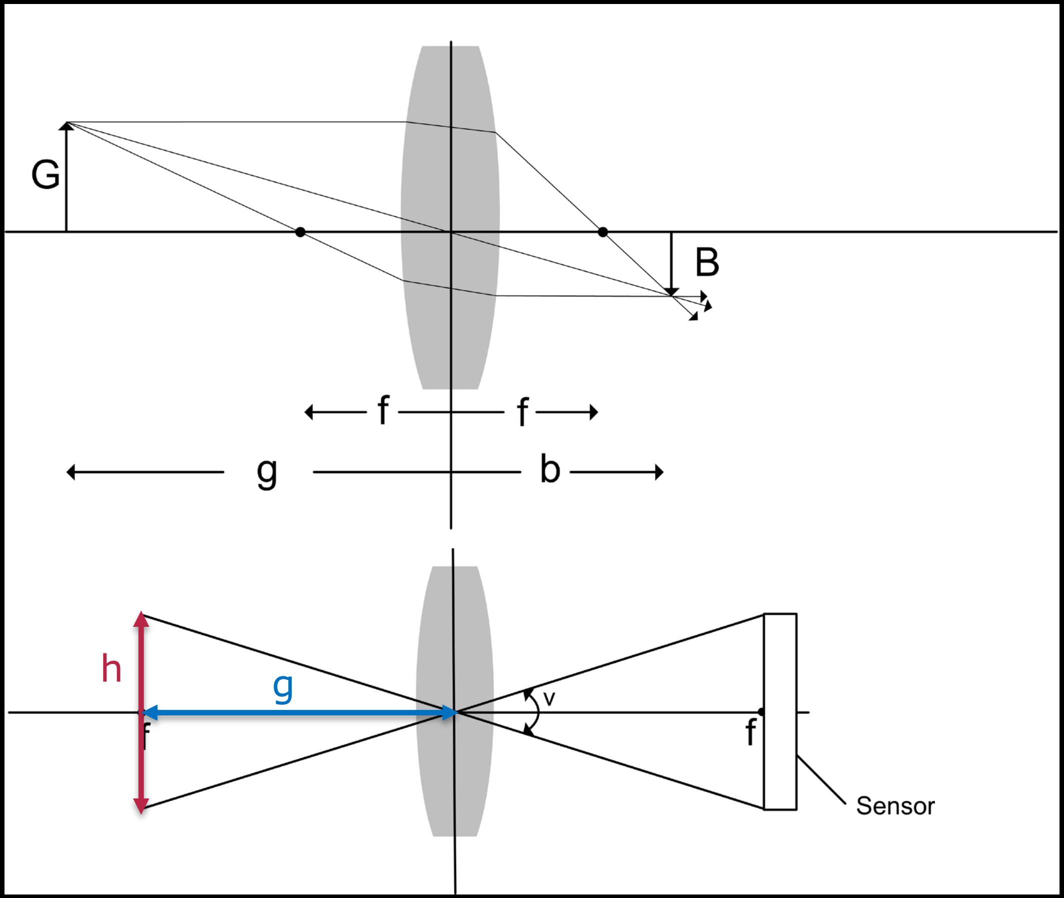
From WikiPedia

Field of view (FOV)



- Described by an angle
  - Large angle the larger FOV
- Depends on
  - CCD size
  - Focal length
- Fisheye lens
  - Small focal length
  - Large field of view
- CCD chip is a rectangle
  - Horizontal field of view
  - Vertical field of view

Field of view (FOV)



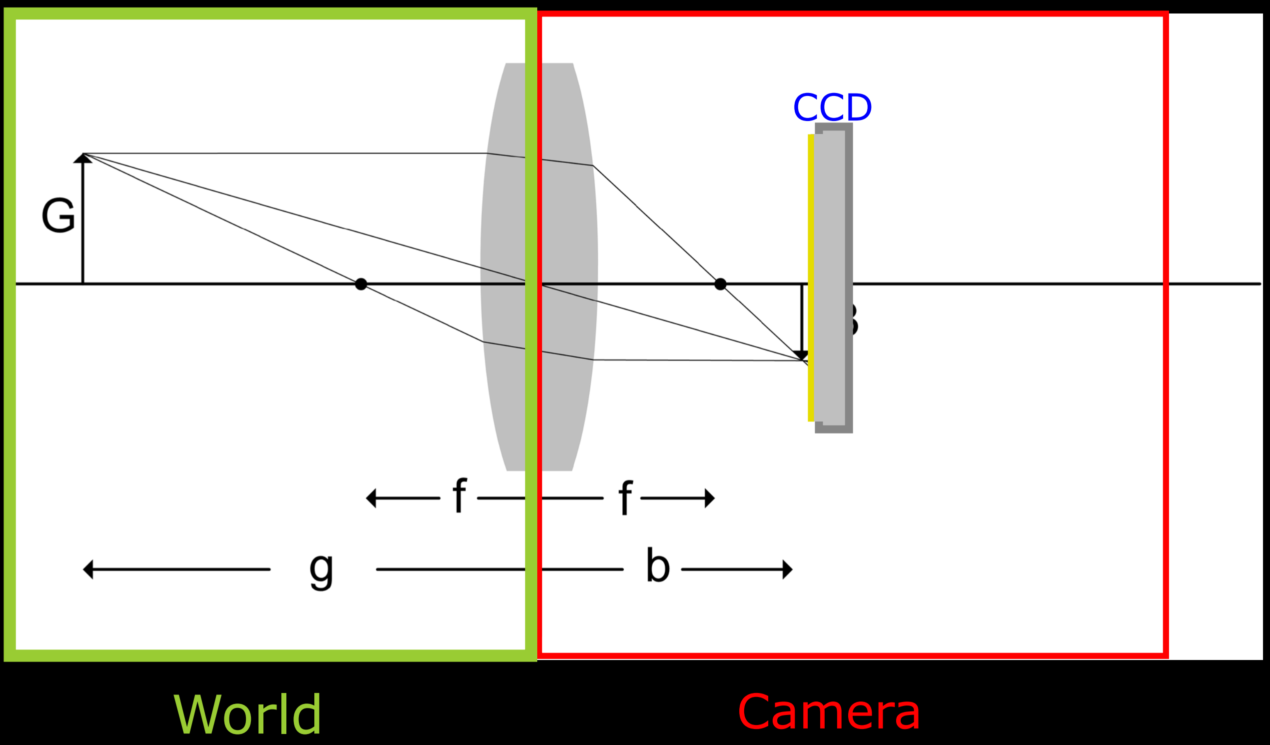
- Important relations

$$h = 2 * G$$

$$\tan v/2 = \frac{G}{g} = \frac{h}{2 * g}$$

Depth of field - dybdeskarphed

Depth of field - dybdeskarphed

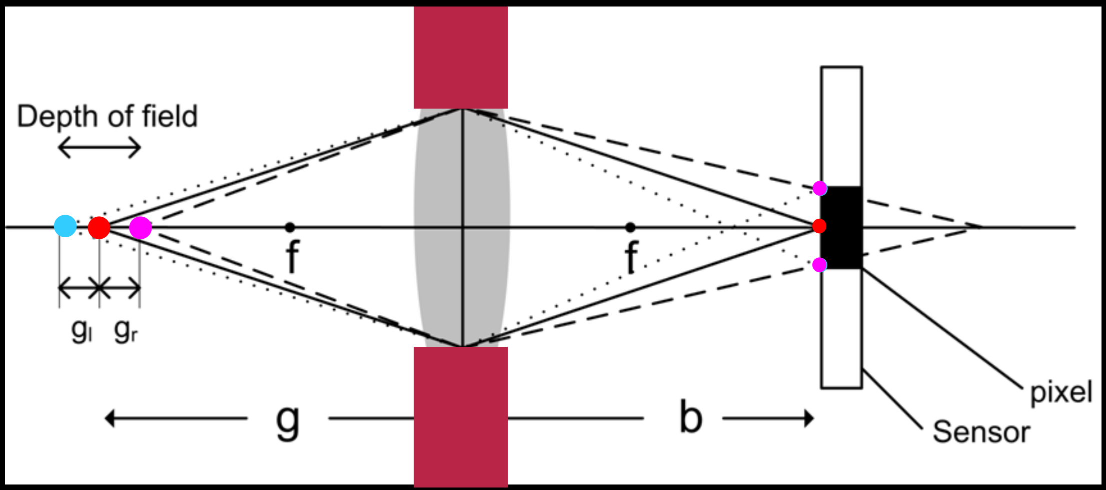


g – distance to object

b – distance to intersection

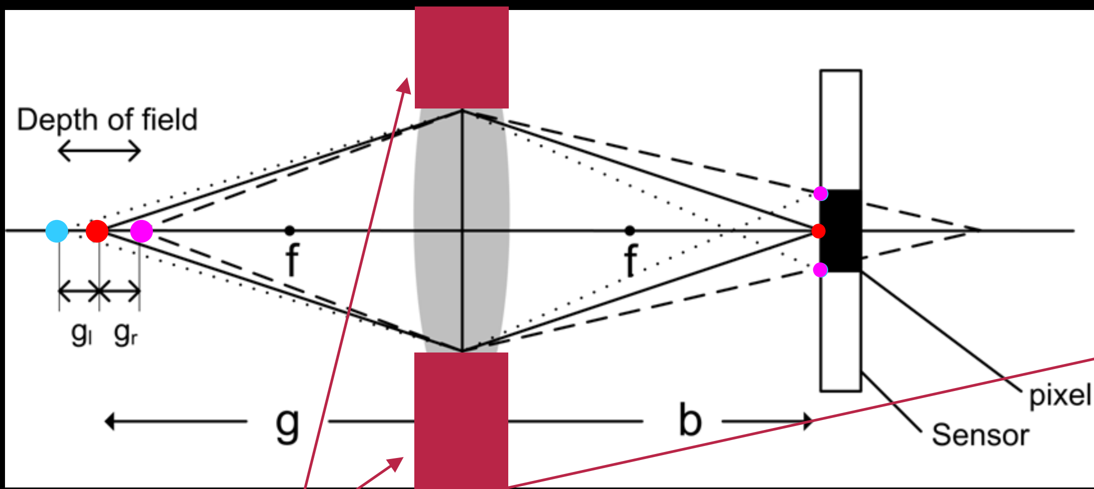
- g is fixed
- CCD should be placed at b
- g is fixed – only focus at one distance!

Depth of field



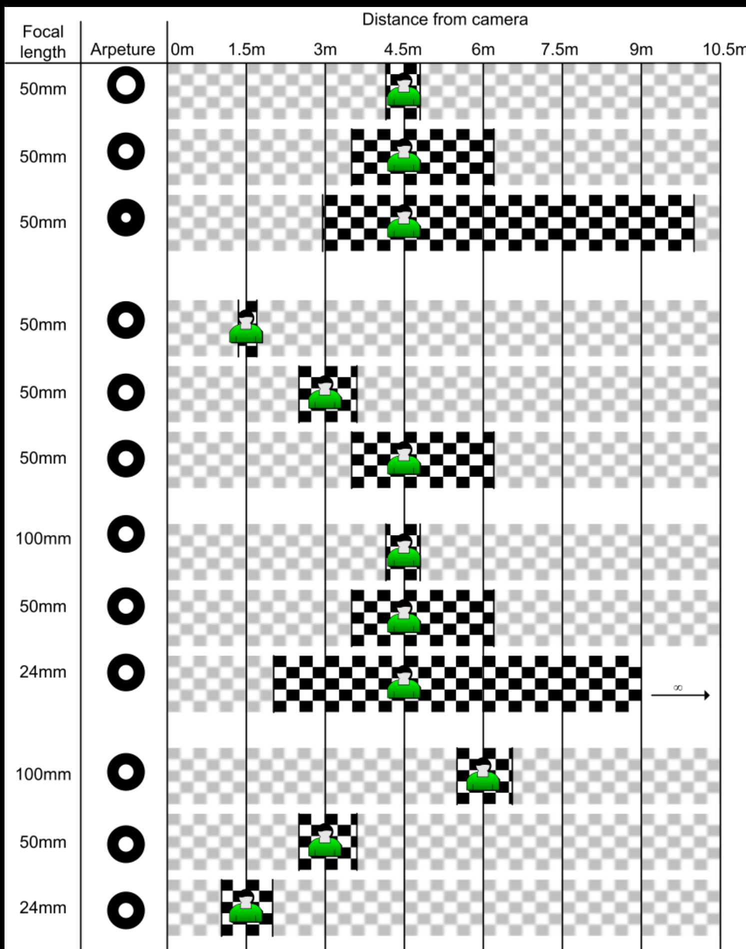
- Look at one pixel in the middle
- The object is placed at distance g
- How much can we move the object?
  - Light has to hit the same pixel
- Move it to the left (g_l)
- move it to the right (g_r) – still hit the same pixel (but twice)

Depth of field – Aperture (blænde)



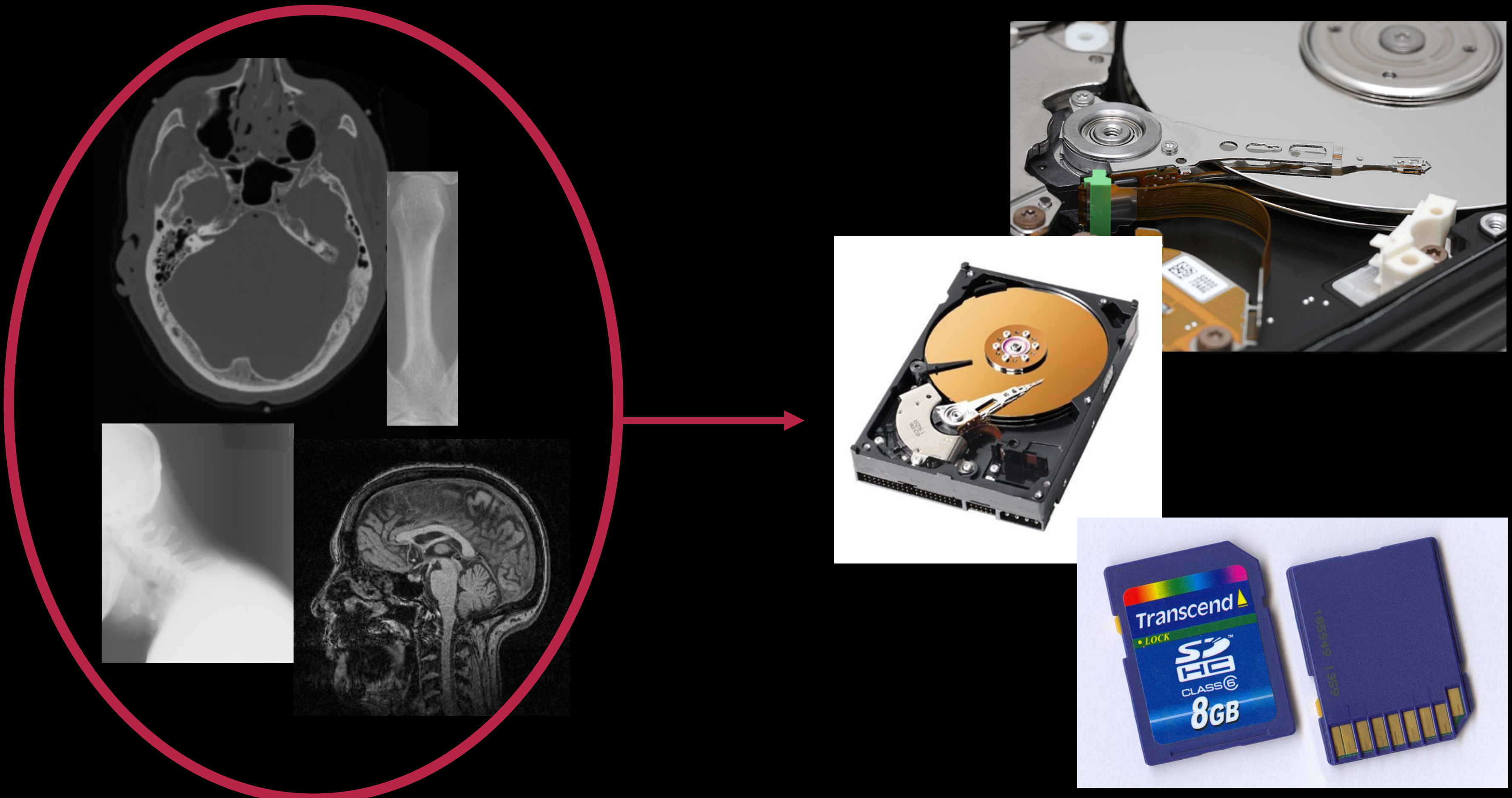
- The aperture controls the amount of light
- Small aperture
  - large depth of field
  - Less light -> longer exposure

How to acquire a good image?



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

Image storage

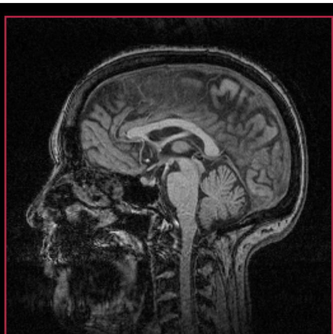


Hard disks, memory cards, CDs etc

- Storage for bytes!
  - 500 GB?
  - 500 GigaBytes = 500.000.000.000 bytes!
- A hard disk do not know anything about images
- Stores data as lists of bytes
  - 17, 255, 1, 3, 87, 98, 11, …
- File on a hard disk
  - It has a length (in bytes, MB, GB)
  - Contains numbers! (Bytes)

We want to make an "image file"

Imagine



Size: 200 x 200

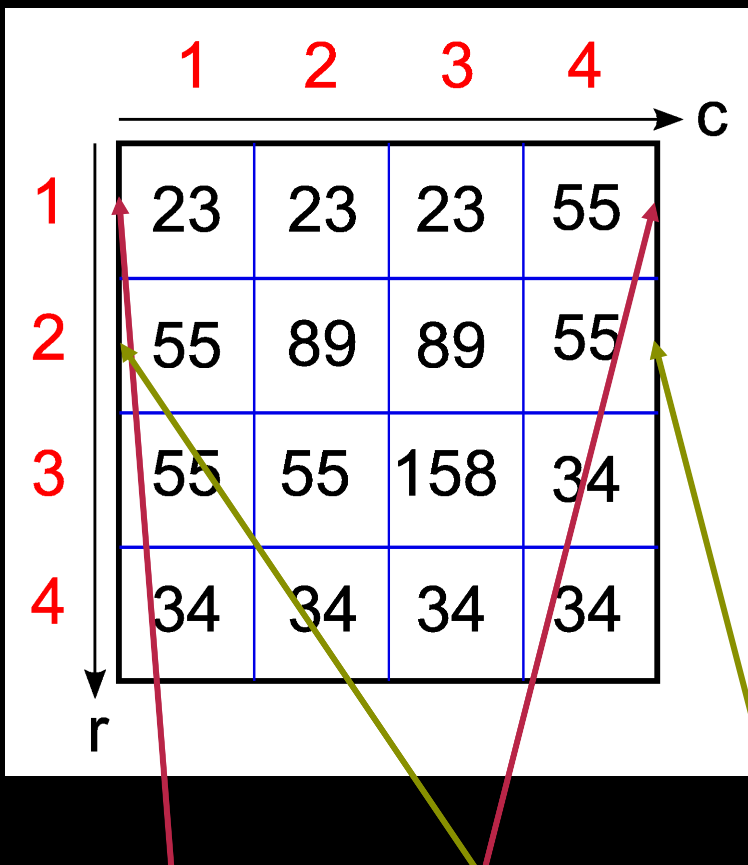
256 grayscales

- You have a telephone. You are only allowed to say no or yes!
- You need to transfer an image to the person in the other end.
- How can we do that?

Remember that each pixel is a byte

A byte is made out of 8 bit

Image as data



- How do we store this image as list of bytes?
- What do we need
  - Size of the image
    - Width as 2 bytes (0-65535)
    - Height as 2 bytes (0-65535)
  - The data

23,23,23,55,55,89,89,55,55,55,158,34,34,34,34,34

Simple image format

r \ c	1	2	3	4
1	23	23	23	55
2	55	89	89	55
3	55	55	158	34
4	34	34	34	34

- Stores the image as
  - A header with information about size
  - Data with no compression
- Windows Bitmap Format (BMP)

Compression - make something smaller

- Is there a more "compact" way to represent the data below?
- Look for patterns
  - A series of numbers can be represented how?
    - The count and the value
- What is the "count and value" code?
  - Reduced from 16 to 12 values

Run length encoding

23,23,23,55,55,89,89,55,55,55,158,34,34,34,34,34

3,23, 2,55, 2,89, 3,55, 1,158, 5,34

Run length encoding

- Simple but useful data compression
- General – not only for images
- Is also used by the Windows Bitmap Format (BMP)

Run Length coding of image

A) 1 1 3 5 2 3 3 2 2 3 4 201 4 130 0 147 2 88

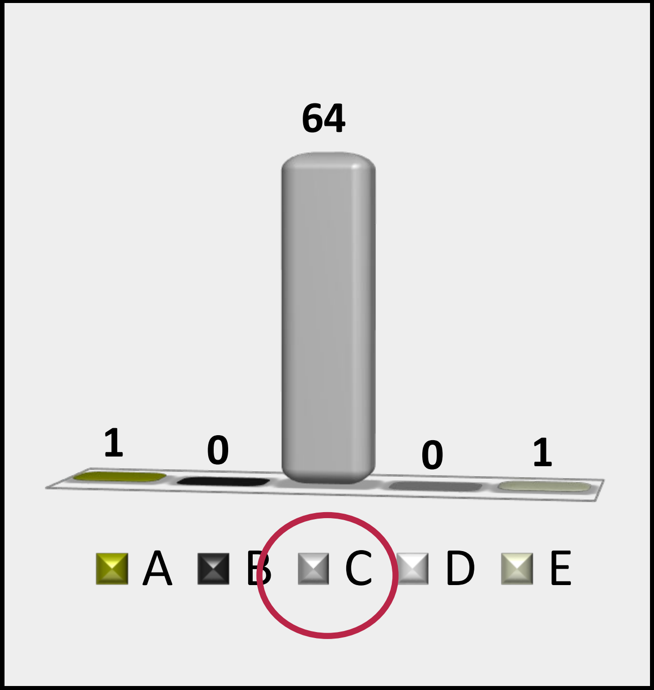
B) 1 1 2 5 2 3 2 3 3 201 3 19 5 147 4 130 1 147 2 88

C) 1 1 3 5 2 3 1 2 2 3 2 201 3 19 2 147 4 130 3 147 2 88

D) 5 1 1 5 2 3 3 2 2 3 2 201 3 19 2 147 3 130 1 147 5 88

E) 1 1 3 5 3 3 5 2 2 4 2 201 6 19 2 147 4 130 2 88

1	5	5	5	3
3	2	3	3	201
201	19	19	19	147
147	130	130	130	130
147	147	147	88	88



Compression ratio – how compressed?

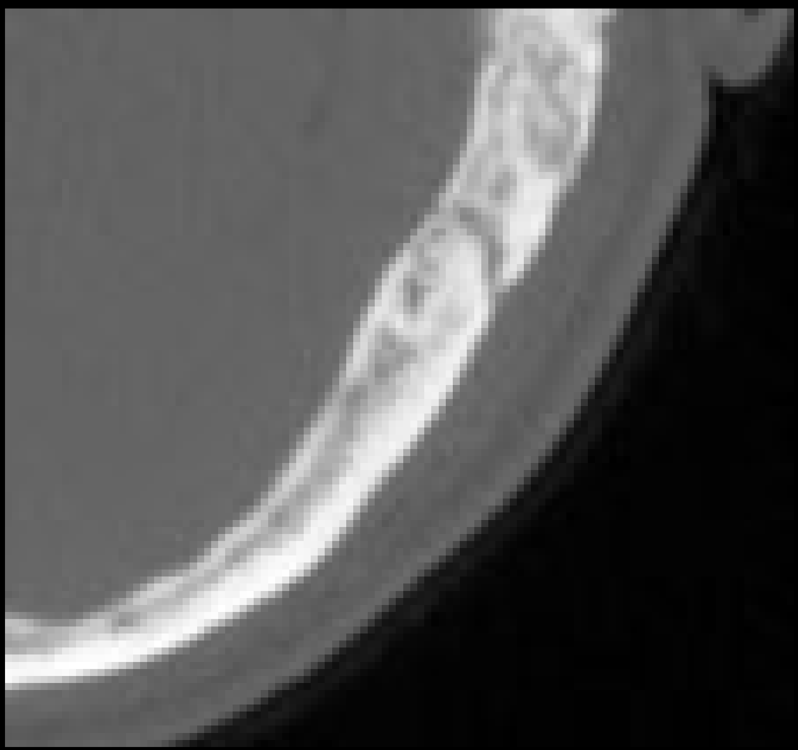
- Gives a measure for how much data is compressed
- Our example
  - From 16 to 12
  - 16 : 12 = 4 : 3
  - Ratio 1.33

Compression ratio = uncompressed size / compressed size

Lossless image formats

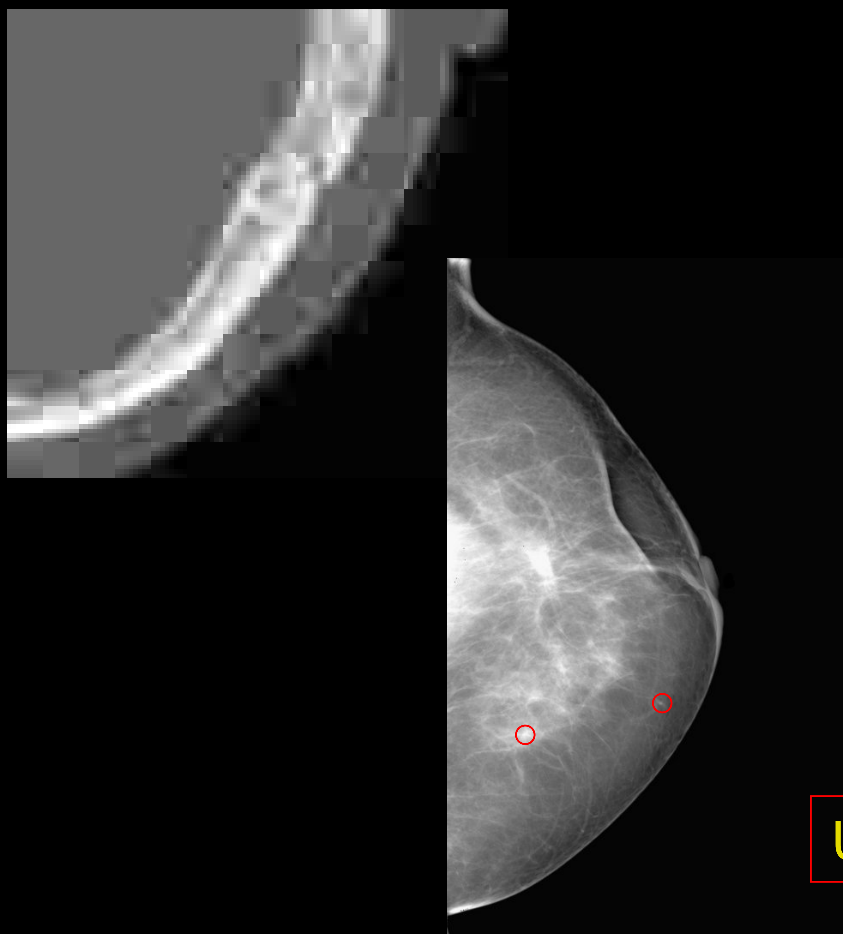
- Do not throw away information
- Good for storing medical images
  - We do not want to destroy any information
- Not very effective for photos. Why?
  - To many changes in the image
- PNG (portable network graphics) is a good format

Lossy image formats



- Removes “unimportant” information
- JPEG is an example
- Removes the “high frequencies”
- Similar to the MP3 sound format

Compression artefacts



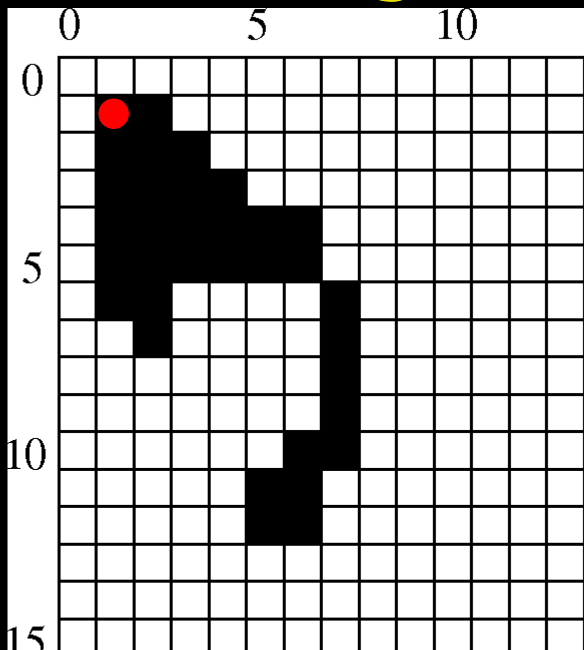
- Lossy compression changes the image
- Normally not a problem for photos
- BIG problem for medical images
- Mammogram
  - Looking for tiny bright spots
  - Would be changed by lossy compression

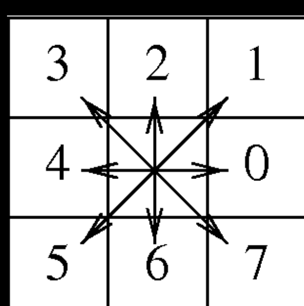
Use JPEG (JPG) for photos only

Binary images

- Binary – means on or off
- Binary image – only two colors
- Background (0 = black)
- Foreground (1 = white)

Chain coding of binary images



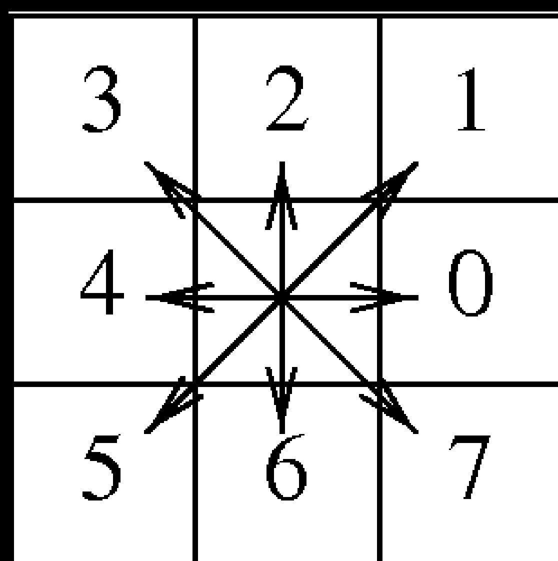


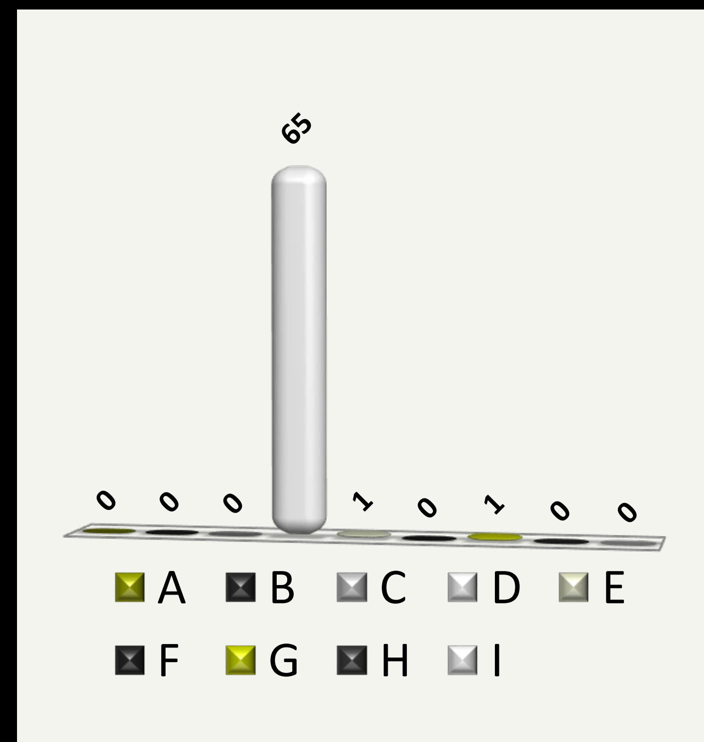
- Sufficient to describe the foreground
- Background given by the foreground
- The coordinates of the starting pixel is stored
- Secondly the sequence of step directions is stored

(1; 1) (07770676666564211222344456322222)

Chain Coding – what is in the image?

A) House
B) Chain
C) Flower
D) Giraffe
E) Dog
F) Teaport
G) Car
H) Glass
I) Bottle





(4;2)(04666624446)

A chain code is computed for the image

(0,0) in upper left corner. (X,Y) system

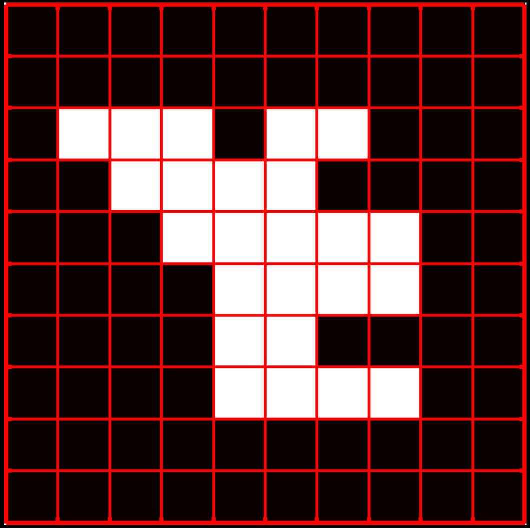
A) (1,2)(00710970695742233)

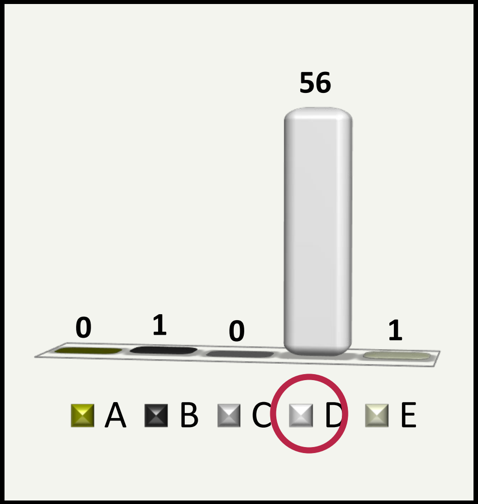
B) (3,6)(00133227312631 4)

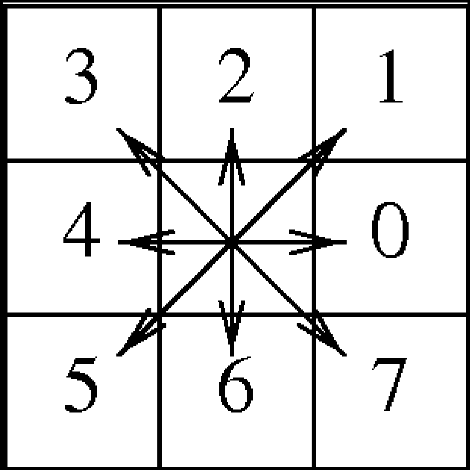
C) (1,2)(003105206437066442233)

D) (1,2)(007105706457044422333)

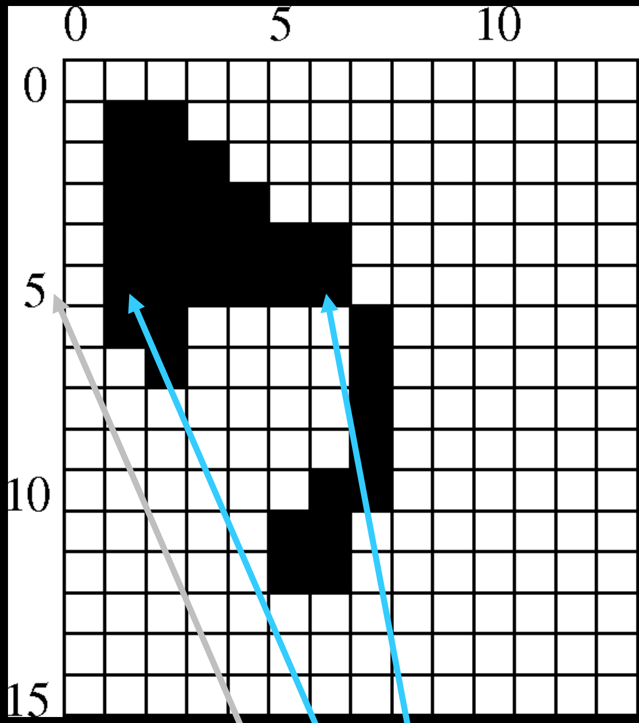
E) (5,3)(1127103335706457044 42233)







Binary images – Run length coding



- Another way to represent binary images
- Again the foreground is described
- Each line of the image is described
- For each "run" the row number is stored
- Secondly, the start column and the end column is stored

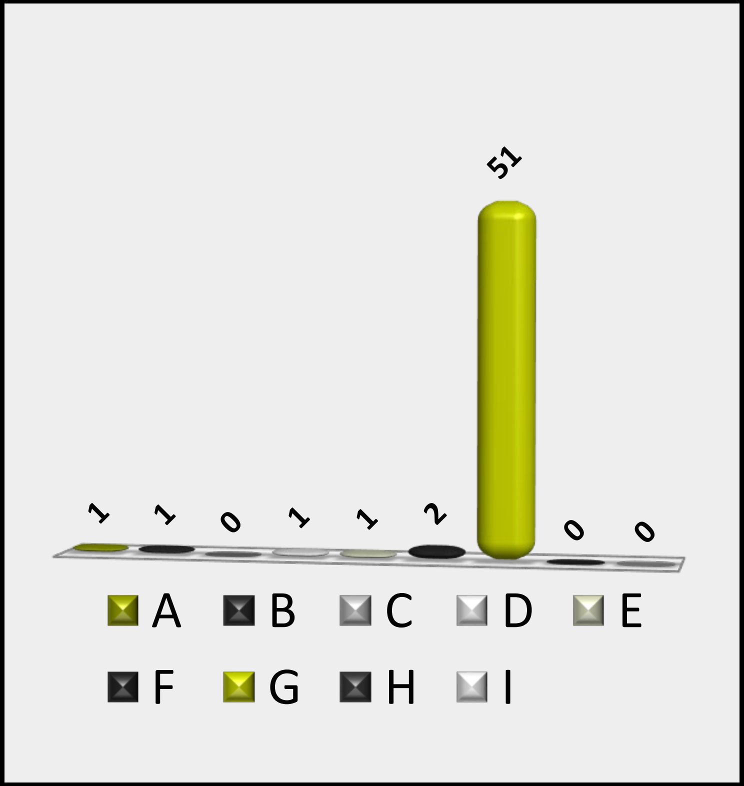
[1; (1; 2)]; [2; (1; 3)]; [3; (1; 4)]; [4; (1; 6)]

[5; (1; 6)]; [6; (1; 2)(7; 7)]; [7; (2; 2)(7; 7)]; [8; (7; 7)]

[9; (7; 7)]; [10; (6; 7)]; [11; (5; 6)]; [12; (5; 6)]

Binary run-length. What is in the image?

A) House
B) Chain
C) Flower
D) Giraffe
E) Dog
F) Teapot
G) Car
H) Glass
I) Bottle



[1;(2,4)],[2;(1,6)],[3;(2,2)],[3;(5,5)]

Next week

- Pixel wise operations
- Colour images
- MIA chapter 4
- MIA chapter 8
- Tim B. Dyrby will give the lecture