UNIVERSITAT DE BARCELONA

>>> IMAGE PROCESSING AND COMPUTATIONAL PHOTOGRAPHY

SESSION 5b: PHOTOGRAPHY

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(c) inspired by D. Hoiem and A. Efros slides

HISTOGRAMS

Histogram is a graphical representation of the frequentist estimation of the probability density function of a random variable.

It works counting the frequency of data in discrete intervals (bins) of the variable.

4	3	6	2	1
8	9	5	3	4
2	3	4	1	6
5	5	2	1	2
3	2	5	6	8

10 bins histogram

3	5	4	4	4	3	0	2	1	0
1	2	3	4	5	6	7	8	9	10

5 bins histogram

7	8	7	2	1
1-2	3-4	5-6	7-8	9-10

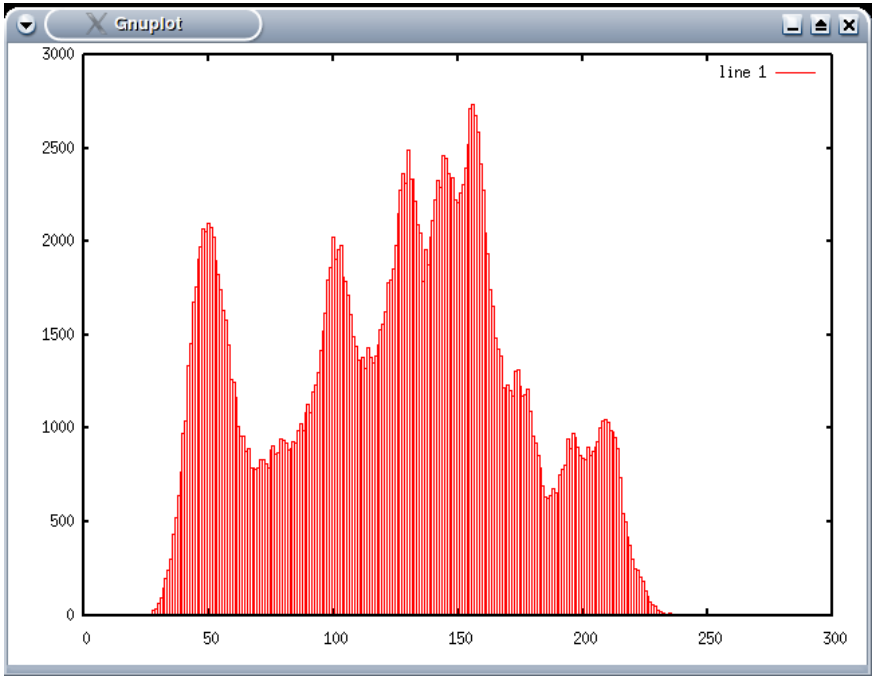
5 bins histogram

2	20	0	3	0
1	2-6	7	8-9	10

Note that these are unnormalized histograms. We should divide each bin by the number of pixels (L=25)

HISTOGRAMS

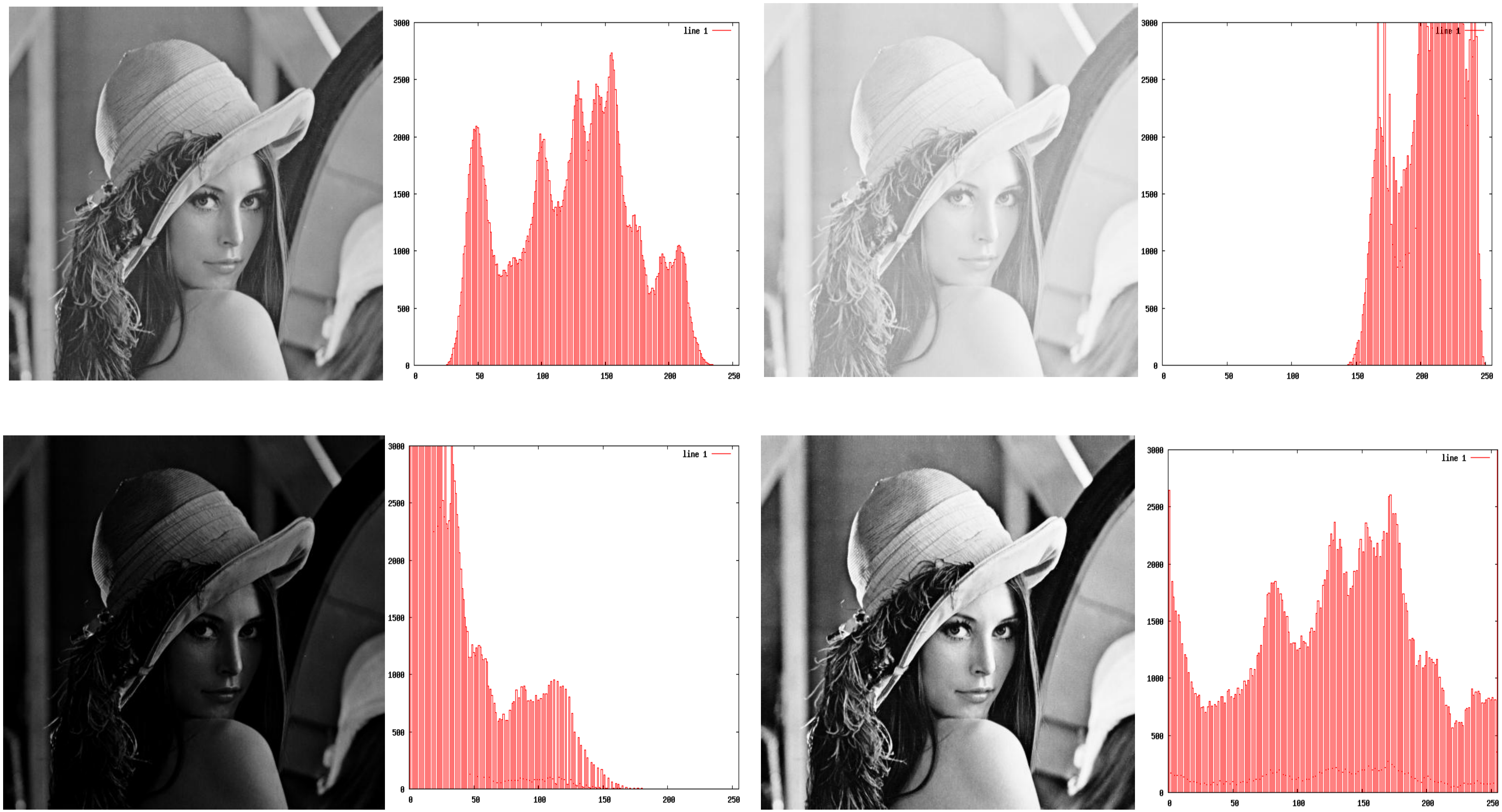
Count the pixel values in each bin (interval) → FAST!!!



What information does histogram provide?
with respect to brightness? with respect to contrast?
With respect to sharpness? with respect to noise?

3D Color Histograms: http://www.senchalabs.org/philogl/PhiloGL/examples/histogram/

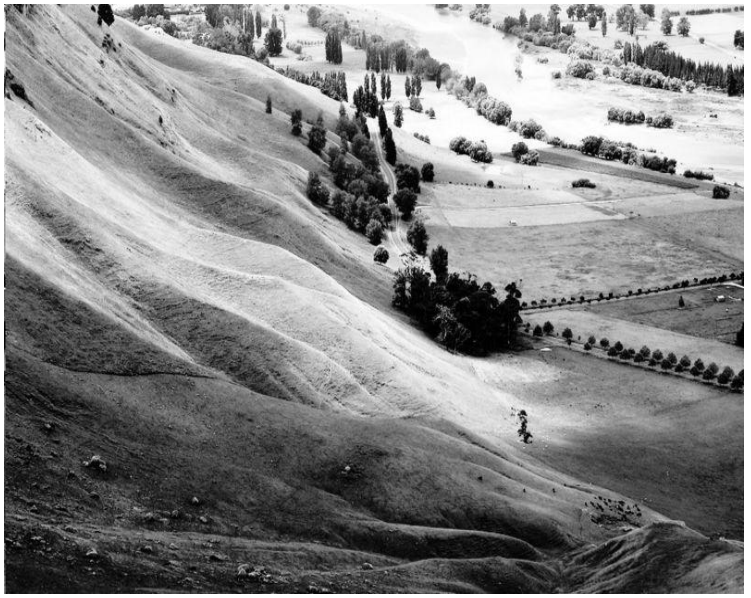
HISTOGRAMS



Note that low contrast has a narrow histogram and high contrast usually covers a wide range of intensities

HISTOGRAM EQUALIZATION

This method increases the global contrast and allows us to follow any desired histogram distribution.



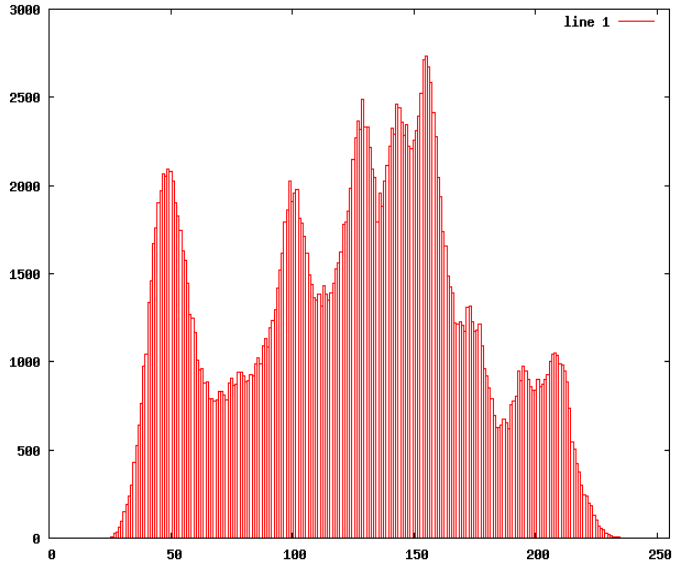
In this example we apply equalization following a uniform distribution

HISTOGRAM EQUALIZATION

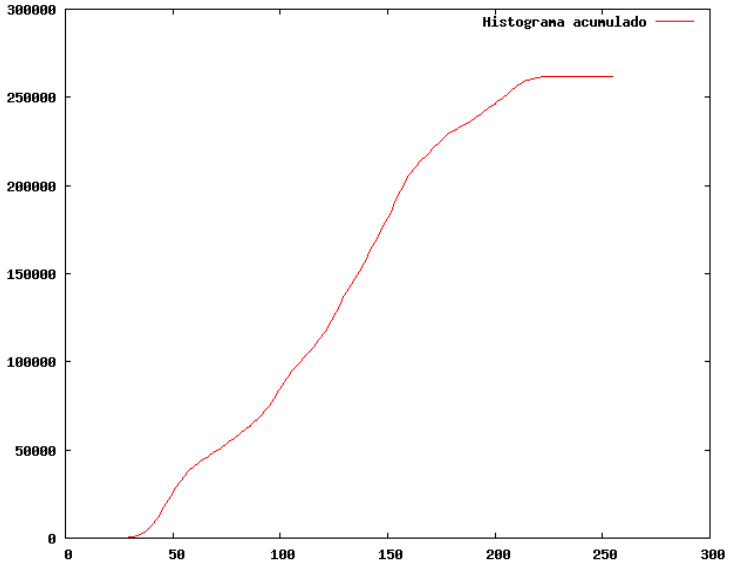
For histogram equalization we need the accumulated histogram. Accumulated histogram assigns to each bin the accumulated sum of the previous bins.

It can be found from the normal histogram as:

$$HA(s) = \sum_{r \leq s} H(s)$$



Histogram



Accumulated histogram

HISTOGRAM EQUALIZATION COMPUTATION

For histogram equalization we need the accumulated histogram. Accumulated histogram assigns to each bin the accumulated sum of the previous bins.

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$$HA(s) = \sum_{r \leq s} H(s)$$

4	3	6	2	1
8	9	5	3	4
2	3	4	1	6
5	5	2	1	2
3	2	5	6	8

2	5	4	4	4	3	0	2	1	0
1	2	3	4	5	6	7	8	9	10

Histogram

2	7	11	15	19	22	22	24	25	25
1	2	3	4	5	6	7	8	9	10

Accumulated histogram

Unnormalized results

HISTOGRAM EQUALIZATION EXAMPLE

4	3	6	2	1
8	9	5	3	4
2	3	4	1	6
5	5	2	1	2
3	2	5	6	8

2	5	4	4	4	3	0	2	1	0
1	2	3	4	5	6	7	8	9	10

Histogram

2	7	11	15	19	22	22	24	25	25
1	2	3	4	5	6	7	8	9	10

Accumulated histogram

We want a transformation from [1,10] to [1,10] but the accumulated histogram transforms from [1,10] to [1,25]. Thus, if we normalize these results multiplying by 10/25, we obtain the transformation [1,10] to [1,10]

0.8	2.8	4.4	6	7.6	8.8	8.8	9.6	10	10
1	2	3	4	5	6	7	8	9	10

Normalized accumulated histogram

HISTOGRAM EQUALIZATION EXAMPLE

4	3	6	2	1
8	9	5	3	4
2	3	4	1	6
5	5	2	1	2
3	2	5	6	8

0.8	2.8	4.4	6	7.6	8.8	8.8	9.6	10	10
1	2	3	4	5	6	7	8	9	10

Normalized accumulated histogram

We should round these values to some integer (i.e. nearest integer).

1	3	4	6	8	9	9	10	10	10
1	2	3	4	5	6	7	8	9	10

Transformation

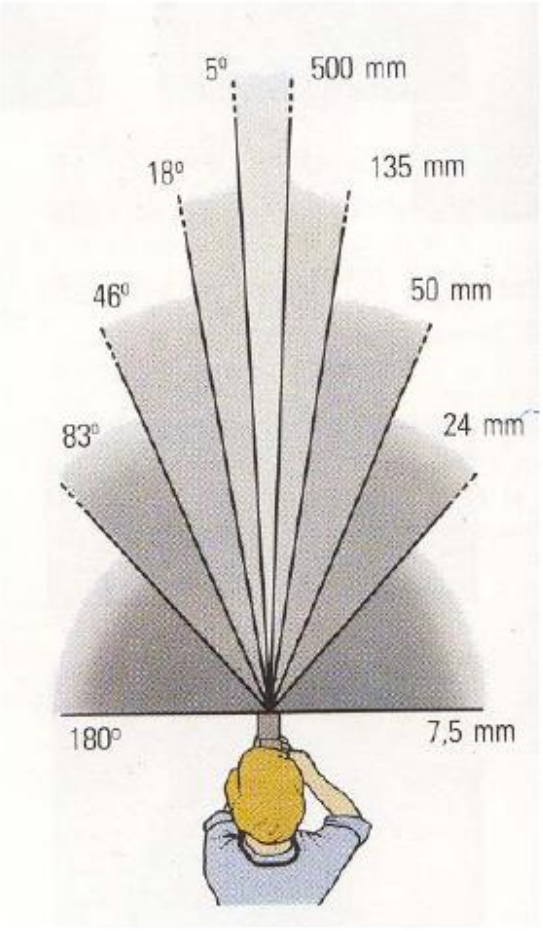
Apply transformation

6	4	9	3	1
10	10	8	4	6
3	4	6	1	9
8	8	3	1	3
4	3	8	9	10

Compute the histogram of the resulting image

THE 10' PHOTOGRAPHY COURSE

FOCAL LENGTH AND FIELD OF VIEW

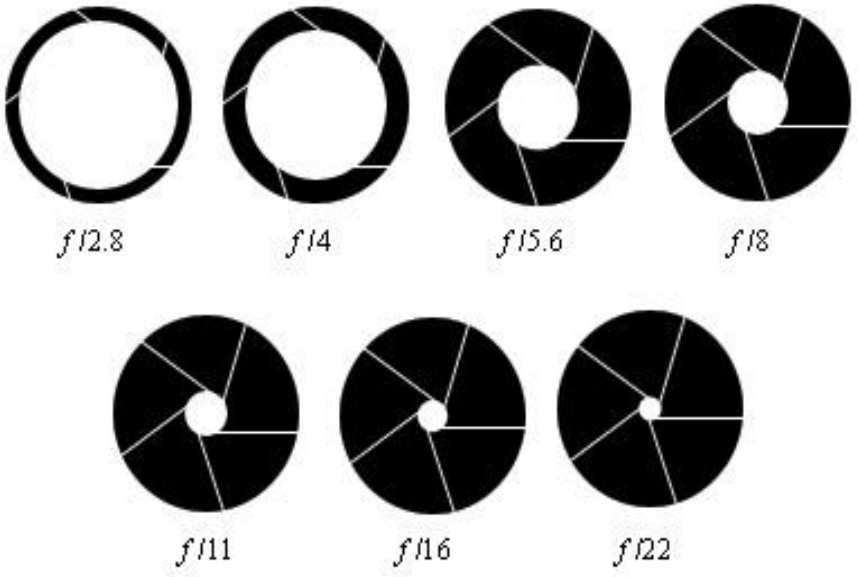


EXPOSURE

Exposure is how much light arrives to the camera.

Two ways to control this:

- **Aperture:** The “hole” in the optical path of the light
- **Shutter speed:** The amount of time the “hole” is opened



Aperture scale

Slow shutter speed images

SHUTTER SPEED AND APERTURE

- **Shutter speed**
  - Expressed in fraction of a second:
  - 1/30, 1/60, 1/125, 1/250, 1/500
  - (in reality, 1/32, 1/64, 1/128, 1/256, . . .)

- **Aperture**
  - Expressed as ratio of aperture size to focal length (f-stop)
  - f/2.0, f/2.8, f/4, f/5.6, f/8, f/11, f/16, f/22, f/32
  - f/X, means focal length is X times bigger than the aperture
  - Each f-stop reduces the area of the aperture by half
  - So, the larger the f-stop, the smaller the aperture

SHUTTER SPEED AND MOTION

500 (1/500 sec)

60 (1/60 sec)

30 (1/30 sec)

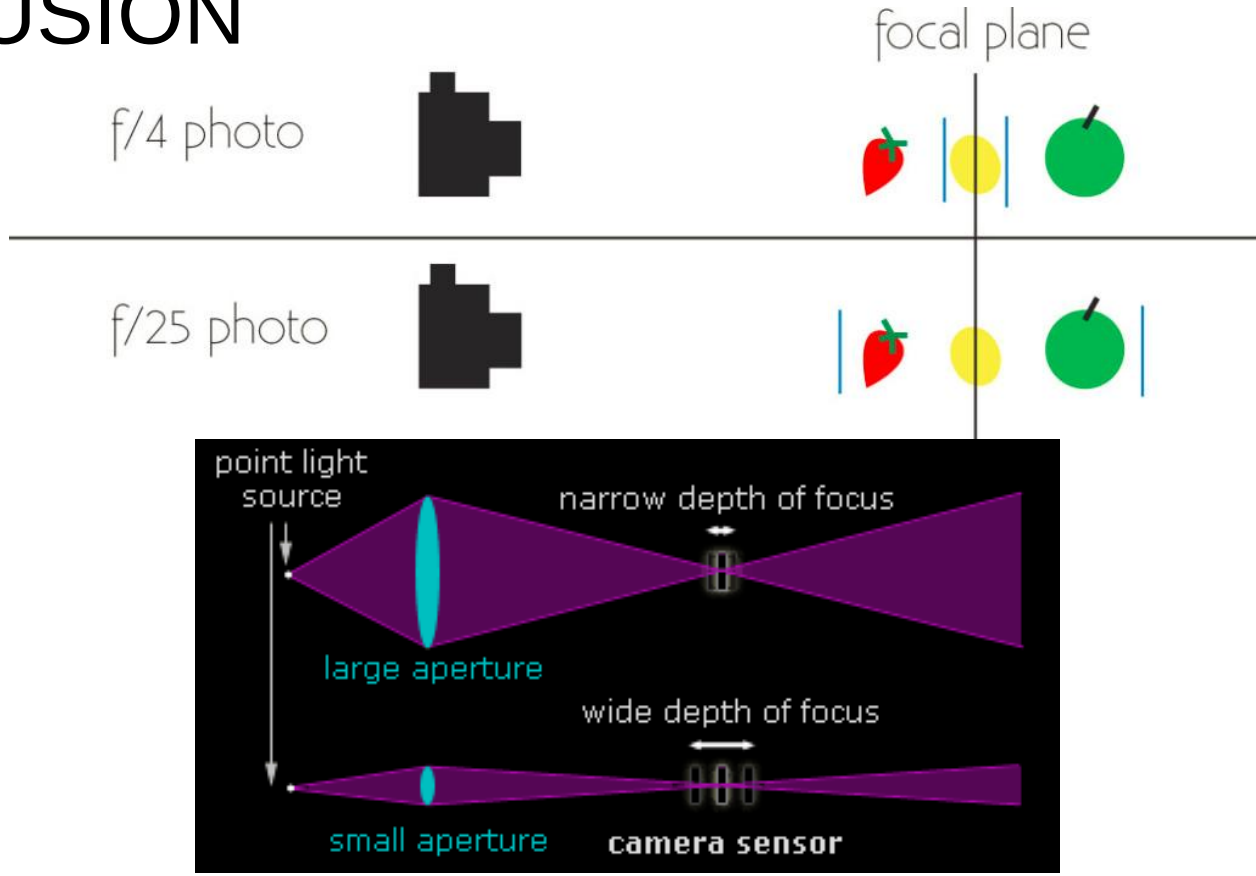
8 (1/8 sec)

Slow shutter speeds can result in motion blur if the scene isn't static or if the camera moves or shakes

Bokeh

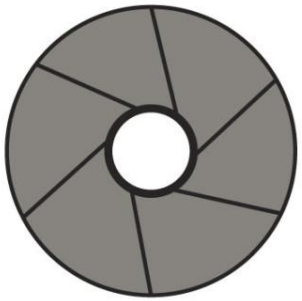
In photography, bokeh is the aesthetic quality of the blur produced in the out-of-focus parts of an image produced by a lens.

APERTURE AND DEPTH OF FIELD
CIRCLE OF CONFUSION



Larger Aperture

Smaller Aperture



Larger Aperture

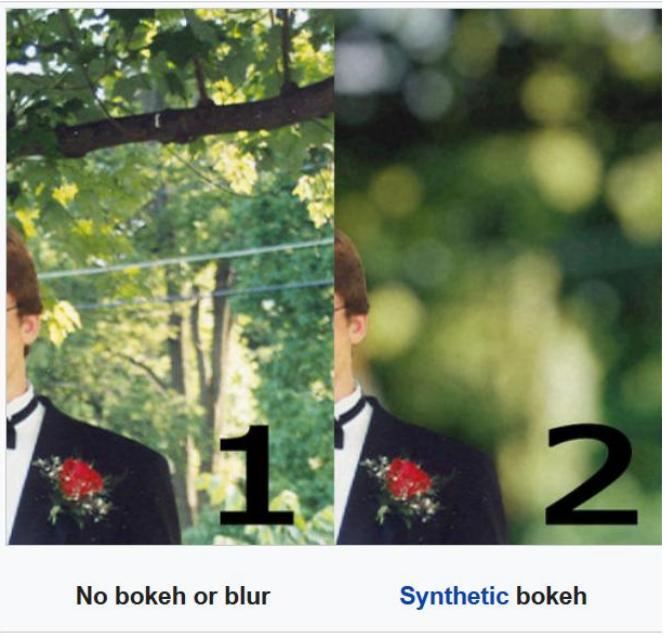
wider opening
more light in
smaller F-number
shallower depth of field

Smaller Aperture

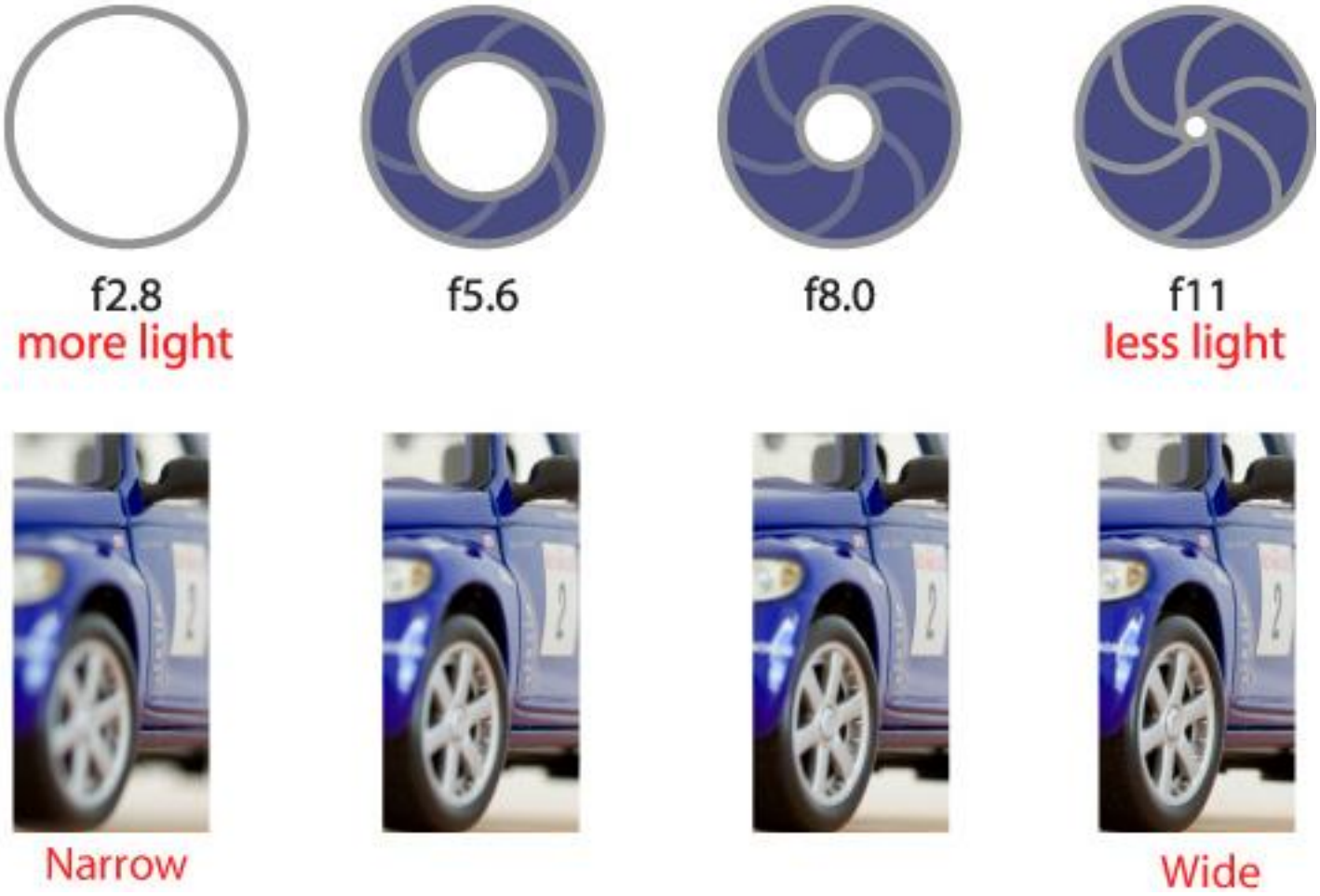
narrower opening
less light in
larger F-number
deeper depth of field

Bokeh Emulation

Bokeh can be simulated by convolving the image with a gaussian kernel to simulate the out-of-focus point source taken with a real camera. The kernel that depends on the distance of each image point and has to include image points that are occluded by objects in the foreground



APERTURE AND SPEED

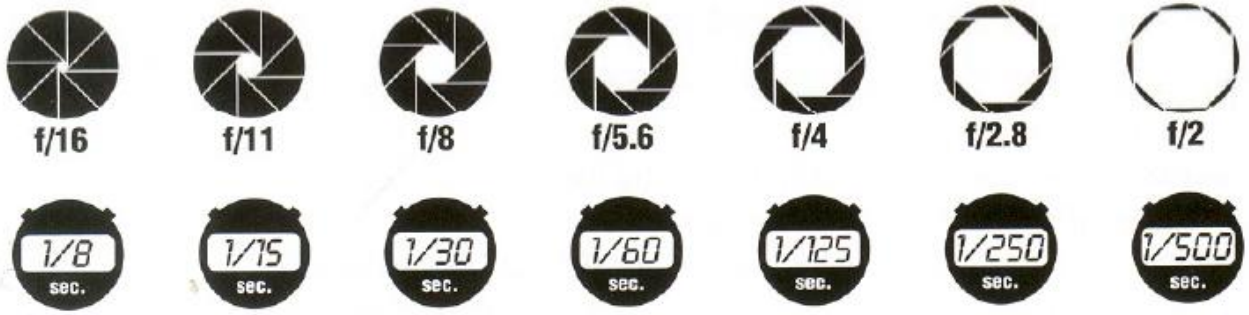


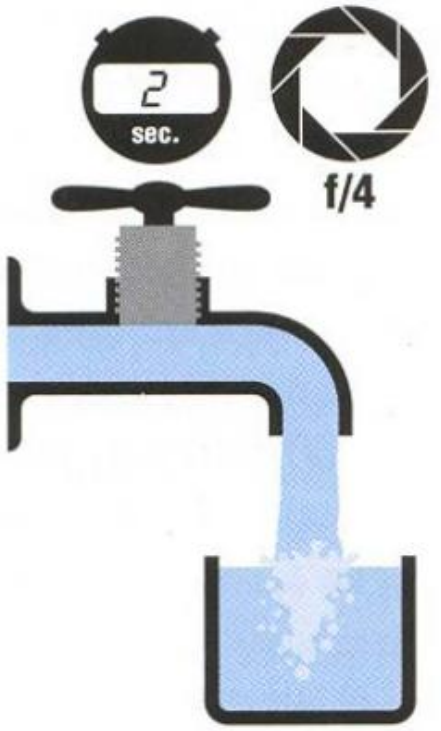
PLAYING WITH EXPOSURE

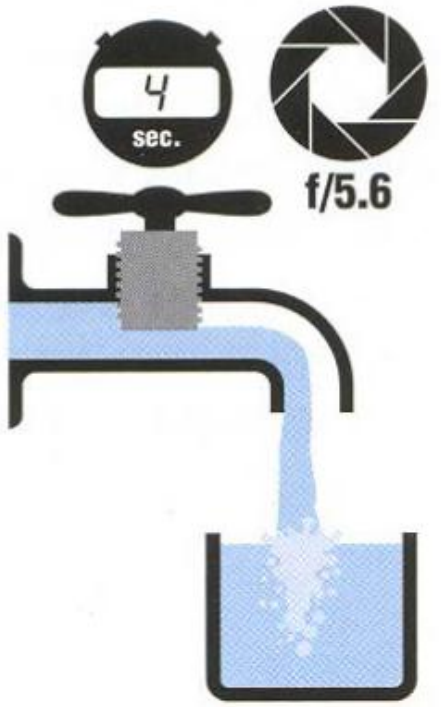
The same exposure is obtained with an exposure time twice as long and an aperture *area* half as big

Assume we know how much light we need

• We have the choice of an infinity of shutter speed/aperture pairs







• What will guide our choice of a shutter speed?

– Freeze motion vs. motion blur, camera shake

• What will guide our choice of an aperture?

– Depth of field

• Often we must compromise

– Open more to enable faster speed (but shallow DOF)

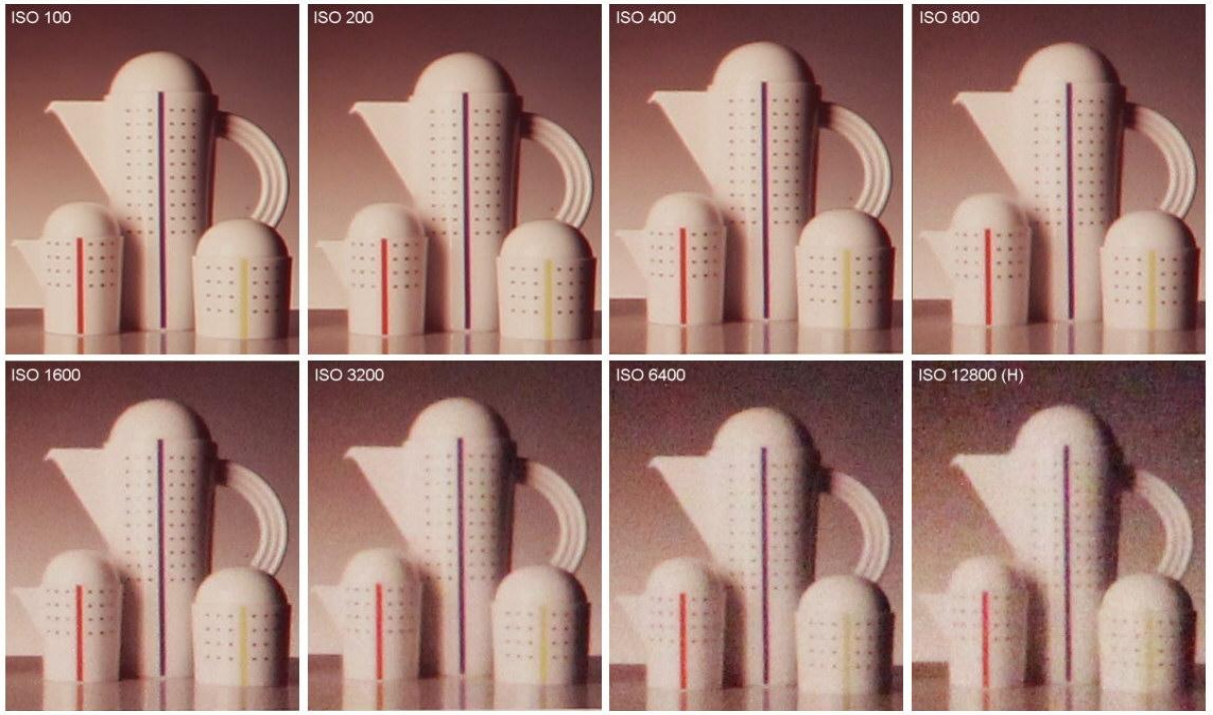
CCD SENSITIVITY (ISO) AND NOISE

One solution to low exposure from a fast shutter speed is to increase the camera's charge-coupled device (CCD) signal (i.e. gain the signal)

- This is analogous to film ISO sensitivity
  – ISO 100 (slow film), ISO 1600 (fast film, x16 more sensitive)

- The drawback?

Amplifying the CCD signal, amplifies the sensor noise!



PHOTOGRAPHY EQUATION

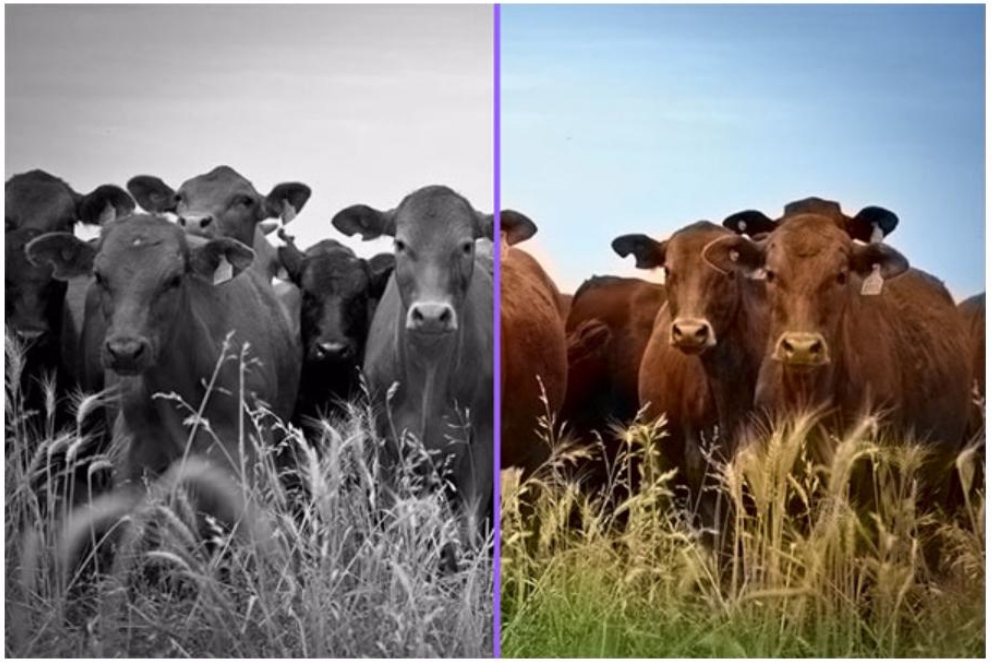
Focal length
– Controls view

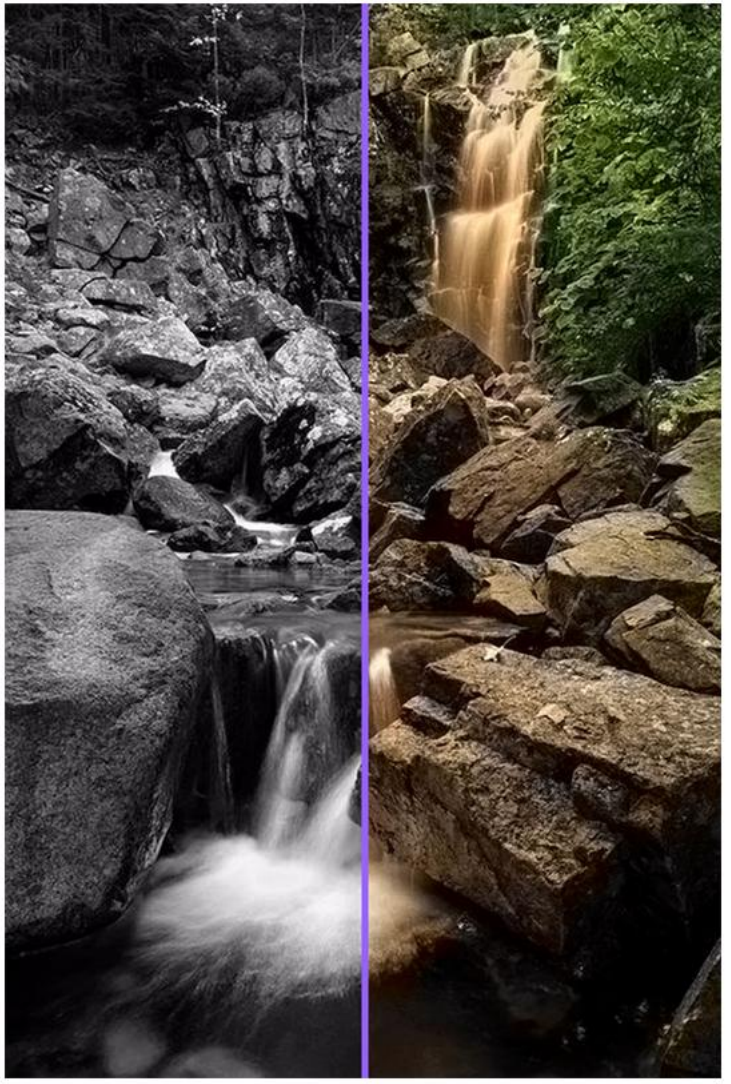
Finessing motion blur, noise, and dof
– Trade-off between shutter speed and aperture

Camera settings	Motion blur artifacts	DoF	Noise
Fast shutter speed Wide aperture Low ISO (gain)	No	Narrow	No
Slow shutter speed Small aperture Low ISO (gain)	Yes	Wide	No
Fast shutter speed Small aperture High ISO (gain)	No	Wide	Yes

AI camera pictures

Learning to color: Can artificial intelligence accurately colorize your black and white photos?





AI camera pictures

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AI camera pictures

Aug 20. 2018

HUAWEI P20'S AI camera: Let Artificial Intelligen ce Do the Heavy Lifting

On the left, the photo features a flower planted against a background of greenery – another scene among the 19 categories supported by Master AI camera. However, since the neural processing u nit (NPU) in the SoC can intelligently identify the objects by assessing their size and position, Mas ter AI had no trouble identifying the flowers and enabling "Flower" mode to highlight the red flowe rs while adding a bokeh effect to the background.

AI camera pictures

Learning to See in the Dark

Chen Chen
UIUC

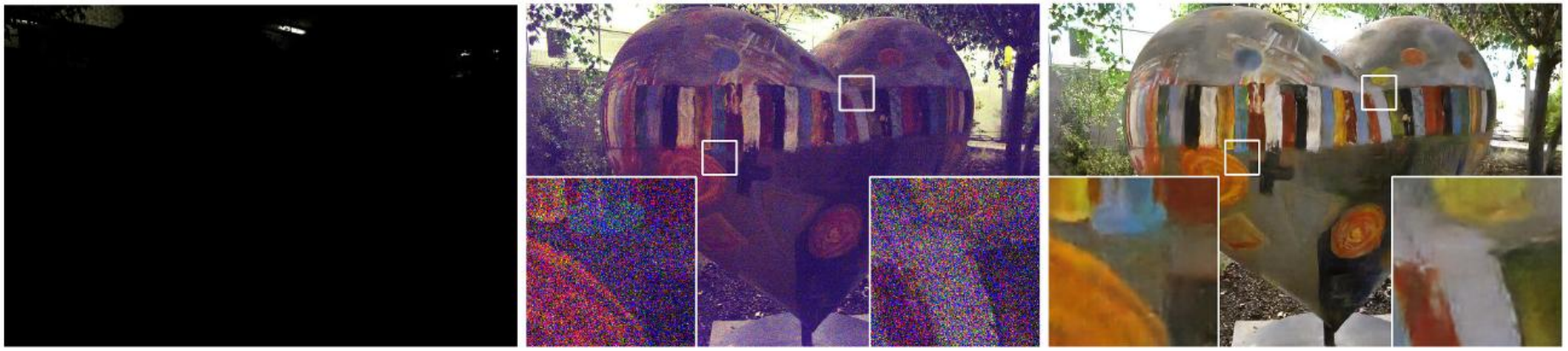
Qifeng Chen
Intel Labs

Jia Xu
Intel Labs

Vladlen Koltun
Intel Labs

(a) Camera output with ISO 8,000 (b) Camera output with ISO 409,600 (c) Our result from the raw data of (a)

Figure 1. Extreme low-light imaging with a convolutional network. Dark indoor environment. The illuminance at the camera is < 0.1 lux. The Sony α7S II sensor is exposed for 1/30 second. (a) Image produced by the camera with ISO 8,000. (b) Image produced by the camera with ISO 409,600. The image suffers from noise and color bias. (c) Image produced by our convolutional network applied to the raw sensor data from (a).



(a) JPEG image produced by camera (b) Raw data via traditional pipeline (c) Our result

Figure 5. (a) An image captured at night by the Fujifilm X-T2 camera with ISO 800, aperture f/7.1, and exposure of 1/30 second. The illuminance at the camera is approximately 1 lux. (b) Processing the raw data by a traditional pipeline does not effectively handle the noise and color bias in the data. (c) Our result obtained from the same raw data.

(a) Traditional pipeline (b) Our result

EXPOSURE FUSION, HIGH DYNAMIC RANGE AND TONE MAPPING

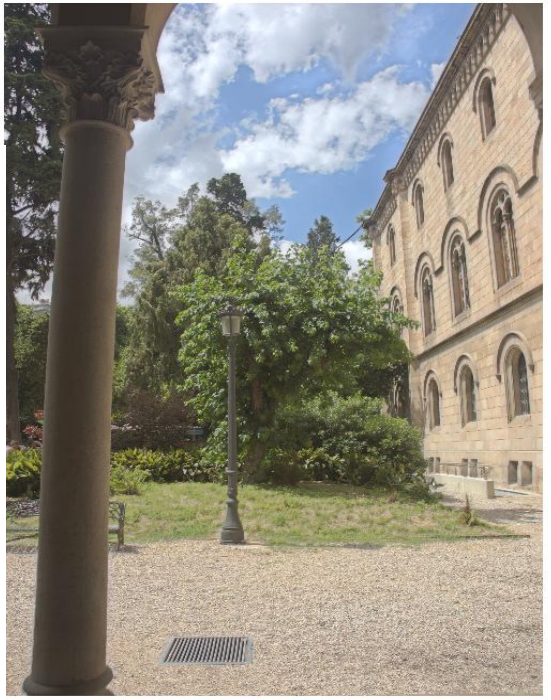
The dynamic range challenge.

Inside is too dark, outside is too bright.

Sun overexposed, foreground is too dark.

Underexposed (EV: -2)

Overexposed (EV: +2)



EXPOSURE FUSION

It is usual to express the game of exposures as
[…, -2, -1 , 0, +1, +2, ...] This value is called Exposure Value:

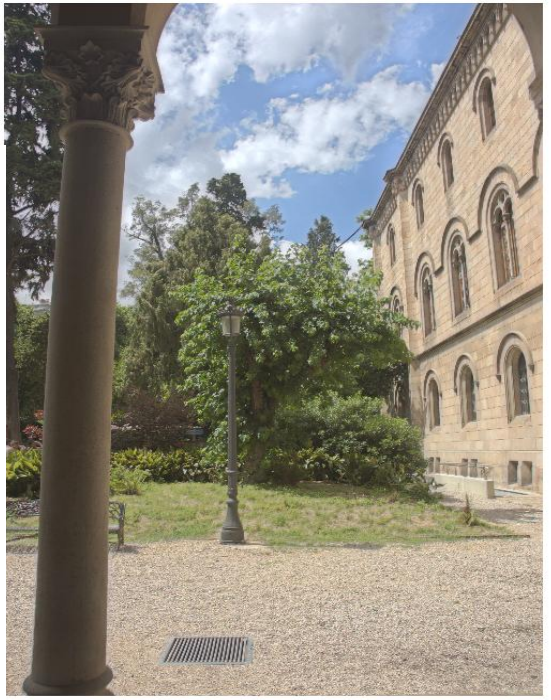
$$EV = \log_2 \frac{N^2}{t}$$

N: Relative aperture (f-number)

t: Exposure time (“shutter speed”)

Underexposed (EV: -2)

Overexposed (EV: +2)



EXPOSURE FUSION

Assume a film response: $I = E\Delta t$

E: Irrandiance

Underexposed (EV: -2)

$I_{\text{under}} = E\frac{\Delta t}{4}$

$I = E\Delta t$

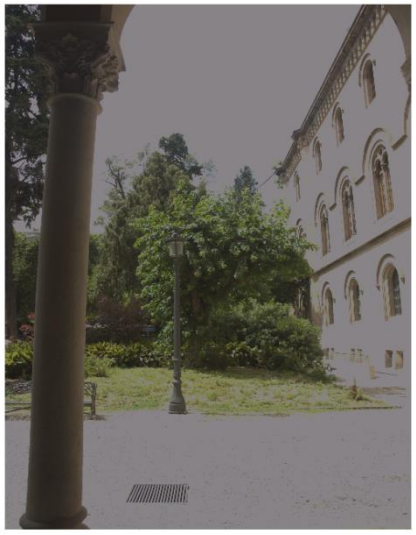
Overexposed (EV: +2)

$I_{\text{over}} = E4\Delta t$

EXPOSURE FUSION

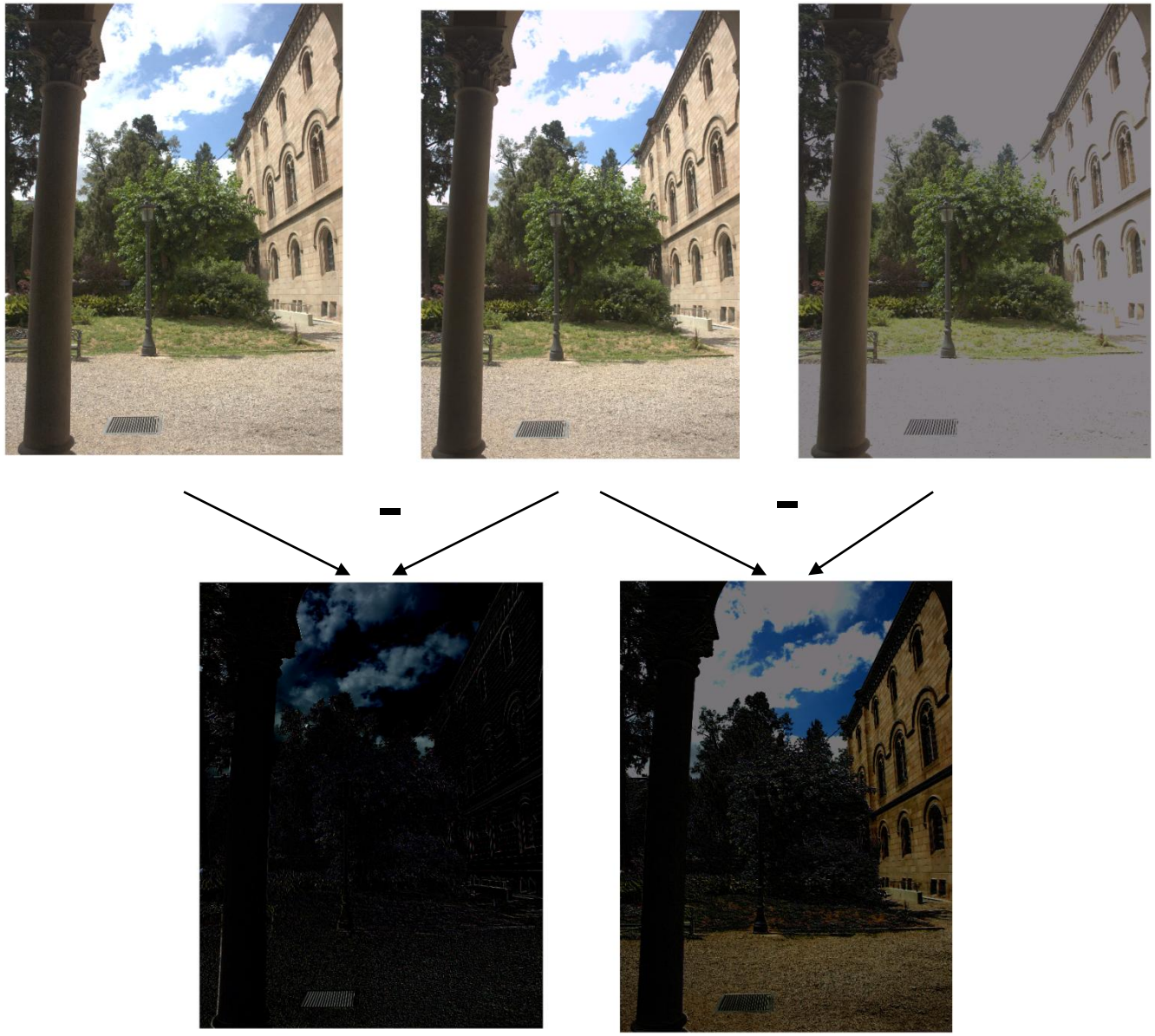
Underexposed (EV: -2)

Overexposed (EV: +2)



$$4I_{\text{under}} = E\Delta t \qquad I = E\Delta t \qquad \frac{I_{\text{over}}}{4} = E\Delta t$$

EXPOSURE FUSION



Error comes from clipping.