

Announcements

- HW 1 online, sign up for piazza, OpenEdX, regularly check course website!
- Weekly problem session: Fridays 4:30-5:20pm in **Huang 18** (also recorded)
- SOCRATIVE.com use Room: ee368
- SCIEN – imaging-related talks series, every Wed afternoon 4:15pm (see scien.stanford.edu)
- cool VR demo (and 10 min user study): email Tal Stramer (tstramer@stanford.edu)
- questions?

Point Operations

- How do gray values relate to brightness?
- Quantization
- Weber's Law
- Gamma characteristic
- Adjusting brightness and contrast

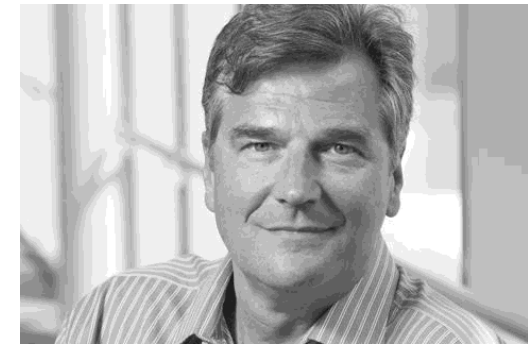
Quantization: how many bits per pixel?



8 bits



5 bits



4 bits



3 bits



2 bits



1 bit

„Contouring“



How many gray levels are required?

- Contouring is most visible for a ramp

32 levels



64 levels



128 levels

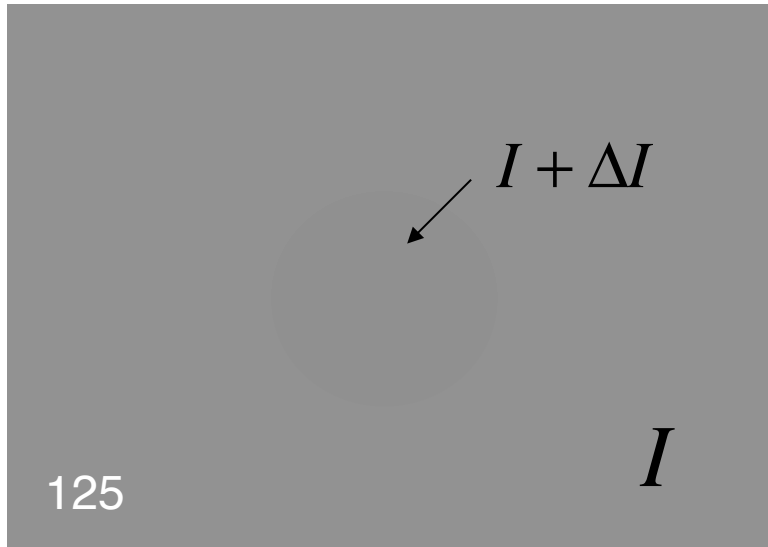


256 levels



- Digital images typically are quantized to 256 gray levels.

Brightness discrimination experiment



Visibility threshold

$$\Delta I / I \approx 1 \dots 2\%$$

„Weber fraction“
„Weber's Law“



Note: I is luminance, measured in cd/m^2

Can you see the circle?

Human brightness perception is uniform
in the $\log(I)$ domain („Fechner's Law“)

Contrast ratio without contouring

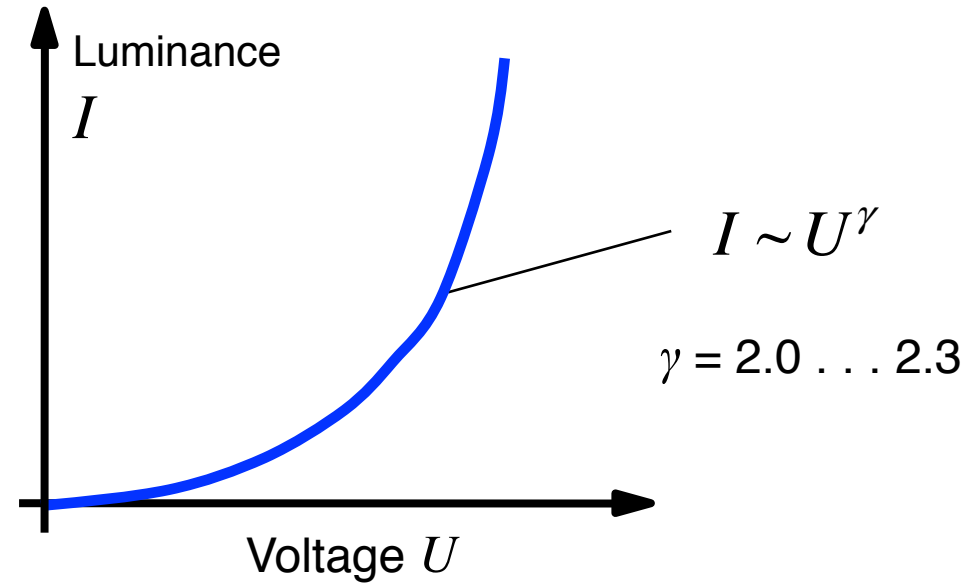
- Luminance ratio between two successive quantization levels at visibility threshold

$$\frac{I_{\max}}{I_{\min}} = (1 + K_{Weber})^{N-1}$$

- For $K_{Weber} = 0.01 \dots 0.02$ $N = 256$ $I_{\max} / I_{\min} = 13 \dots 156$
- Typical display contrast ratio
 - Modern flat panel display in dark room 1000:1
 - Cathode ray tube 100:1
 - Print on paper 10:1

Gamma characteristic

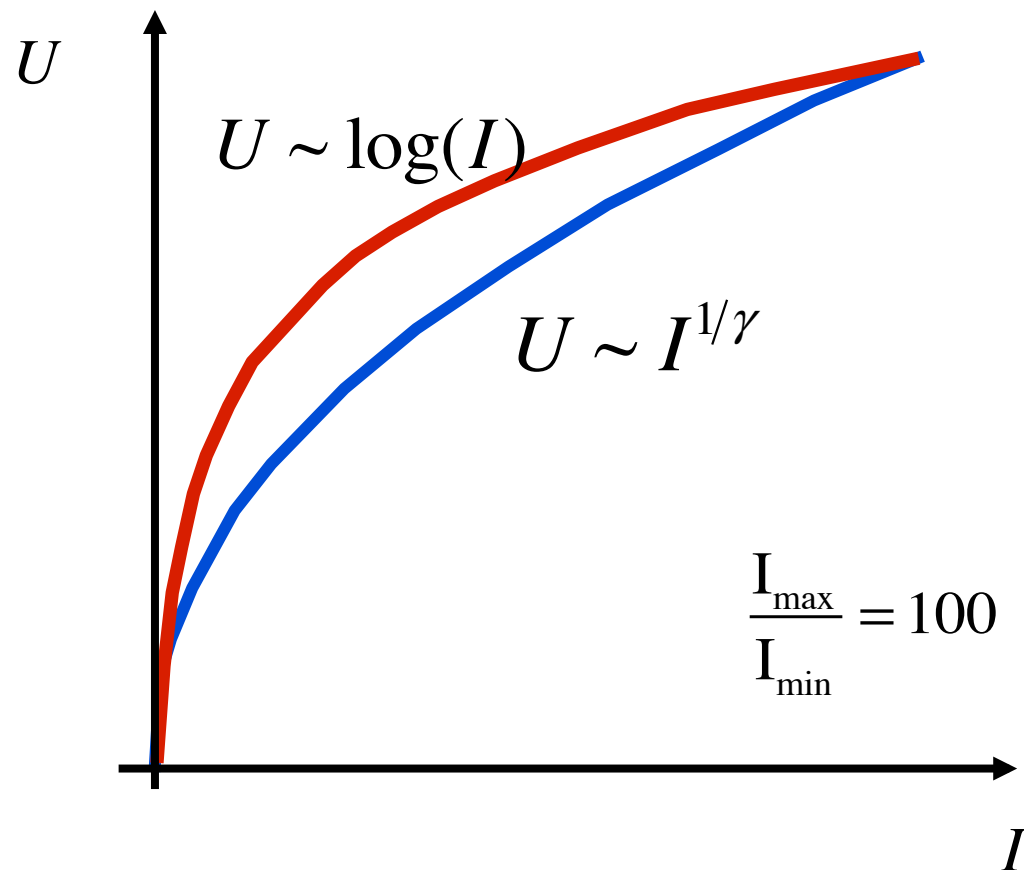
- Cathode ray tubes (CRTs) are nonlinear



- Cameras contain γ -predistortion circuit

$$U \sim I^{1/\gamma}$$

log vs. γ -predistortion



- Weber's Law suggests uniform perception in the $\log(I)$ domain
- Similar enough for most practical applications

Brightness adjustment by intensity scaling

Original image



$f[x,y]$

Scaled image



$a \cdot f[x,y]$

Scaling in the γ -domain is equivalent to scaling in the linear luminance domain

$$I \sim (a \cdot f[x,y])^\gamma = a^\gamma \cdot (f[x,y])^\gamma$$

. . . same effect as changing camera exposure time.



Contrast adjustment by changing γ

Original image



$$f[x,y]$$

γ increased by 50%



$$a \cdot (f[x,y])^\gamma$$

with $\gamma = 1.5$

. . . same effect as using a different photographic film . . .



Contrast adjustment by changing γ

