Focusing & metering

CS 448A, Winter 2010

Marc Levoy
Computer Science Department
Stanford University

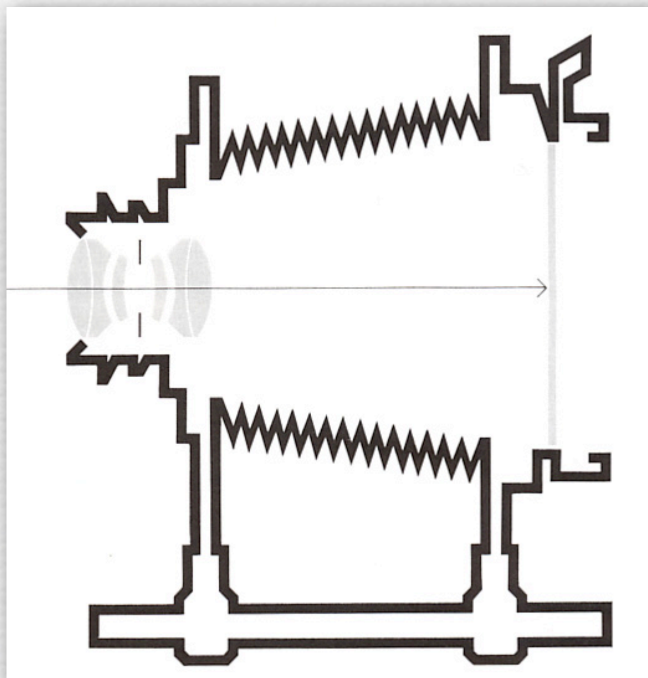
Outline: focusing

- viewfinders and manual focusing
- view cameras and tilt-shift lenses
- active autofocusing
  - time-of-flight
  - triangulation
- passive autofocusing
  - phase detection
  - contrast detection
- autofocus modes
- lens actuators

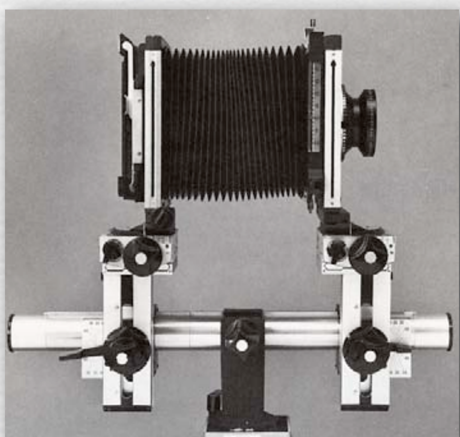
- metering

Large format camera with focusing screen

- 4×5" or 8×10" formats
  - film or scanned digital
- ground glass focusing screen
  - dim
  - hard to focus
  - inverted image



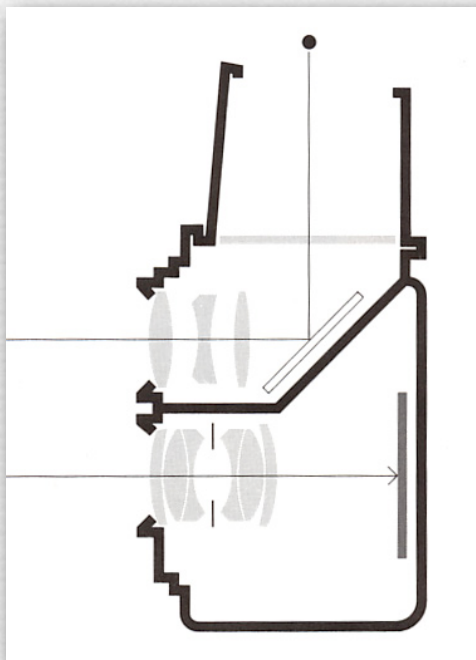
(Adams)



Sinar 4×5

Twin-lens reflex with focusing screen

- older medium format cameras
  - 2¼ × 2¼” film
- different perspective view than main lens sees



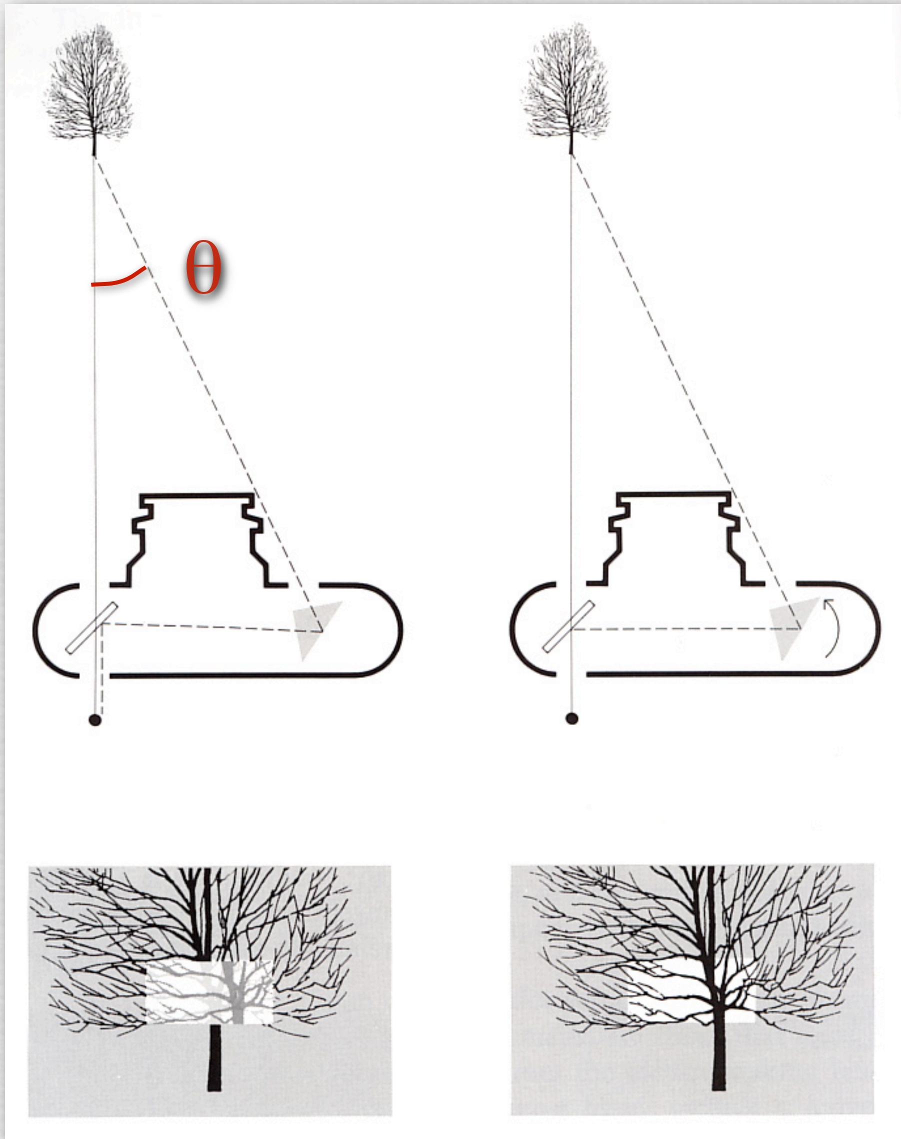
(Adams)

Manual rangefinder

- accurate
- painstaking
- different perspective view than main lens sees
- triangulation concept widely applicable

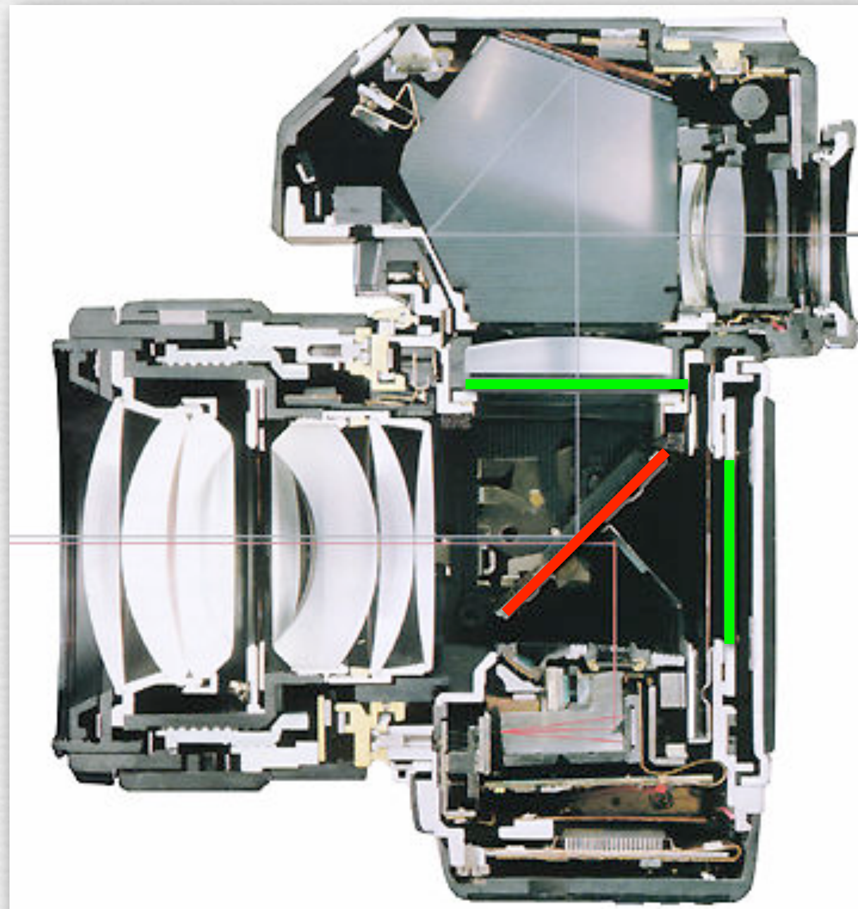
Leica

(Adams)



Single lens reflex with viewfinder

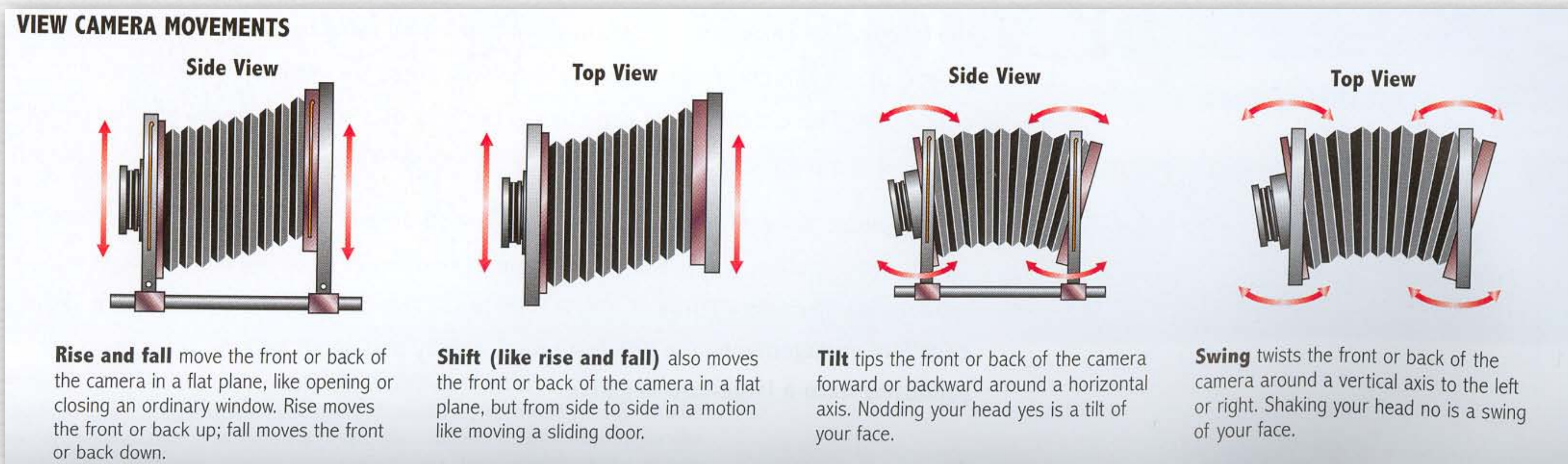
- image formed on focusing screen, seen (upright) through viewfinder
- same view as main lens
- mirror must be moved (quickly) to take picture
- manual or autofocus



Nikon F4

Special-purpose lenses: view camera

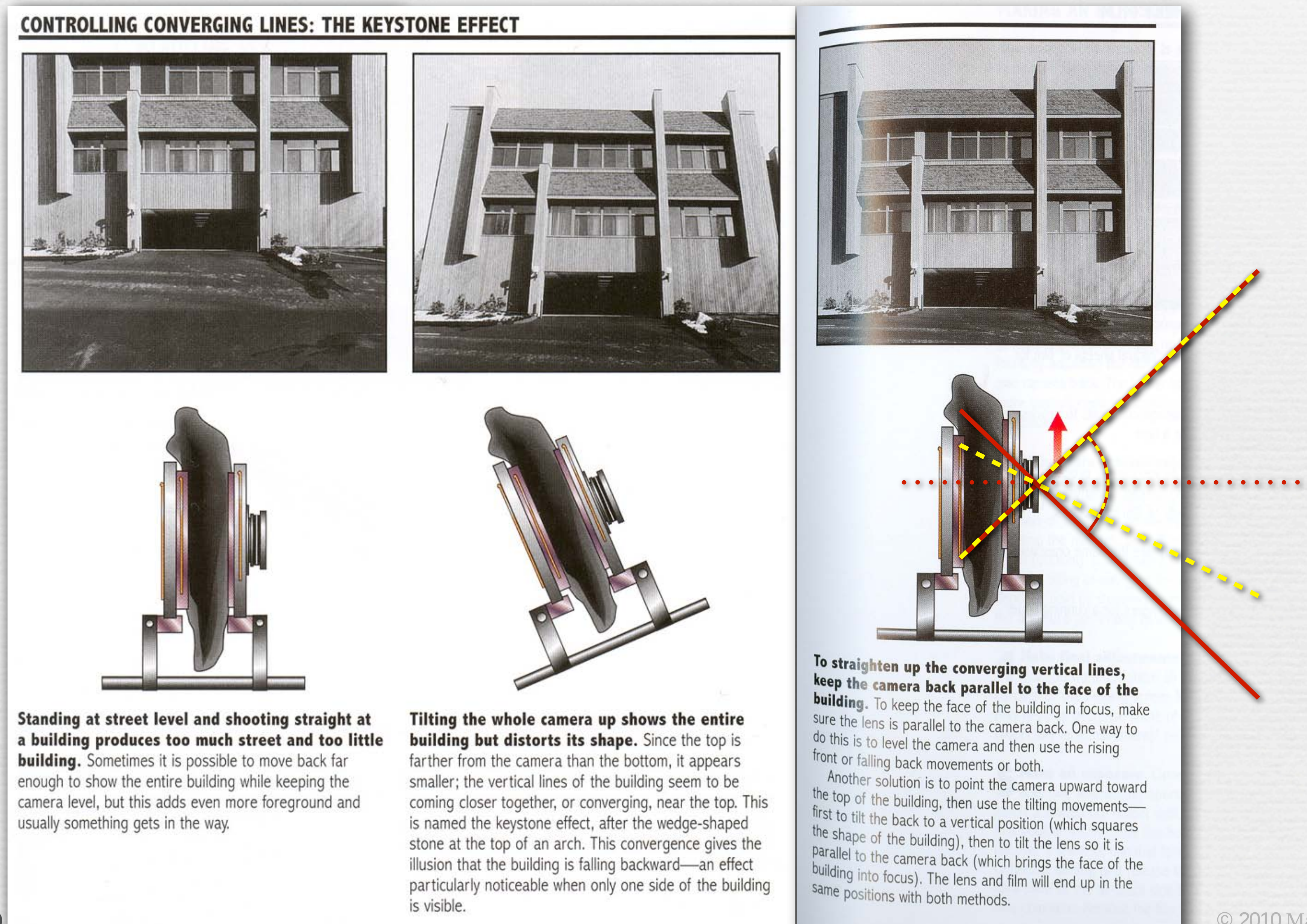
Sinar view camera with digital back



(London)

Off-axis perspective

NOW AVAILABLE IN PHOTOSHOP !!



CONTROLLING CONVERGING LINES: THE KEYSTONE EFFECT

Standing at street level and shooting straight at a building produces too much street and too little building. Sometimes it is possible to move back far enough to show the entire building while keeping the camera level, but this adds even more foreground and usually something gets in the way.

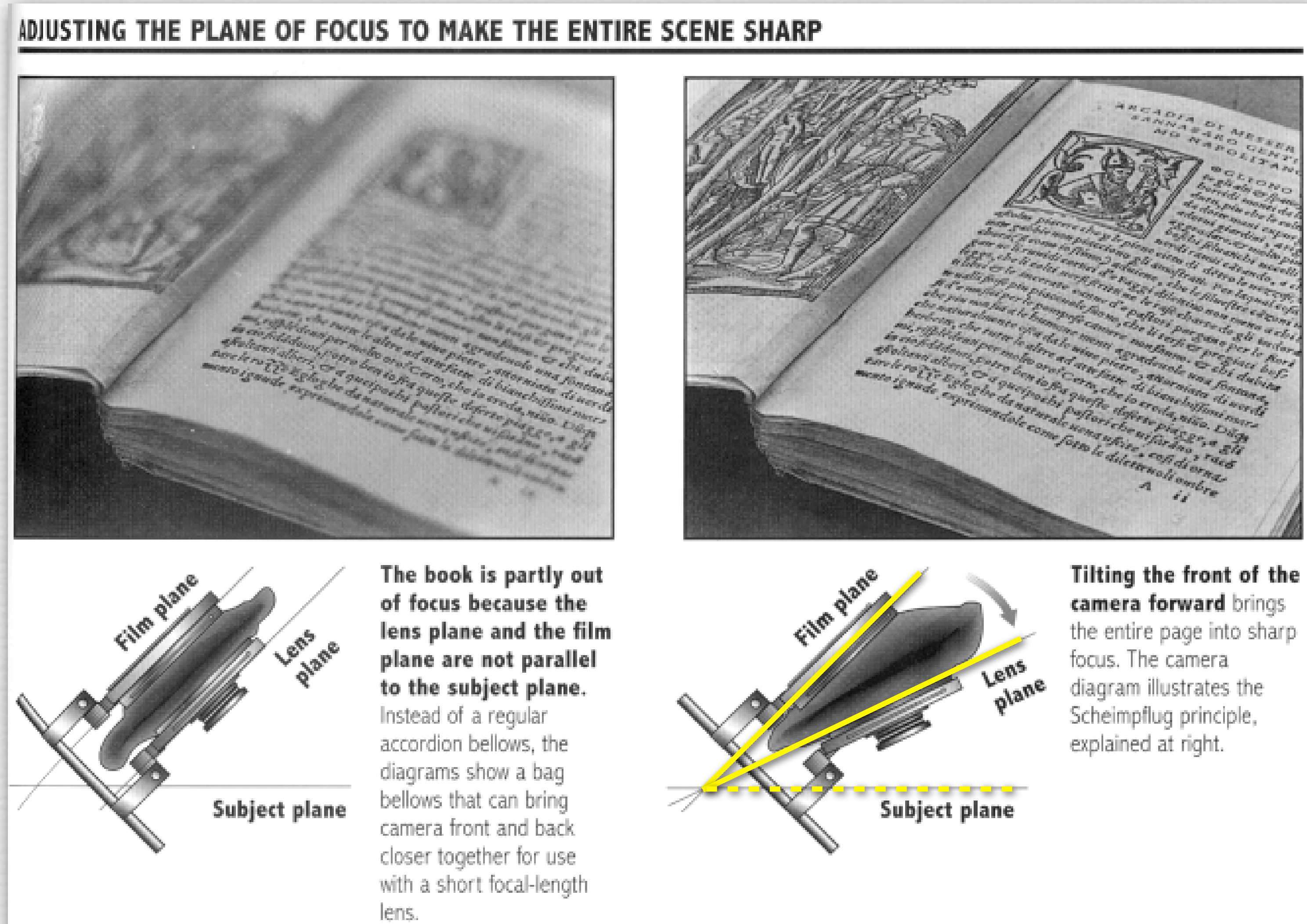
Tilting the whole camera up shows the entire building but distorts its shape. Since the top is farther from the camera than the bottom, it appears smaller; the vertical lines of the building seem to be coming closer together, or converging, near the top. This is named the keystone effect, after the wedge-shaped stone at the top of an arch. This convergence gives the illusion that the building is falling backward—an effect particularly noticeable when only one side of the building is visible.

To straighten up the converging vertical lines, keep the camera back parallel to the face of the building. To keep the face of the building in focus, make sure the lens is parallel to the camera back. One way to do this is to level the camera and then use the rising front or falling back movements or both.

Another solution is to point the camera upward toward the top of the building, then use the tilting movements—first to tilt the back to a vertical position (which squares the shape of the building), then to tilt the lens so it is parallel to the camera back (which brings the face of the building into focus). The lens and film will end up in the same positions with both methods.

(London)

Tilted focal plane



(London)

- Scheimpflug condition

✦ cannot be done after the photograph is taken

Ansel Adams, Railroad Tracks

Ansel Adams, Monument Valley

Tilt-shift lenses

Canon TS-E
90mm lens

Tilt-shift lenses

Canon TS-E
90mm lens

The "miniature model" look

Canon TS-E 24mm II

- simulates a macro lens with a shallow depth of field, hence makes any scene look like a miniature model

The "miniature model" look

Canon TS-E
24mm II

- simulates a macro lens with a shallow depth of field, hence makes any scene look like a miniature model

Not a tilt-shift lens

(http://www.tiltshiftphotography.net/)

- gradient blur in Photoshop

Not a tilt-shift lens

(http://www.tiltshiftphotography.net/)

- gradient blur in Photoshop

original

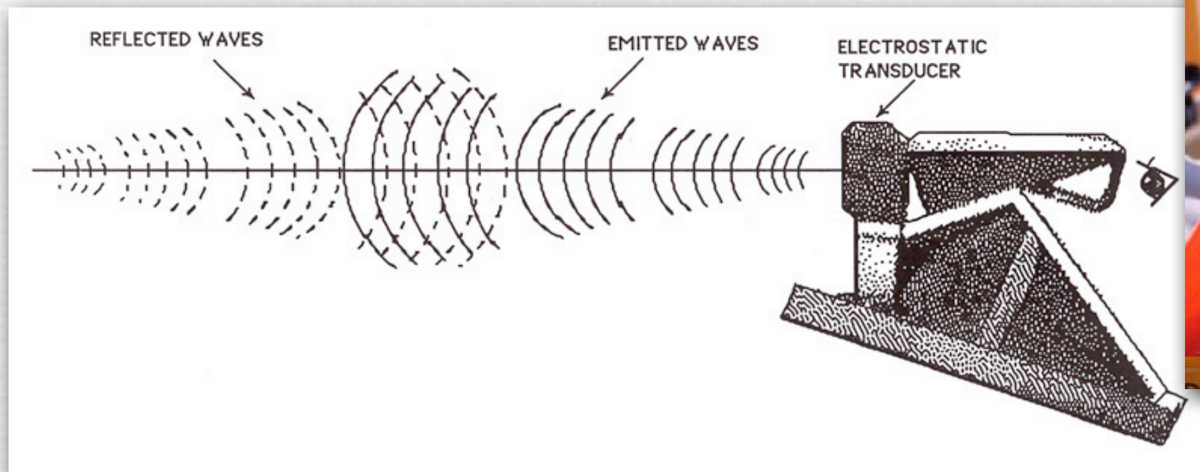
Not a tilt-shift lens

- gradient blur in Photoshop

Q. Is this "fake" identical to the output of a real tilt-shift lens?

(http://www.tiltshiftphotography.net/)

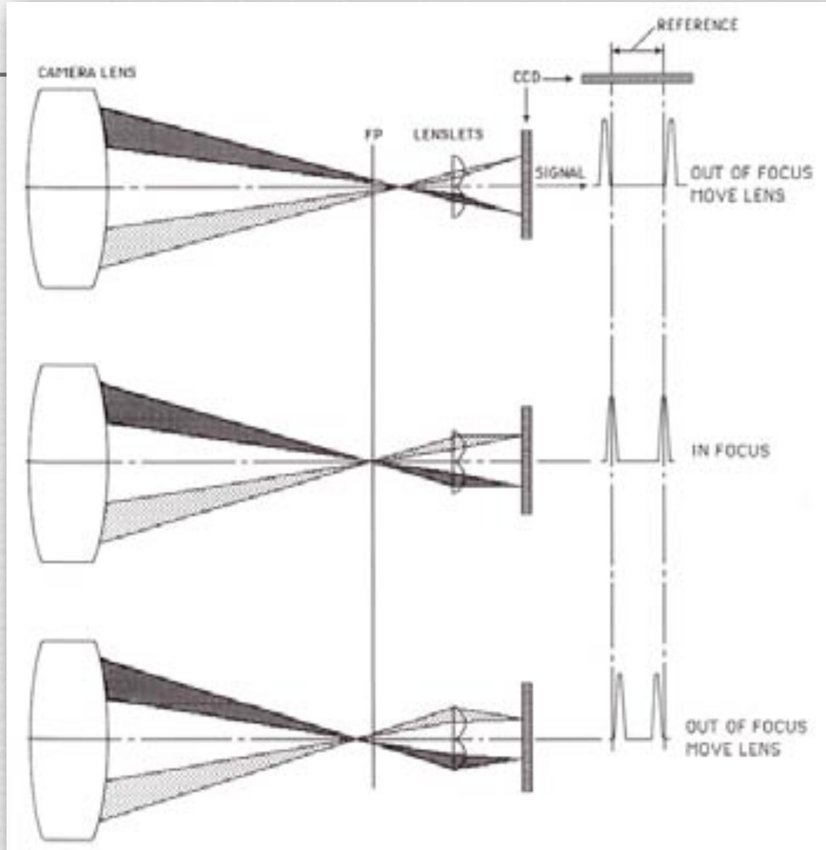
Active autofocus: time-of-flight



(Goldberg)

- SONAR = Sound Navigation and Ranging
- Polaroid system used ultrasound (50KHz)
  - well outside human hearing (20Hz - 20KHz)
- limited range, stopped by glass
- hardware salavaged and re-used in amateur robotics

Passive autofocus: phase detection



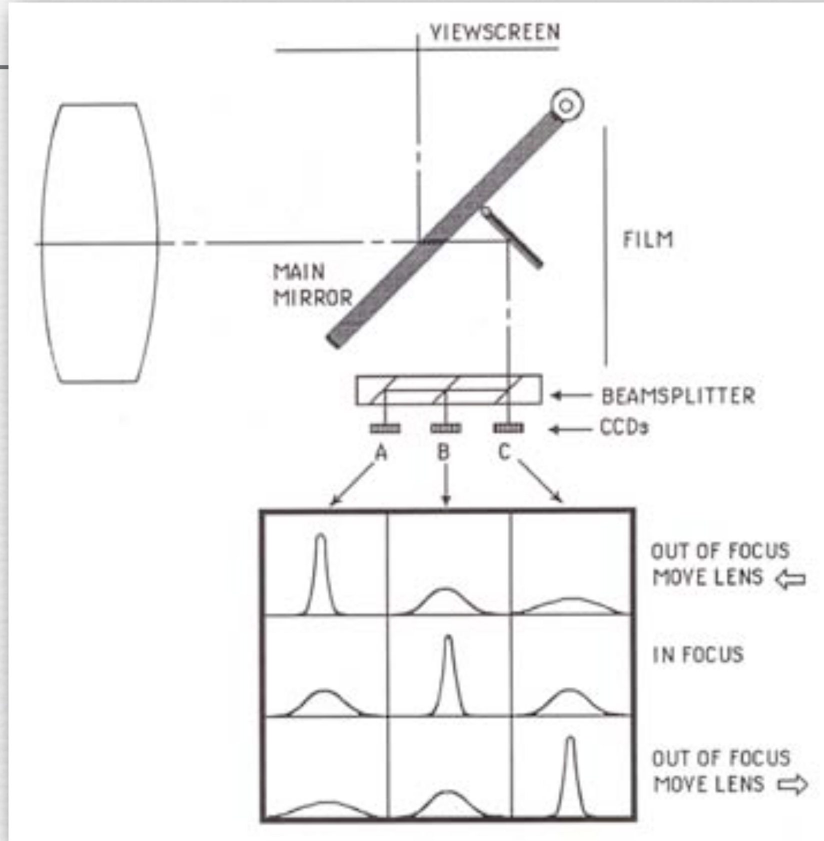
(Goldberg)

(FLASH DEMO)

http://graphics.stanford.edu/courses/cs178/applets/autofocuspd.html

- as the lens moves, ray bundles from an object converge to a different point in the camera and change in angle
- this change in angle causes them to refocus through two lenslets to different positions on a separate AF sensor
- a certain spacing between these double images is "in focus"

Passive autofocus: contrast detection



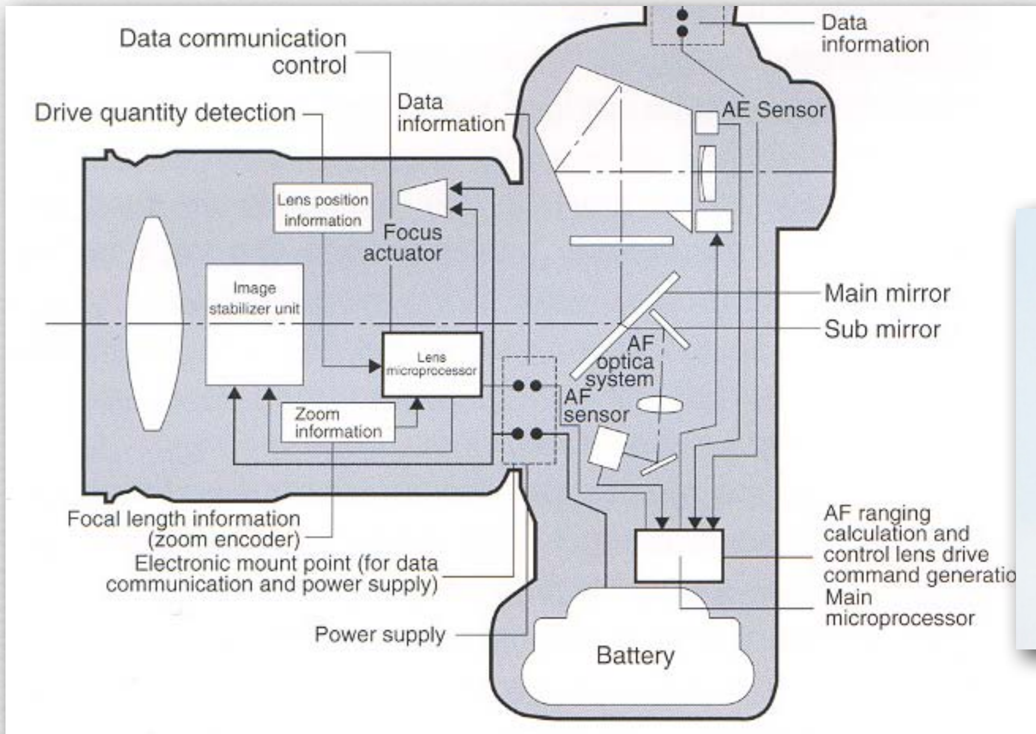
(Goldberg)

(FLASH DEMO)

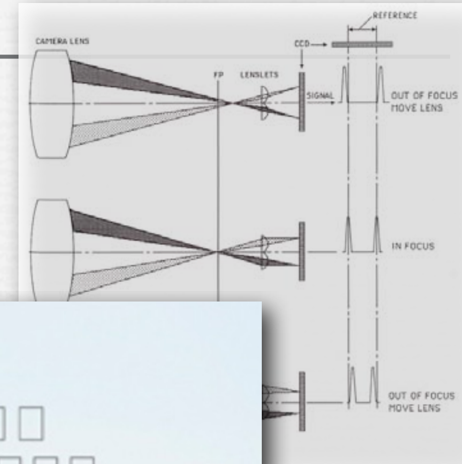
http://graphics.stanford.edu/courses/cs178/applets/autofocuscd.html

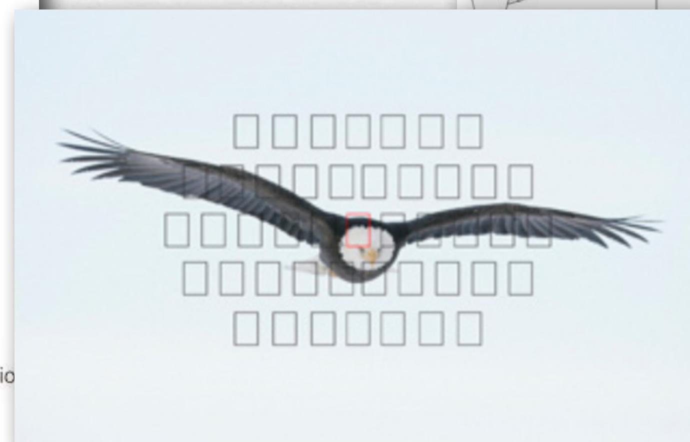
- sensors at different image distances will see the same object as contrasty if it's in focus, or of low contrast if it's not
- move the lens until the contrasty subimage falls on the middle sensor, which is conjugate to the camera's main sensor
- compute contrasty-ness using local differences of pixel values

Most SLRs use phase detection

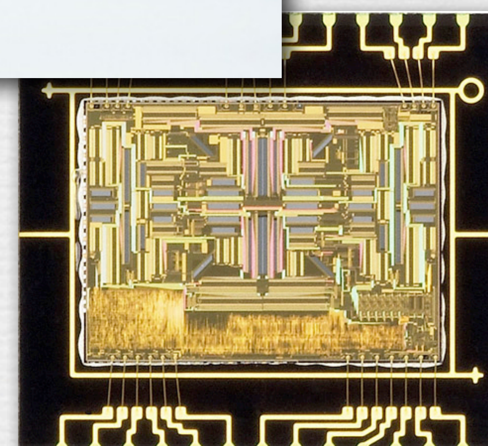


(Canon)





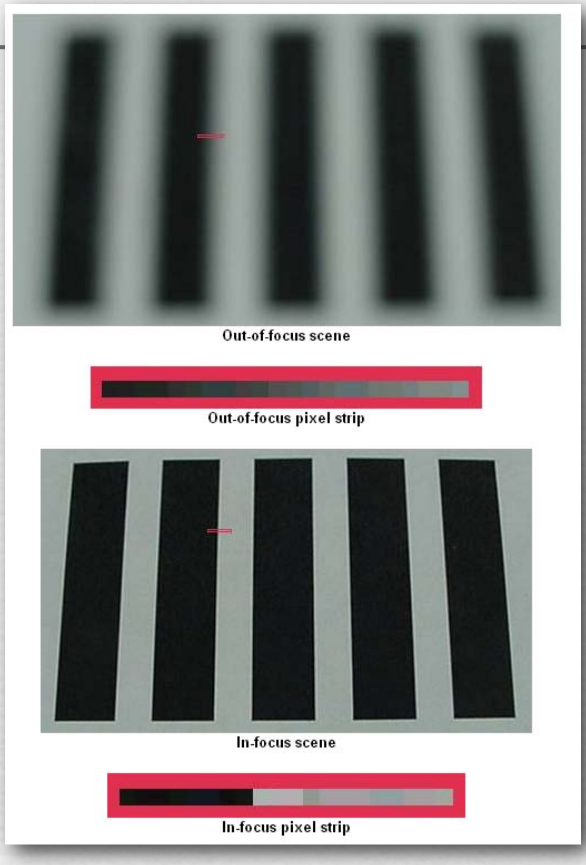
Canon 7D

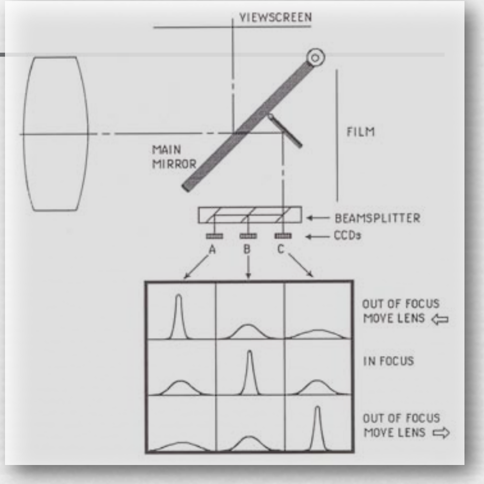


- distance between subimages allows lens to move directly into focus, without hunting
  - equivalent to depth-from-stereo in computer vision
- many AF points, complicated algorithms for choosing among them
  - generally use closest point, but also consider position in FOV

Most DSCs use contrast detection

(howstuffworks.com)





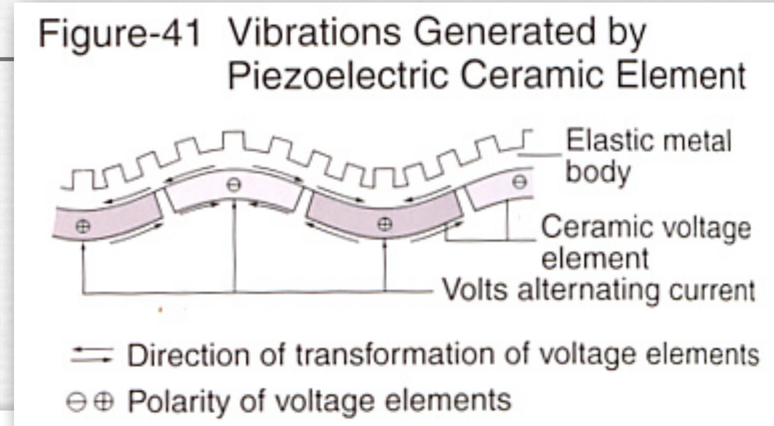
- uses main camera sensor
- requires repeated measurements as lens moves, which are captured using the main sensor
  - equivalent to depth-from-focus in computer vision
- slow, requires hunting, suffers from overshooting
  - it's ok if still cameras overshoot, but video cameras shouldn't

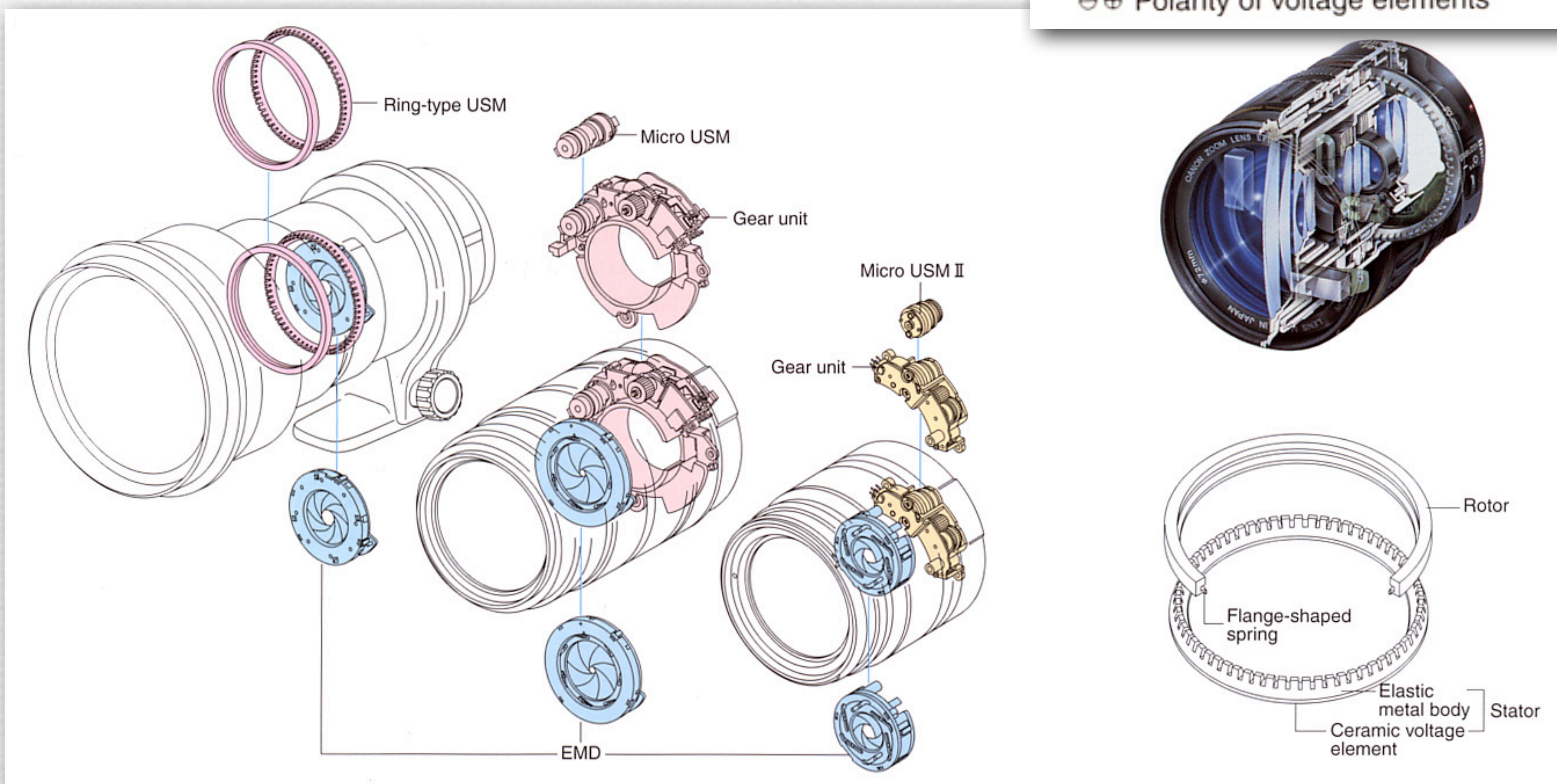
Autofocus modes

- AI servo (Canon) / Continuous servo (Nikon)
  - continues autofocusing as long as shutter is pressed halfway
  - predictive tracking so focus doesn't lag objects moving axially
- focusing versus metering
  - autofocus first, then meter on those points
- "trap focus"
  - trigger a shot if an object comes into focus (Nikon)
- depth of field focusing
  - find closest and furthest object; set focus and N accordingly
- overriding autofocus
  - manually triggered autofocus (AF-ON in Canon)

Lens actuators

- Canon ultrasonic motor (USM)





(Canon)

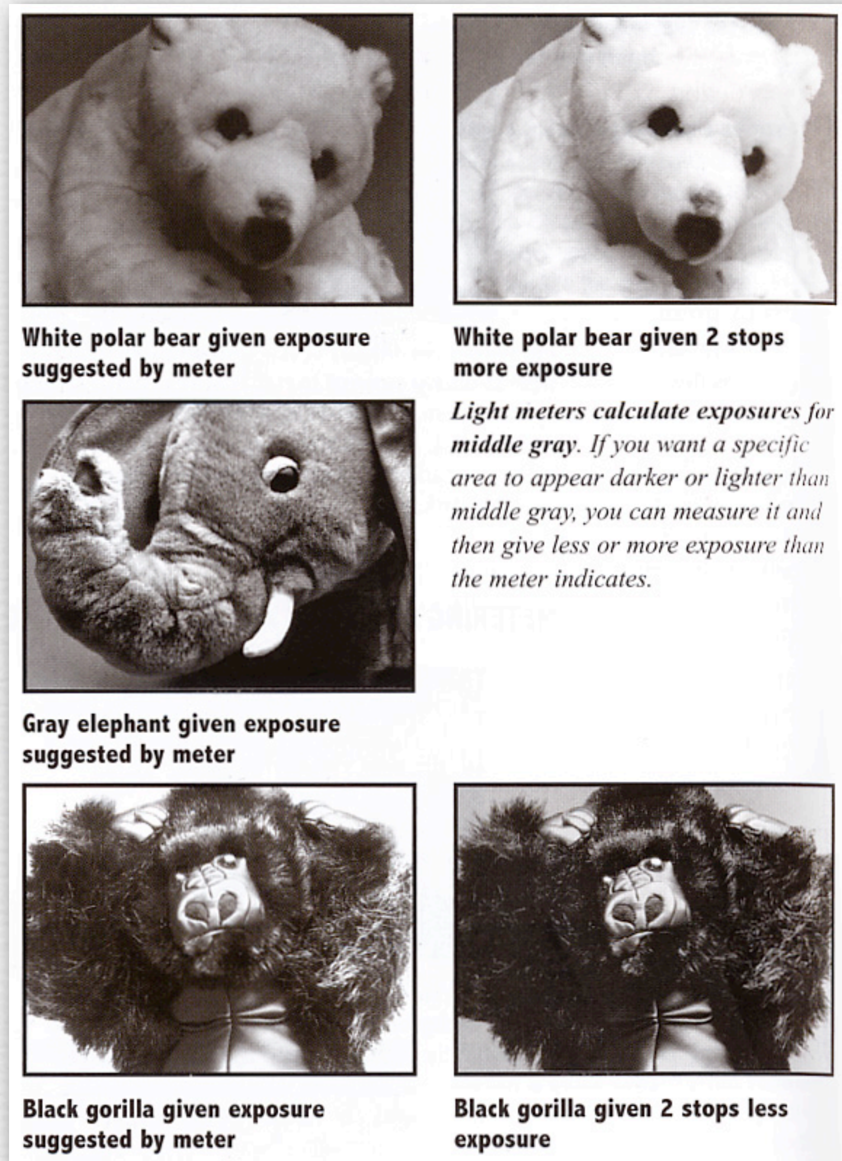
Outline: metering

- What makes metering hard?
  - the meter doesn't know what you're looking at
  - the dynamic range problem
- background topics
  - Ansel Adams' zone system
  - gamma and gamma correction
- metering technologies
- metering modes (center, evaluative,...)
- shooting modes (Av, Tv, P, M)
- exposure compensation, etc.

What makes metering hard?

(London)

- light meters don't know what you're looking at
  - so they assume the scene is mid-gray (18% reflective)
- the world is full of hard metering problems...

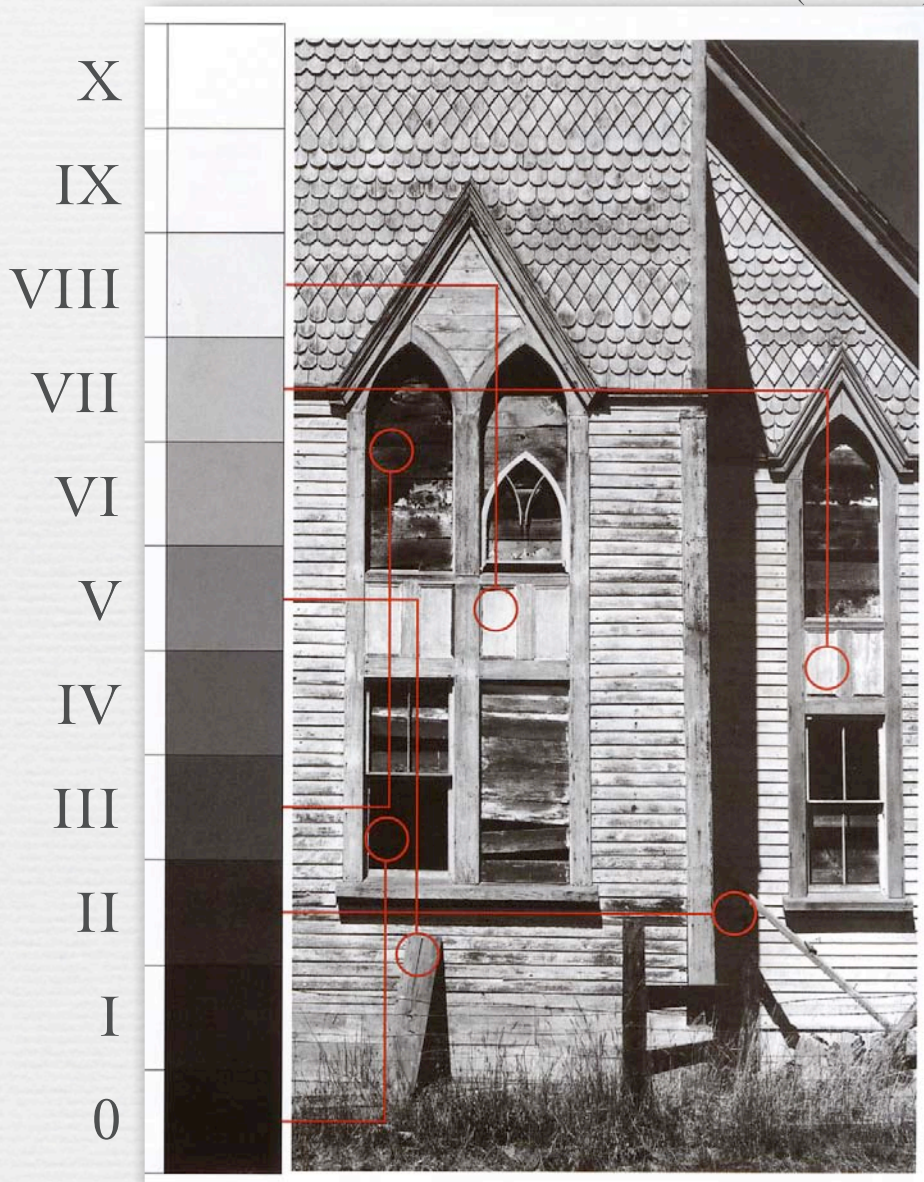


(http://fotocommunity.de)

Ansel Adams's zone system

- roughly 1 f/stop per zone
  - X = "maximum white of the paper base"
  - IX = "slight tonality, but no texture: flat snow in sunlight"
  - VIII = "textured snow, lightest wood at right"
  - .....
  - V = 18% gray card
  - .....
  - 0 = "maximum black that photographic paper can produce"
- lesson for the digital age
  - plan the tones you want in your image for each part of the scene

(London)



Gamma and gamma correction

- the goal of digital imaging is to accurately reproduce relative scene luminances on a display screen
  - absolute luminance is impossible to reproduce
  - humans are sensitive to relative luminance anyway
  - "system gamma" adjusts for ambient viewing conditions

(FLASH DEMO)

http://graphics.stanford.edu/courses/cs178/applets/gamma.html

- in some workflows, pixel value is proportional to scene luminance, in other systems to perceived brightness
  - the first simplifies CG rendering calculations; the second makes better use of limited bitdepth

JPEG file: pixel value ∝ ~perceived brightness

(Marc Levoy)

RAW file, "linear" option: pixel value ∝ scene luminance (Marc Levoy)

Gamma and gamma correction

- the goal of digital imaging is to accurately reproduce relative scene luminances on a display screen
  - absolute luminance is impossible to reproduce
  - humans are sensitive to relative luminance anyway
  - "system gamma" adjusts for ambient viewing conditions

(FLASH DEMO)

http://graphics.stanford.edu/courses/cs178/applets/gamma.html

- in some workflows, pixel value is proportional to scene luminance, in other systems to perceived brightness
  - the first simplifies CG rendering calculations; the second makes better use of limited bitdepth
- gamma correction has been unstandardized for 20 years
  - but Macs and now PCs are color managed, as are most browsers, so the situation is improving

The dynamic range problem

- even if meters were omniscient, the dynamic range of the world is higher than the dynamic range of a camera

- the real world

800,000:1	surface illuminated by sun vrs by moon, (20 f/stops, or 1/1000 sec vrs 13 minutes)
100:1	diffuse white surface versus black surface
80,000,000:1	**total dynamic range**

- human vision

100:1	photoreceptors (including bleaching)
10:1	variation in pupil size
100,000:1	neural adaptation
100,000,000:1	**total dynamic range**

The dynamic range problem

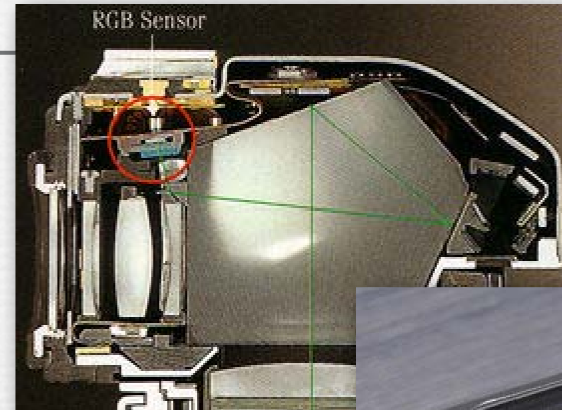
- media (approximate and debatable)

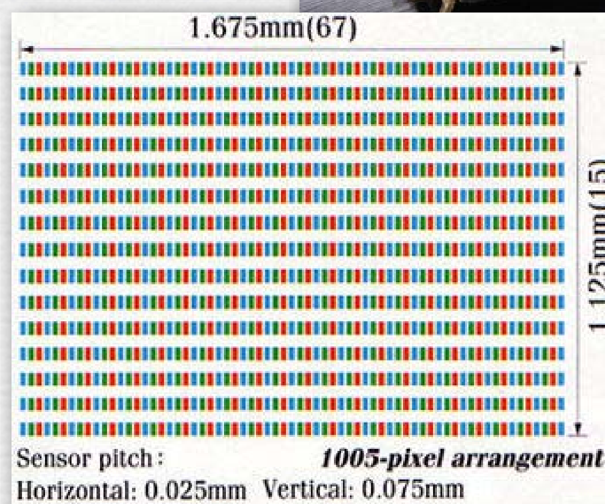
10:1	photographic print (higher for glossy paper)
20:1	artist's paints
200:1	slide film
500:1	negative film
1000:1	LCD display
2000:1	digital SLR (~11 bits)

- challenges
  - choosing which 6-12 bits of the world to include in your photograph (cell phone to professional SLR, respectively)
  - metering the world to help you make this decision, since the world has more dynamic range than any light meter
  - compressing 12 bits into 4 bits for print, or 10 for LCD
    - this is the *tone mapping* problem

Metering technologies

- SLRs use a low-res sensor looking at the focusing screen
  - Nikon: 1005-pixel RGB sensor
  - Canon: silicon photocell (SPC) with 35 B&W zones
  - big pixels, so low res, but wide dynamic range (Canon=20 bits)
- point-and-shoots use the main image sensor
  - small pixels, so easily saturated
  - if saturated, reduce exposure time and try again
- both are through the lens (TTL)

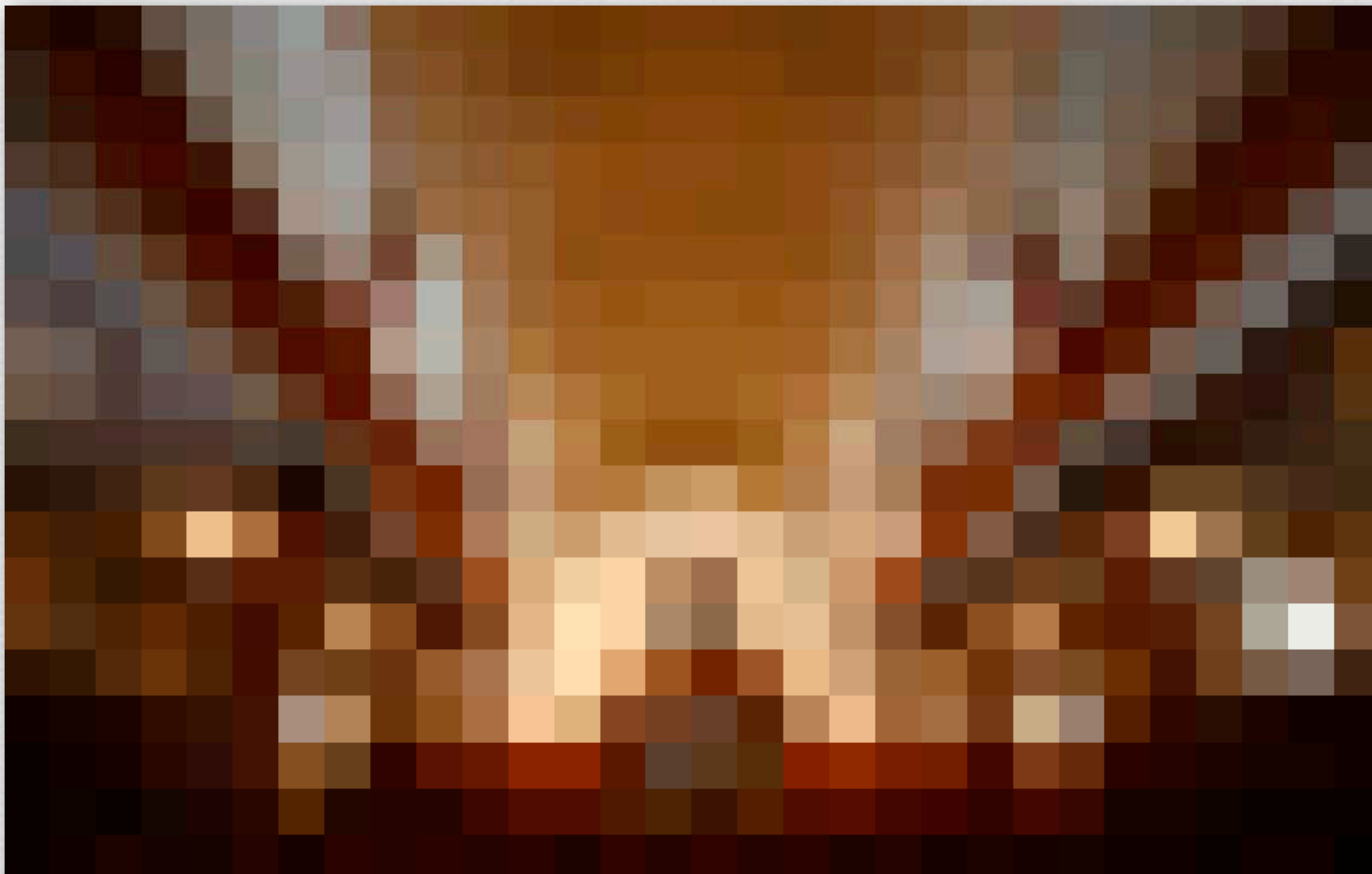




(http://steves-digicams.com & http://mir.com.my)

Low resolution makes metering hard

- What's this scene? What should the exposure be?



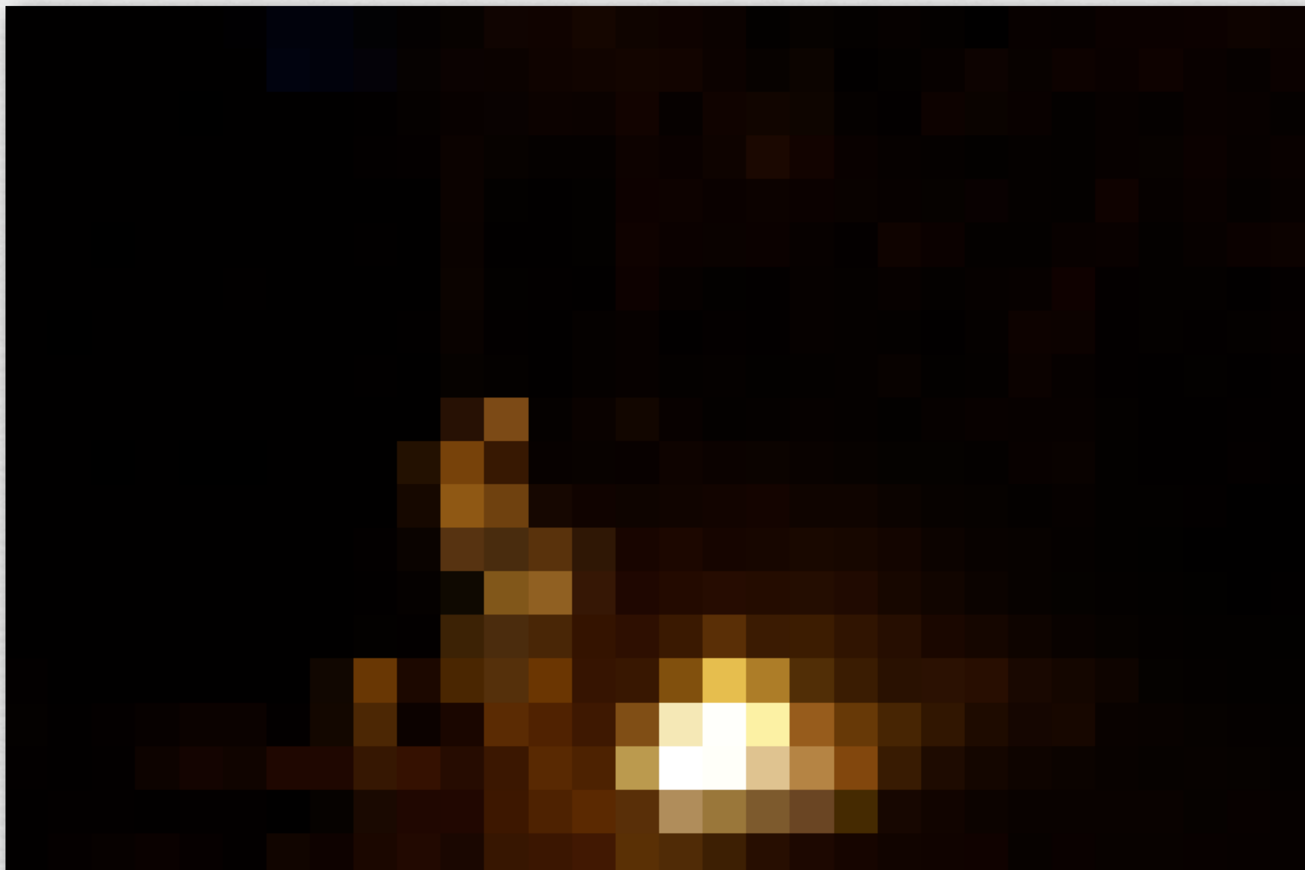
Low resolution makes metering hard

- What's this scene? What should the exposure be?

(Marc Levoy)

Low resolution makes metering hard

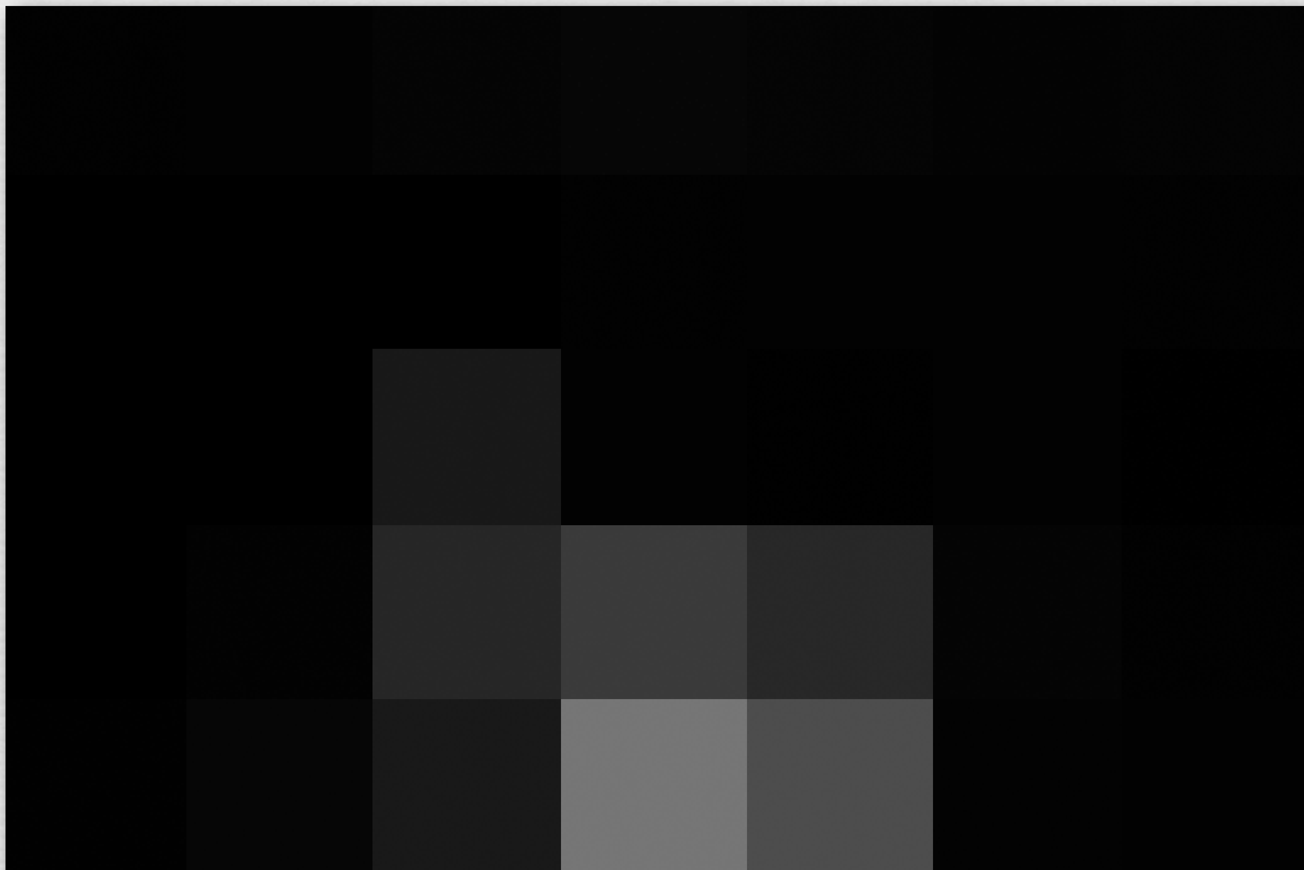
- How about this scene?
  Should the bright pixels be allowed to saturate?



Nikon: 1005 color pixels

Low resolution makes metering hard

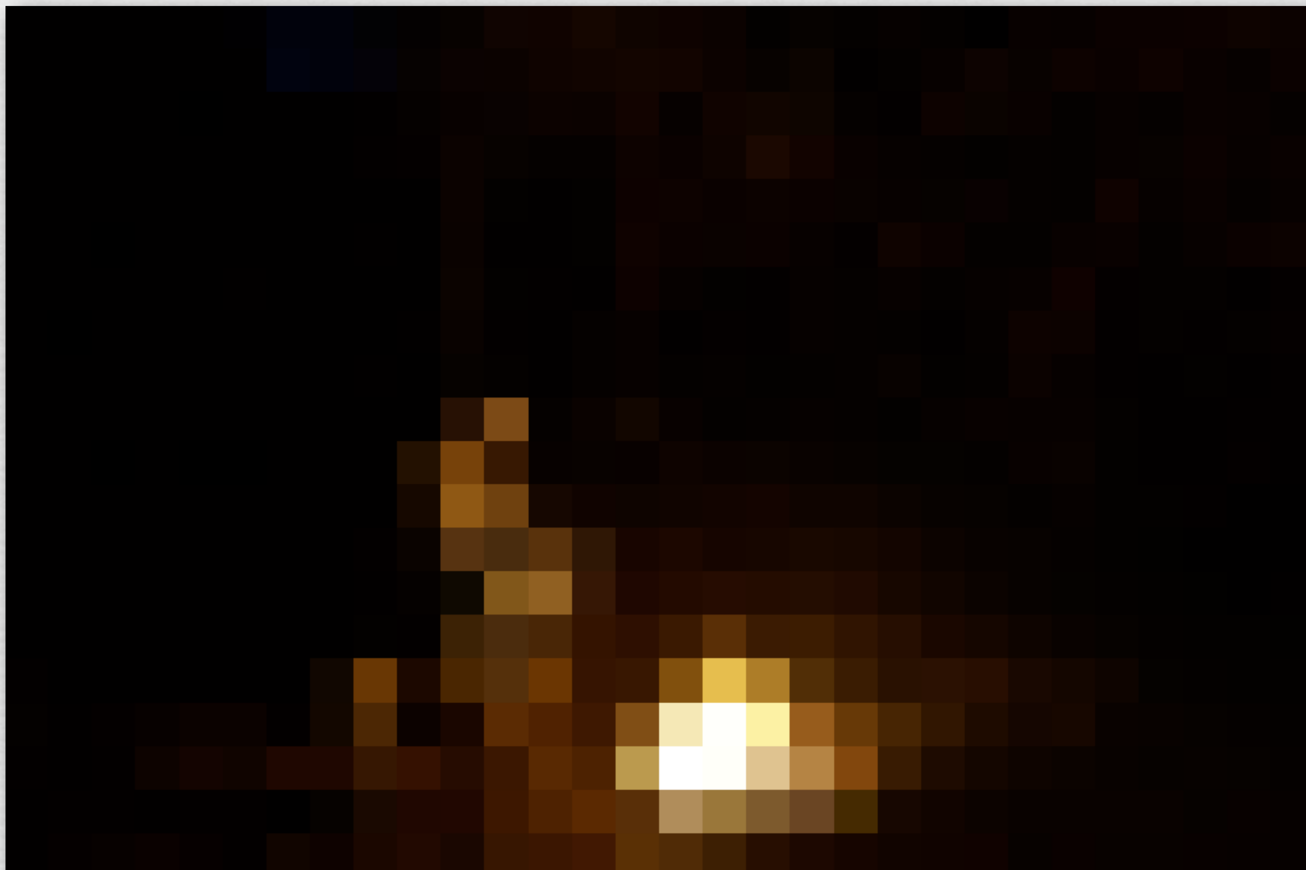
- How about this scene?
  Should the bright pixels be allowed to saturate?



Canon: 35
B&W zones

Low resolution makes metering hard

- How about this scene?
  Should the bright pixels be allowed to saturate?



Nikon: 1005 color pixels

Low resolution makes metering hard

- How about this scene?
  Should the bright pixels be allowed to saturate?

(Andrew Adams)

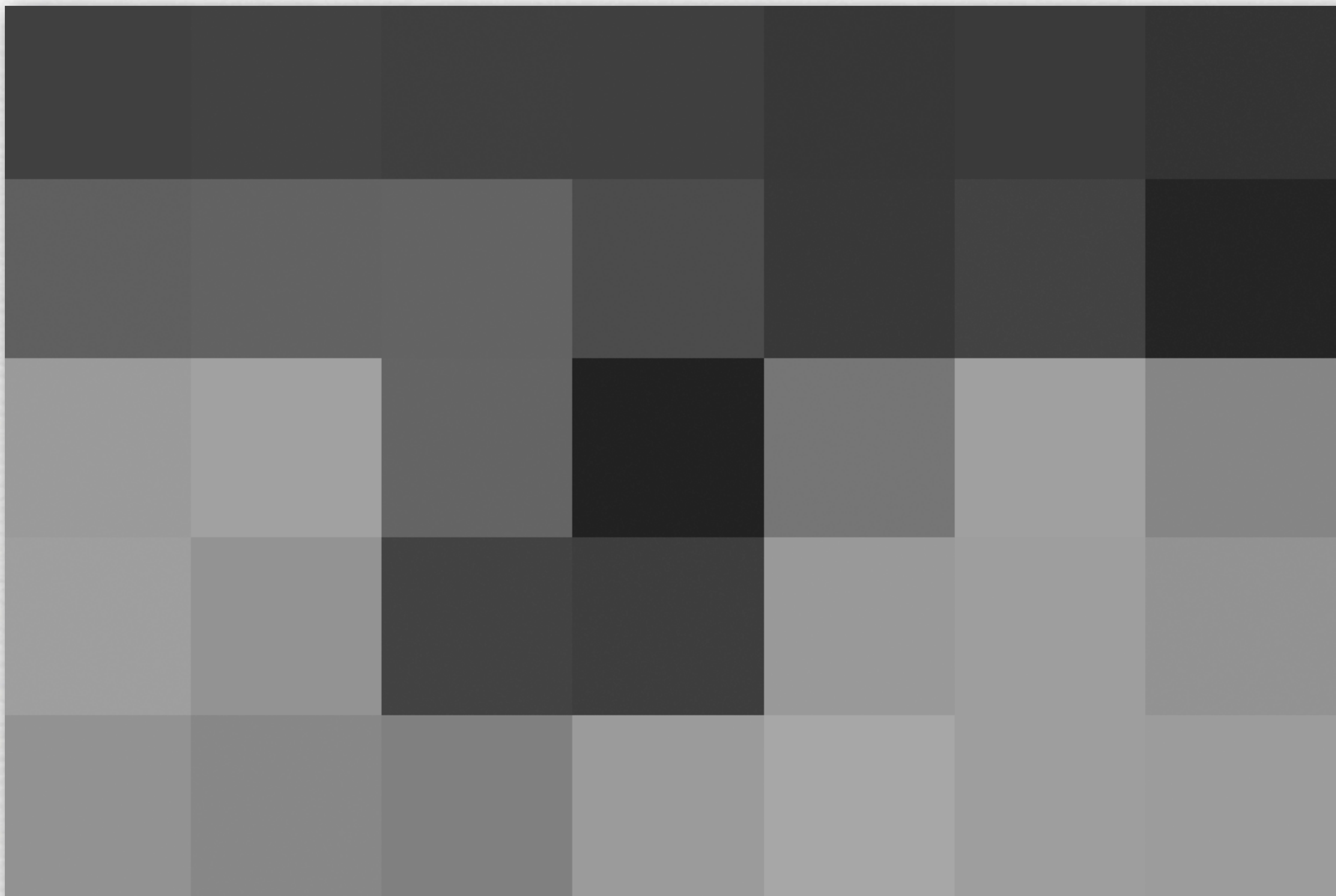
Low resolution makes metering hard

- What about the bright pixel in this scene?

Nikon: 1005 color pixels

Low resolution makes metering hard

- What about the bright pixel in this scene?



Canon: 35
B&W zones

Low resolution makes metering hard

- What about the bright pixel in this scene?

Nikon: 1005 color pixels

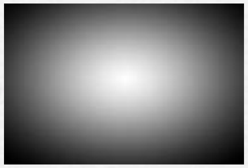
Low resolution makes metering hard

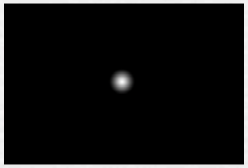
- What about the bright pixel in this scene?

(Marc Levoy)

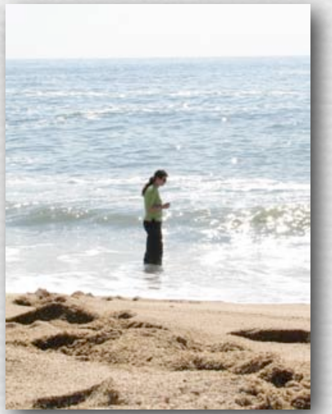
Metering modes

- center-weighted average
- spot (3.5% of area on Canon)





- evaluative
  - learn from database of images
  - decision may depend on brightness from each zone, color, local contrast, spatial arrangement of zones, focus distance
  - decision affected by camera mode (Portrait, Landscape,...)



- face detection
- future?
  - object recognition, personalization based on my shooting history or online image collections, collaborative metering

Shooting modes

- Aperture priority (Av)
  - photographer sets aperture (hence depth of field)
  - camera sets shutter speed
- Shutter priority (Tv)
  - photographer sets shutter speed (hence motion blur)
  - camera sets aperture
- Program (P)
  - camera decides both
  - photographer can trade off aperture against shutter speed with a dial
- Manual (M)
  - photographer decides both (with feedback from meter or viewfinder)
- Auto
  - camera decides both
  - photographer can't make stupid mistakes

Other modes

- exposure compensation
  - tells camera to under/over-expose by specified # of f/stops
  - use to ensure correct appearance of dark or light subjects
  - don't forget to reset it to zero when you're done!
- exposure lock (a.k.a. AE lock)
  - freezes exposure
  - pressing shutter button halfway only focuses
- exposure bracketing
  - takes several pictures a specified number of f/stops apart

Slide credits

- Andrew Adams
- Fredo Durand

- London, Stone, and Upton, *Photography* (ninth edition), Prentice Hall, 2008.
- Goldberg, N., *Camera Technology: The Dark Side of the Lens*, Academic Press, 1992.
- Canon, *EF Lens Work III: The Eyes of EOS*, Canon Inc., 2004.
- Adams, A., *The Camera*, Little, Brown and Co., 1980.
- Kerr, D.A., *Principle of the Split Image Focusing Aid and the Phase Comparison Autofocus Detector in Single Lens Reflect Cameras.*