

# Autofocus (AF)

CS 178, Spring 2010

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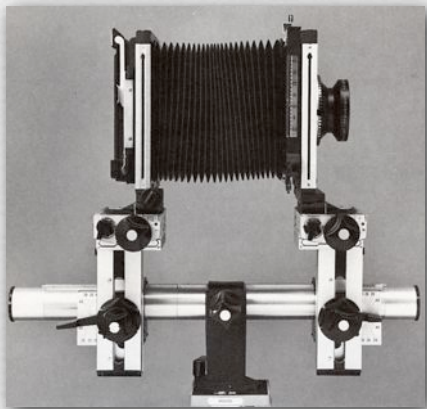
# Outline

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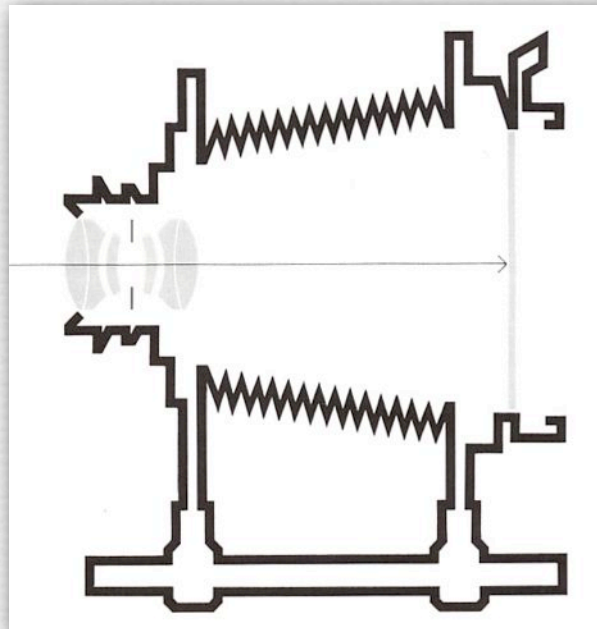
- ◆ viewfinders and manual focusing
- ◆ view cameras and tilt-shift lenses
- ◆ active autofocus
  - time-of-flight
  - triangulation
- ◆ passive autofocus
  - phase detection
  - contrast detection
- ◆ autofocus modes
- ◆ lens actuators

# View camera with focusing screen

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



Sinar 4×5



(Adams)

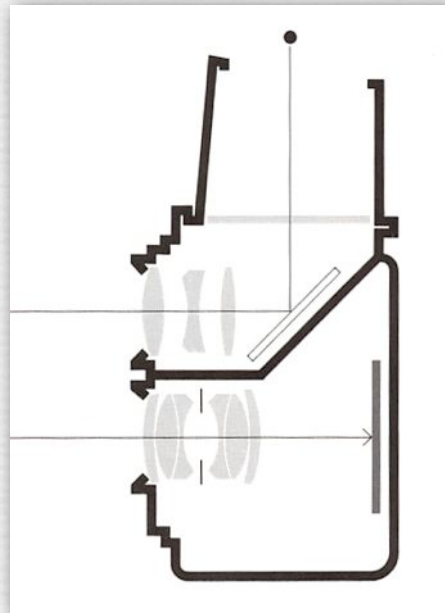


© QT Luong / terragalleria.com #kica39809

# Twin-lens reflex with focusing screen

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- ◆ medium format:  $2\frac{1}{4} \times 2\frac{1}{4}$ "
  - film only, no longer manufactured
  - medium format still exists, but only in SLRs
- ◆ different perspective view than main lens sees



(Adams)

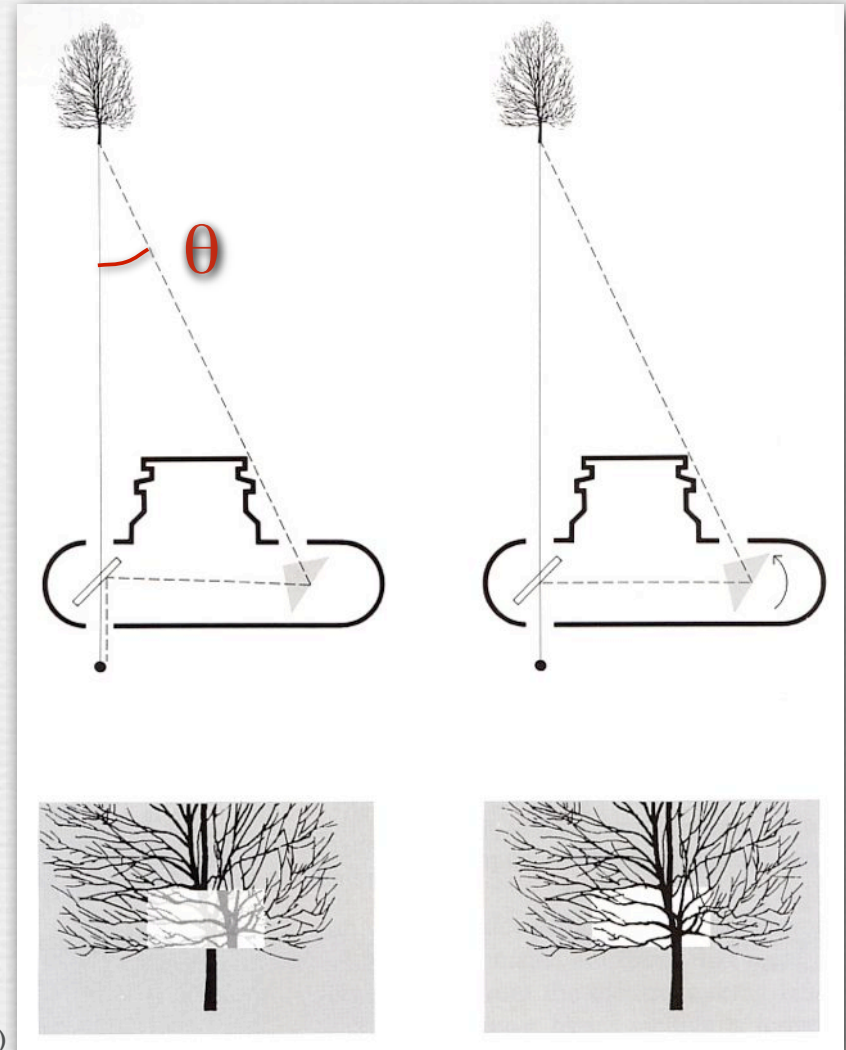


# Manual rangefinder

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



Leica M9  
(digital full-frame)



(Adams)

# Single lens reflex (SLR) with autofocus

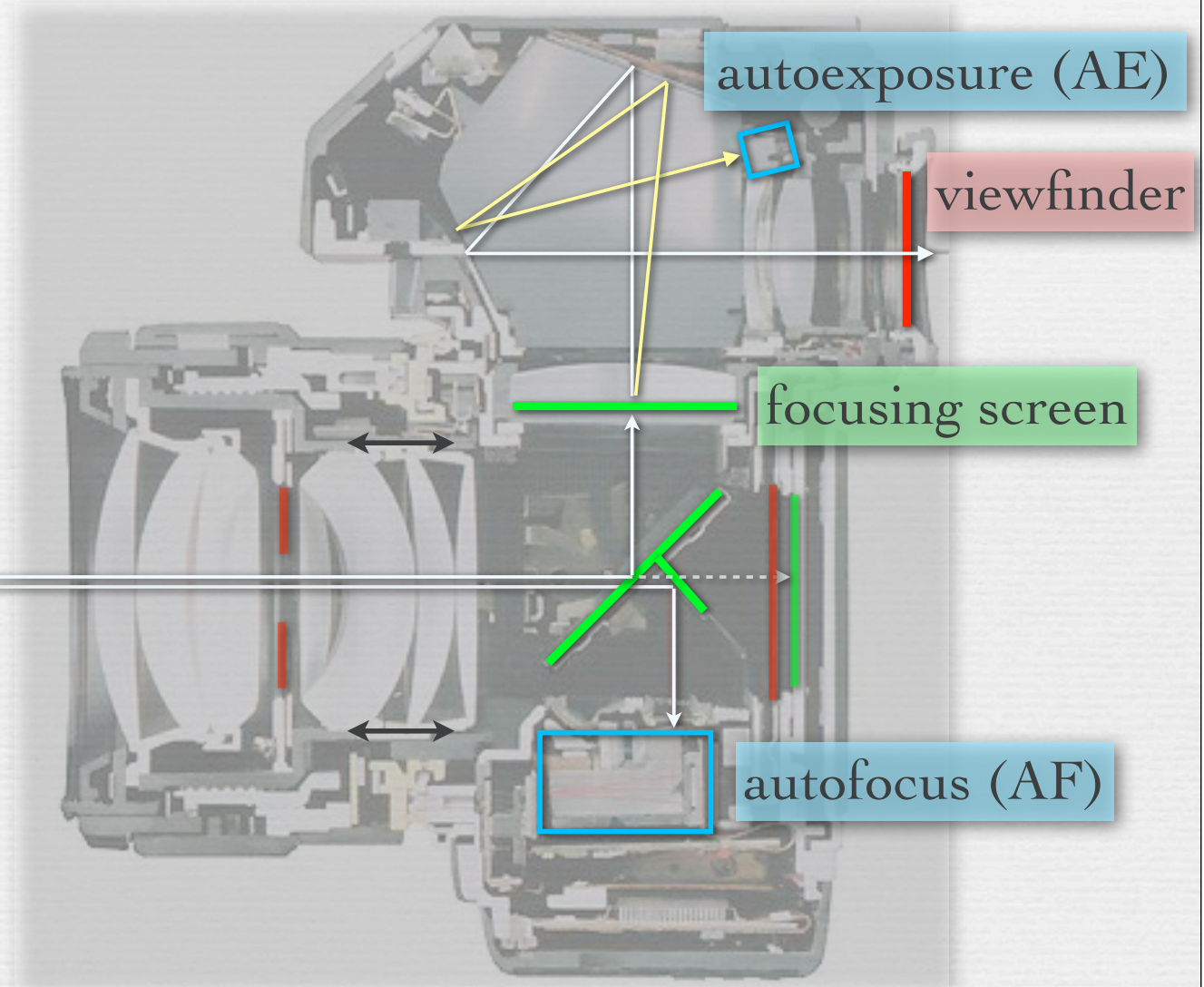
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Nikon F4  
(film camera)

# Single lens reflex (SLR) with autofocus

- ◆ with mirror down, some light is shunted to AF
- ◆ remainder reflected up to form image on diffuse focusing screen
- ◆ seen (upright) in viewfinder, with same perspective as main sensor
- ◆ AE light meter also sees focusing screen
- ◆ mirror rotates to expose main sensor when taking picture



# Viewfinder coverage & magnification

- coverage is fraction of sensor image covered by the viewfinder, i.e.

$$\frac{h_1}{h_2} \quad \text{or sometimes} \quad \frac{\text{area}_1}{\text{area}_2}$$

- magnification is apparent size of objects in viewfinder relative to unaided eye, i.e.

$$\frac{\theta_1}{\theta_2} \approx \frac{\tan \theta_1}{\tan \theta_2}$$

with a 50mm lens on camera

- example: Canon 5D II
  - coverage = 98%
  - magnification = 0.71x

This topic is somewhat arcane, so I've recolored it orange. (You're not responsible for it.) If you really want to read more gory details, I've added a URL to the text box below.

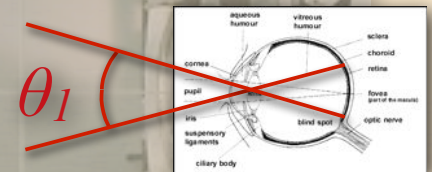
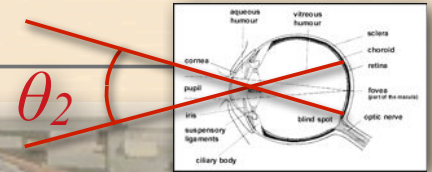
Beware of crop factor!

- example #2: Canon 7D

- coverage = 100%
- magnification = 1.0x

(but 50mm lens acts like 80mm on 7D; and 7D's 1.0x would be 0.62x on 5DII)

(see [http://www.neocamera.com/feature\\_viewfinder\\_sizes.php](http://www.neocamera.com/feature_viewfinder_sizes.php))



$h_1$

$h_2$



# Electronic viewfinders



point-and-shoot



SLR “live view”



electronic viewfinder

## ◆ pros

- same view as lens without need for reflex mirror
- can tone map to show effect of chosen exposure

## ◆ cons

- poor resolution and low dynamic range relative to optical
- Is the display being tone mapped? Will the shot look like this?

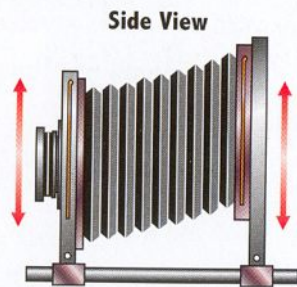
As I mentioned in class, I'll come back to this question of how to tone map an electronic viewfinder display after we have learned about exposure metering.

# View cameras

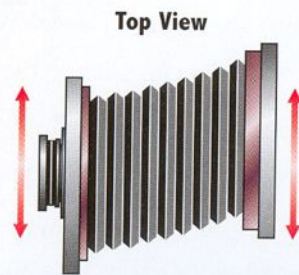


Sinar view camera with digital back

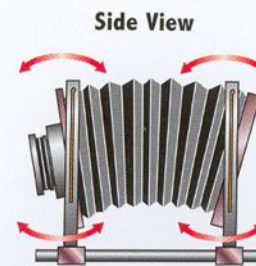
## VIEW CAMERA MOVEMENTS



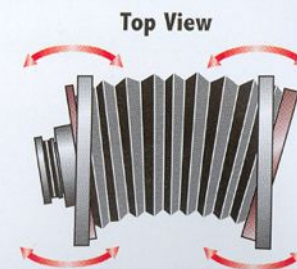
**Rise and fall** move the front or back of the camera in a flat plane, like opening or closing an ordinary window. Rise moves the front or back up; fall moves the front or back down.



**Shift (like rise and fall)** also moves the front or back of the camera in a flat plane, but from side to side in a motion like moving a sliding door.



**Tilt** tips the front or back of the camera forward or backward around a horizontal axis. Nodding your head yes is a tilt of your face.



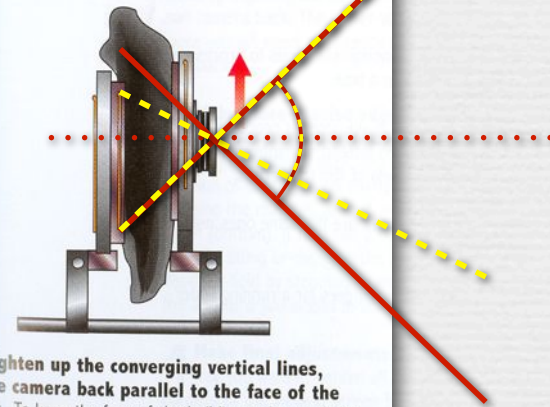
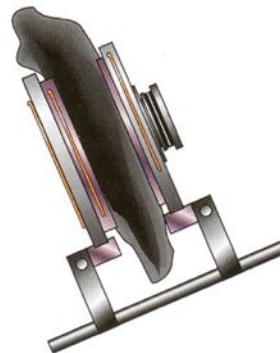
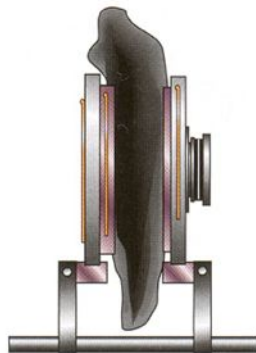
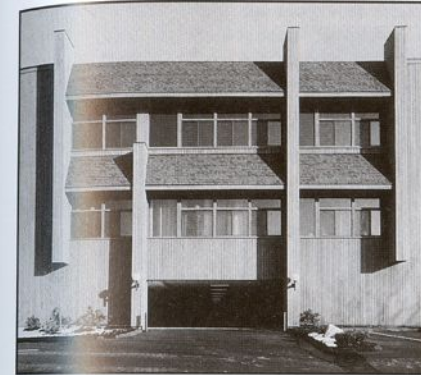
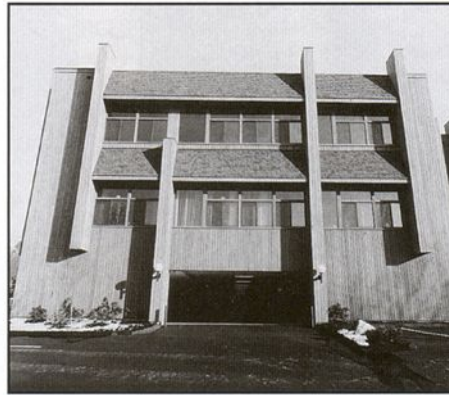
**Swing** twists the front or back of the camera around a vertical axis to the left or right. Shaking your head no is a swing of your face.

(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.

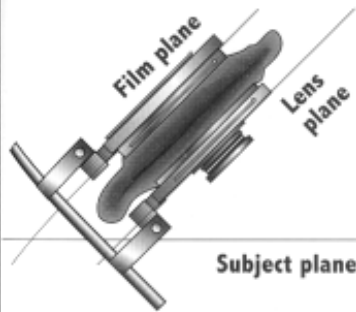
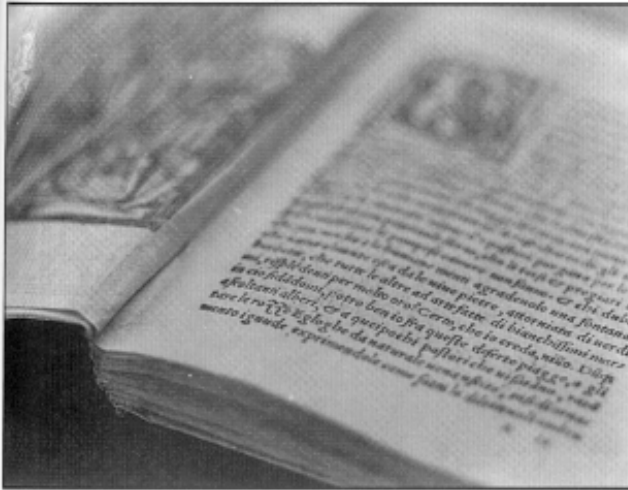
**Tilting the whole camera up shows the entire building but distorts its shape.** Since the top is farther from the camera than the bottom, it appears smaller; the vertical lines of the building seem to be coming closer together, or converging, near the top. This is named the keystone effect, after the 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.

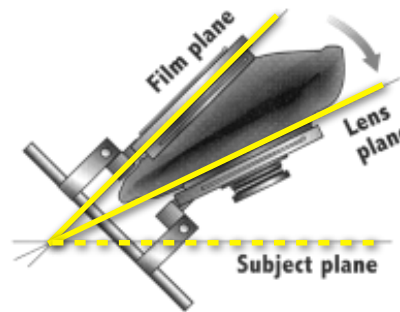
Another solution is to point the camera upward toward the top of the building, then use the tilting movements—first to tilt the back to a vertical position (which squares the shape of the building), then to tilt the lens so it is parallel to the camera back (which brings the face of the building into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

# Tilted focal plane

## ADJUSTING THE PLANE OF FOCUS TO MAKE THE ENTIRE SCENE SHARP



The book is partly out of focus because the lens plane and the film plane are not parallel to the subject plane. Instead of a regular accordion bellows, the diagrams show a bag bellows that can bring camera front and back closer together for use with a short focal-length lens.



Tilting the front of the camera forward brings the entire page into sharp focus. The camera diagram illustrates the Scheimpflug principle, explained at right.

- Scheimpflug condition

(London)

◆ cannot be done after the photograph is taken



Ansel Adams, Railroad Tracks



Ansel Adams, Monument Valley

# Tilt-shift lenses

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Canon TS-E  
90mm lens



# Tilt-shift lenses

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Canon TS-E  
90mm lens





# The “miniature model” look

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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

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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

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(<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

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

- ◆ gradient blur in Photoshop

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



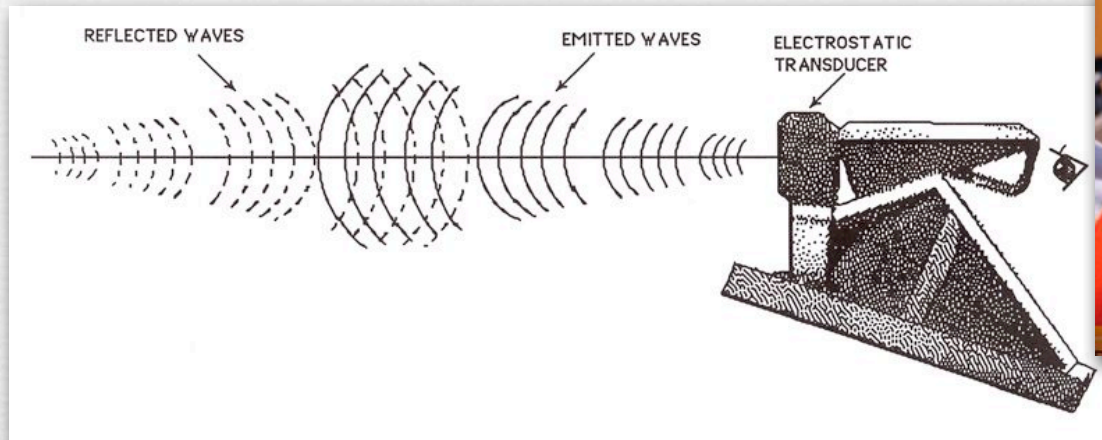
# Recap

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- ◆ the optical viewfinder in a single lens reflex camera (SLR)
  - gives you the same perspective as your final photograph
  - has high resolution and no limit on dynamic range
  - can't tone map to show effect of exposure
- ◆ view cameras let you eliminate vanishing points
  - this can alternatively be done in Photoshop
- ◆ view cameras also let you tilt the focal plane
  - this cannot be done in Photoshop, although you can fake it
- ◆ tilt-shift lenses provide both functions for SLRs

## Questions?

# Active autofocus: time-of-flight

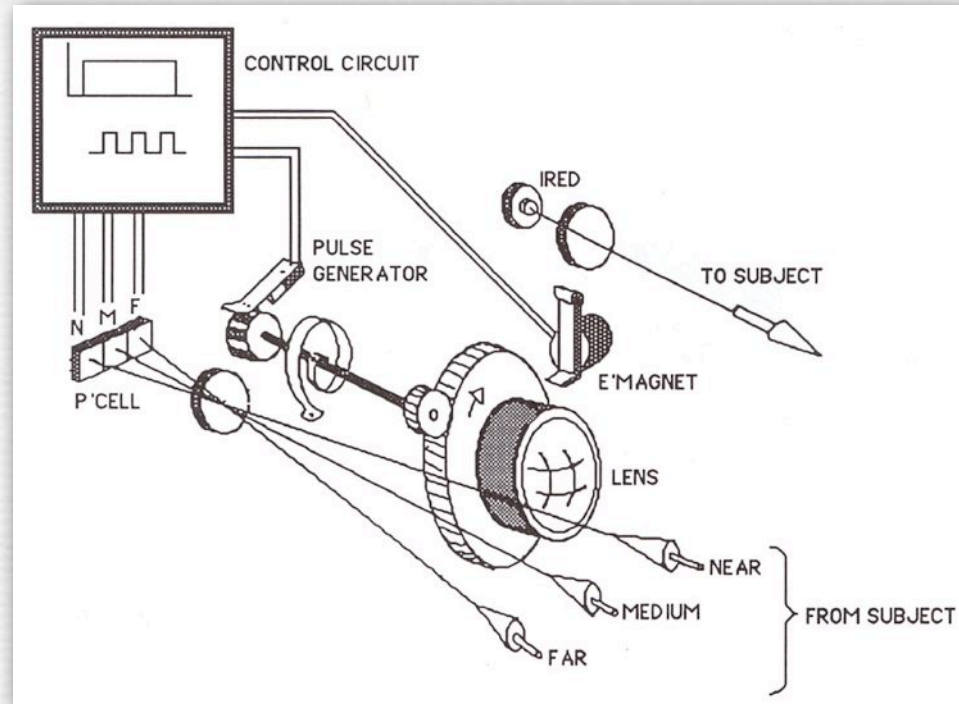


(Goldberg)



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

# Active autofocus: triangulation



(Goldberg)

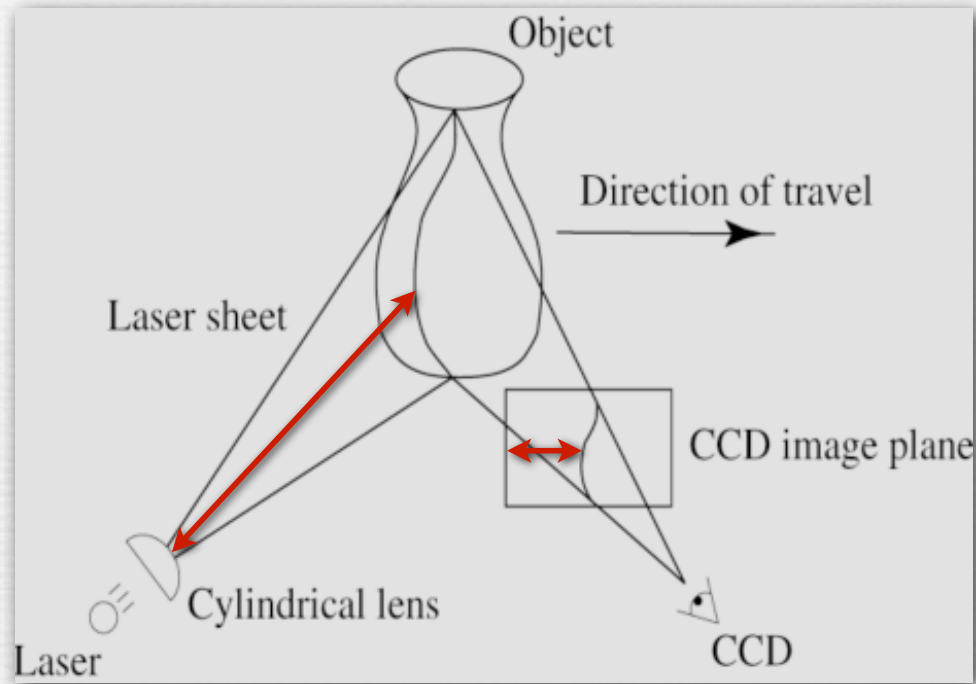
- ◆ infrared (IR) LED flash reflects from subject
- ◆ angle of returned reflection depends on distance
- ◆ fails on dark or shiny objects



Sidebar:

# laser triangulation rangefinding

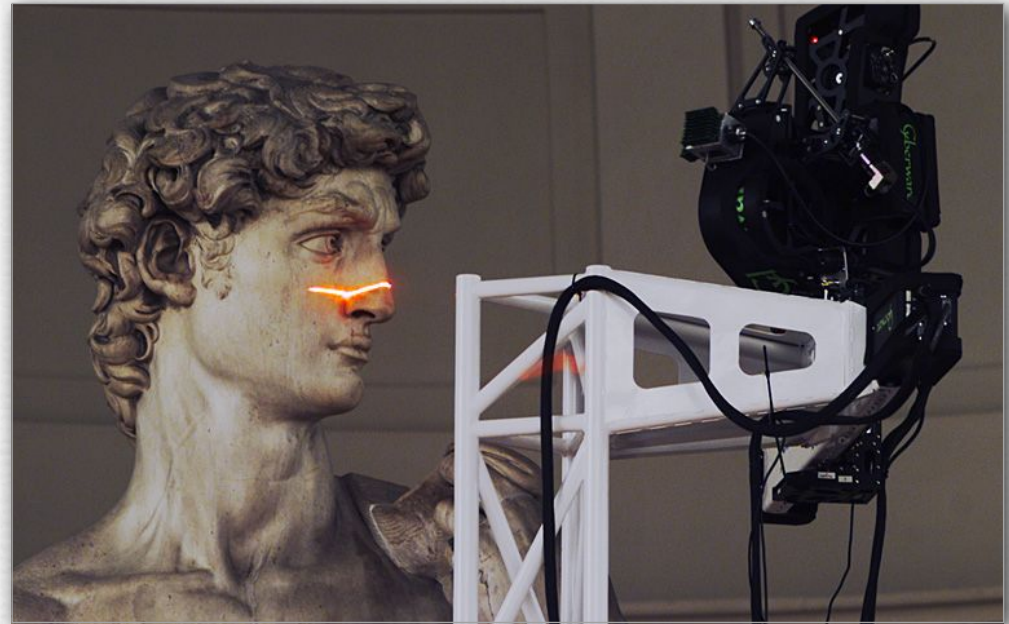
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- ◆ laser sheet illuminates a curve on the object
- ◆ distance from left edge of image gives distance from laser
- ◆ move object or sweep laser to create *range image*  $z(x,y)$

# Scanning Michelangelo's David

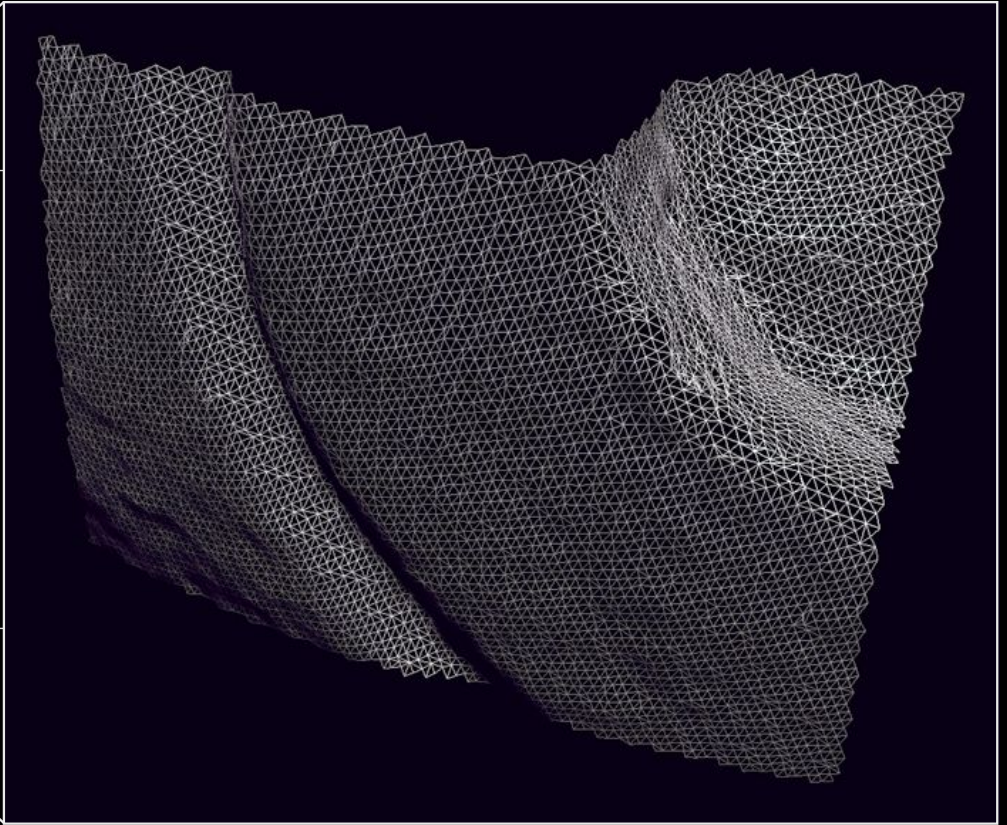
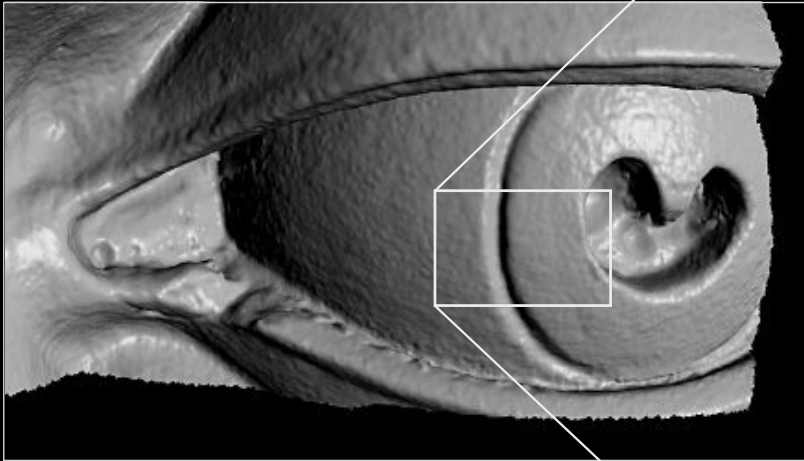
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- ◆ 480 range images
- ◆ 2 billion polygons
- ◆ 22 people × 30 nights

<http://graphics.stanford.edu/projects/mich/>





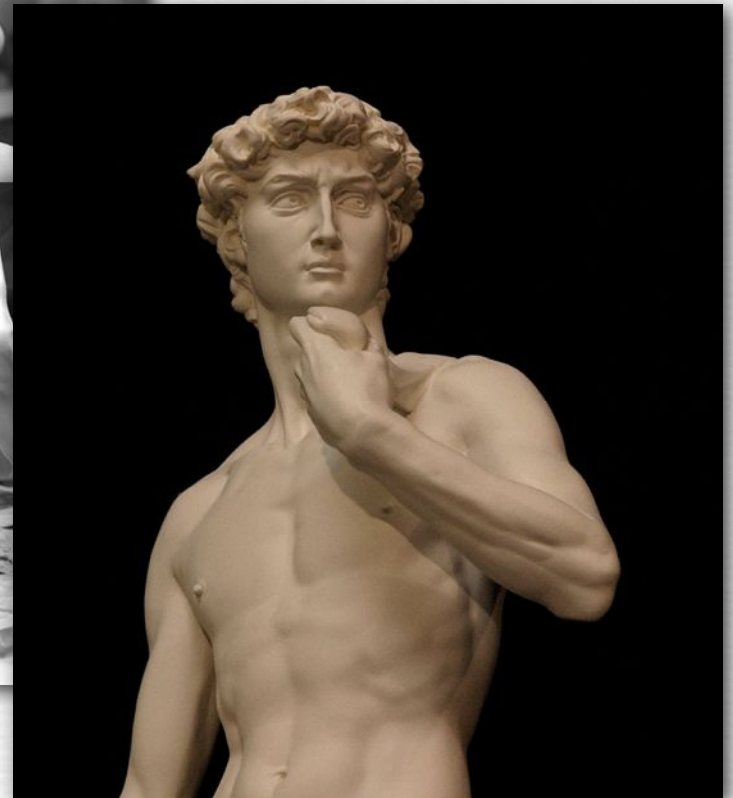
# Uses of the 3D model



interactive kiosk



physical replica

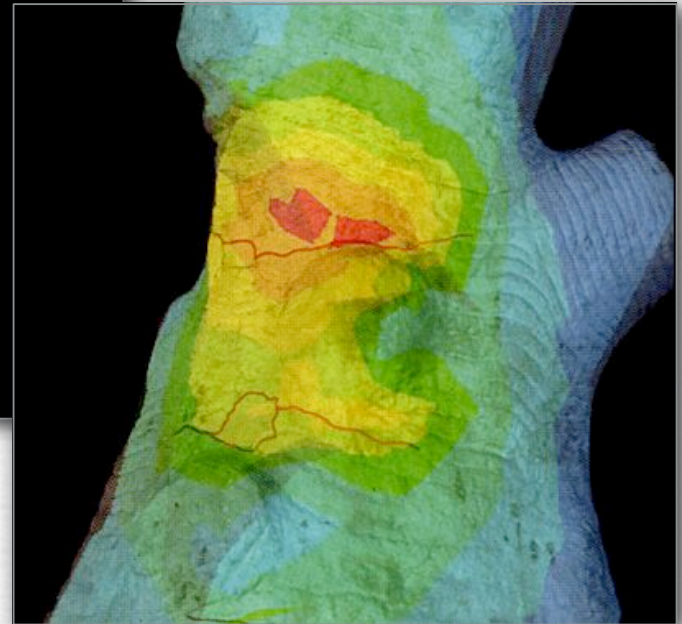
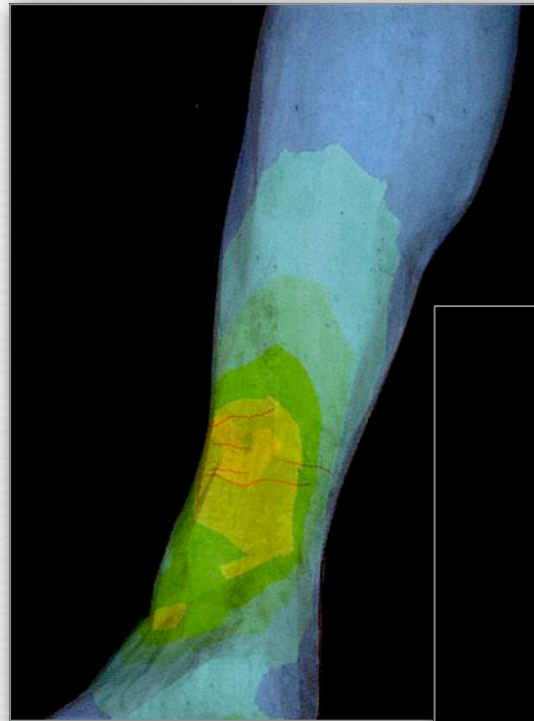


# Uses of the 3D model

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scientific studies

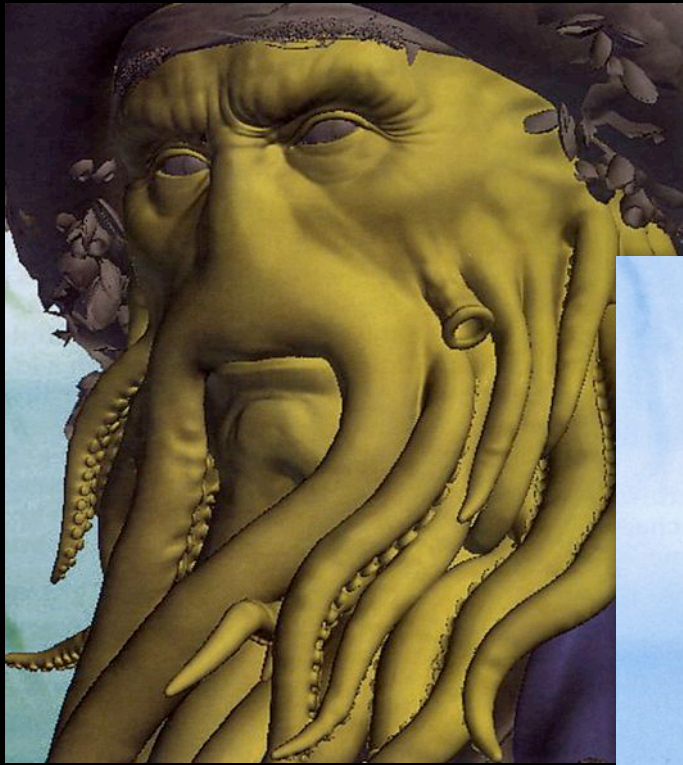


The image shows the cover of Cinefex magazine, issue number 107. The cover features a detailed close-up of a creature's face, likely from the movie 'The Abyss', showing its eyes and tentacles. The creature's skin is textured and yellowish-brown, with blue eyes. The background is dark and appears to be a rocky or metallic surface with some small, glowing elements. The magazine title 'cinefex' is written in a stylized, yellow, serif font at the top left. In the top right corner, the issue number 'number 107', the price '\$12.50', and the Canadian price 'Canada - \$15.00' are listed in a smaller, yellow font.

cinefex

number 107  
\$12.50  
Canada - \$15.00

- ◆ commonly used to digitize physical maquettes to ease creation of 3D CG models



3D model



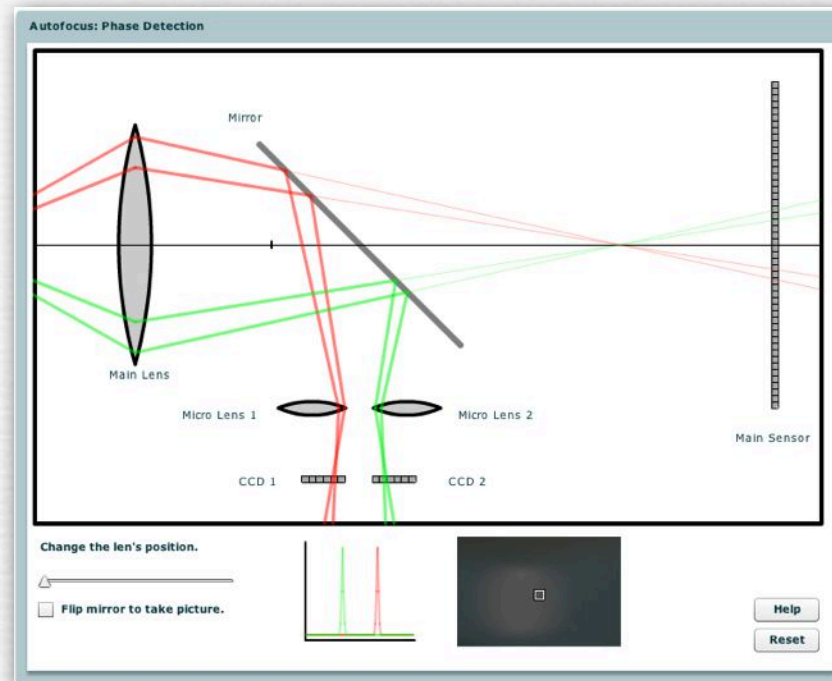
mocap



rendered



# Passive autofocus: phase detection

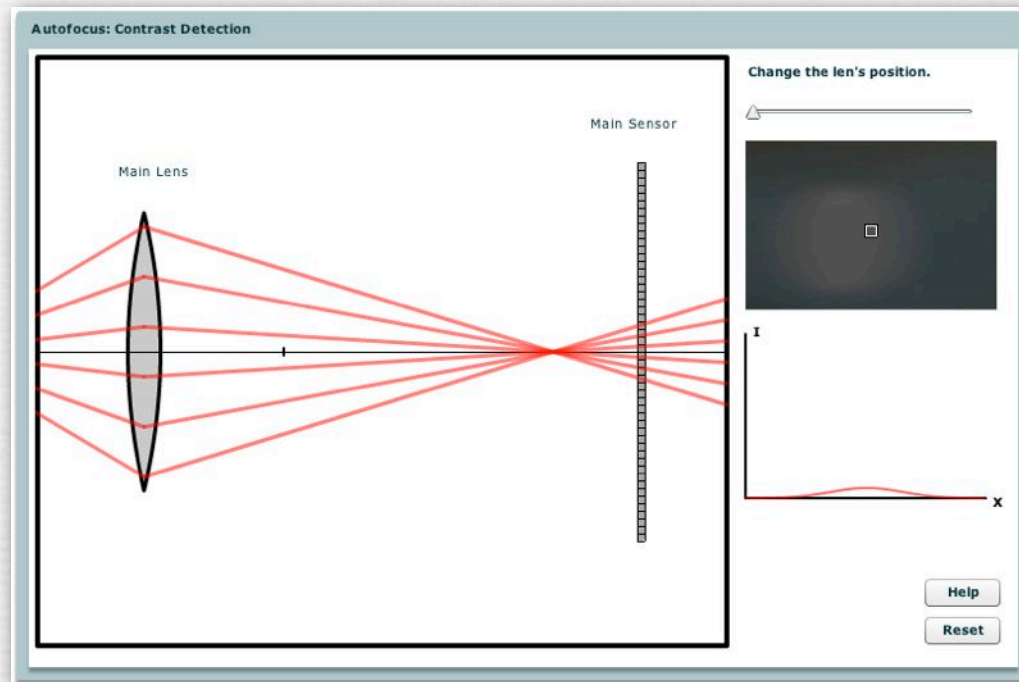


**(FLASH DEMO)**

<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 (*disparity*) between these images is “in focus”

# Passive autofocus: contrast detection

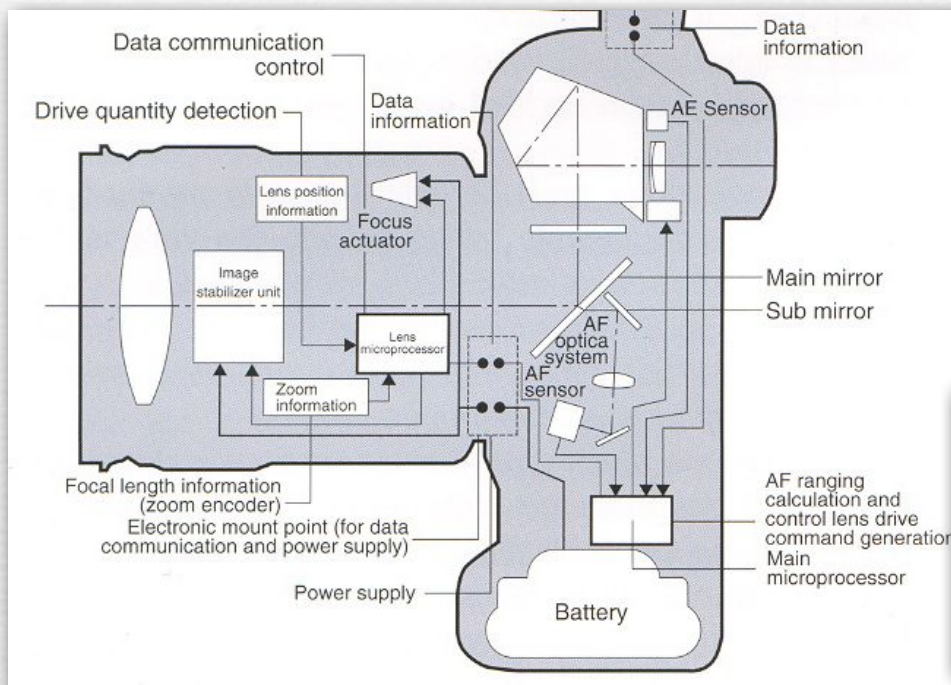


**(FLASH DEMO)**

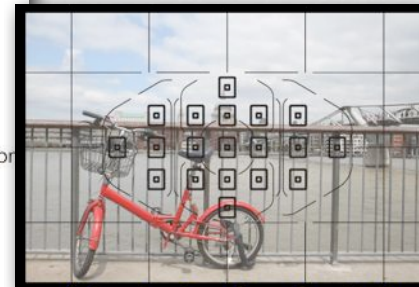
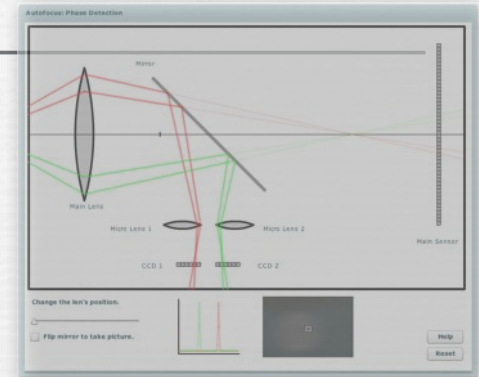
<http://graphics.stanford.edu/courses/cs178/applets/autofocuscd.html>

- ◆ 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 *gradient* of pixel values

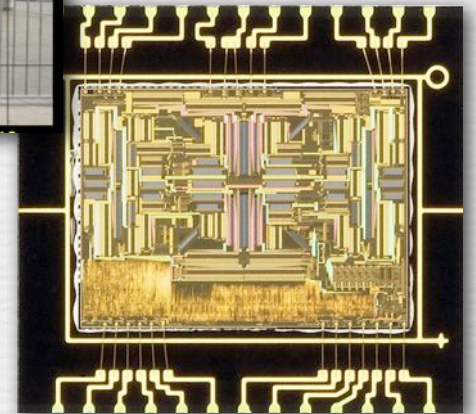
# Most SLRs use phase detection



(Canon)



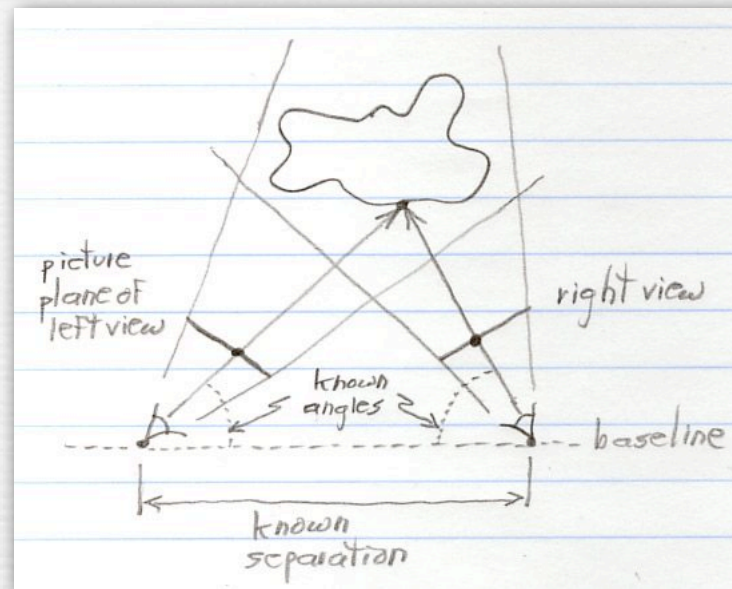
Canon 7D



- ◆ distance between subimages allows lens to jump directly into focus, without hunting
  - equivalent to *depth-from-stereo* in computer vision
- ◆ many AF points, manual or automatic way to choose among them
  - closest scene feature is often the best, but also consider position in FOV

# Phase detection is like depth from stereo (contents of whiteboard)

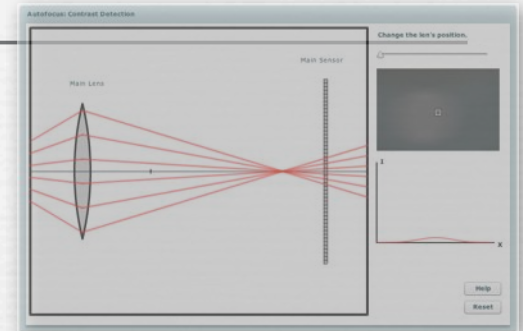
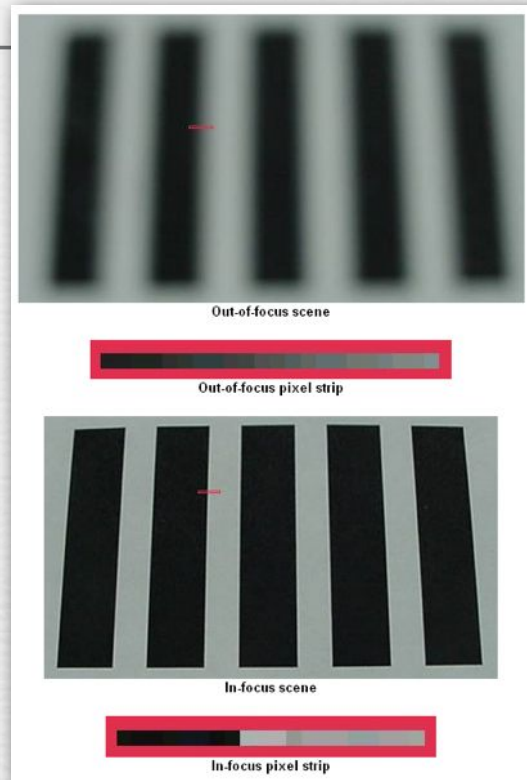
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- ◆ start by finding corresponding features in two views of an object; express each correspondance as a pair of pixels (dots)
- ◆ knowing the separation and aim (angles) of the two cameras, the positions of these two pixels can be projected (arrows) until they intersect; this gives the 3D location of the feature
- ◆ the larger the separation, the more accurate the depth estimate

# Most DSCs use contrast detection

(howstuffworks.com)



I mentioned in class that movie mode on a Canon 5D II uses contrast detection, requires hunting, and suffers from overshooting. This doesn't happen in professional moviemaking because they never use autofocus. They have a dedicated person, called a "focus puller", who stands beside the camera and changes the focus manually when the script calls for it.

- ◆ uses main camera sensor
- ◆ requires repeated measurements (hunting) 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

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- ◆ AI servo (Canon) / Continuous servo (Nikon)
  - predictive tracking so focus doesn't lag axially moving objects
  - continues as long as shutter is pressed halfway

# Servo focus can misfocus quickly

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Canon 1D Mark III, 300mm f/2.8

# Servo focus can misfocus quickly



Servo focusing is especially intended for objects moving axially. In retrospect this may not be a good example, since the people are moving laterally (parallel to the sensor). This is simply an example of misfocusing.

Canon 1D Mark III, 300mm f/2.8



# Servo focus can misfocus quickly

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Canon 1D Mark III, 300mm f/2.8

# Autofocus modes

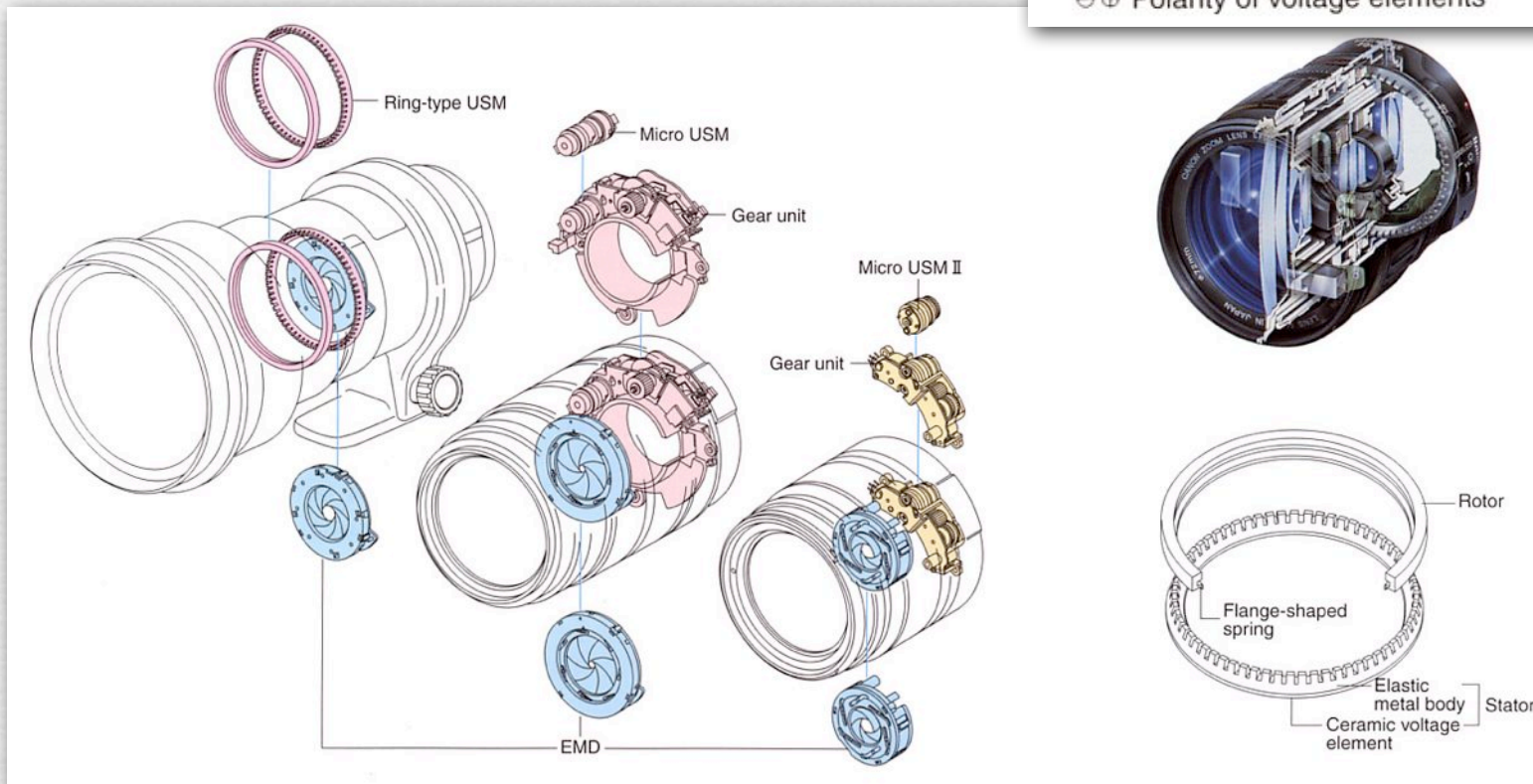
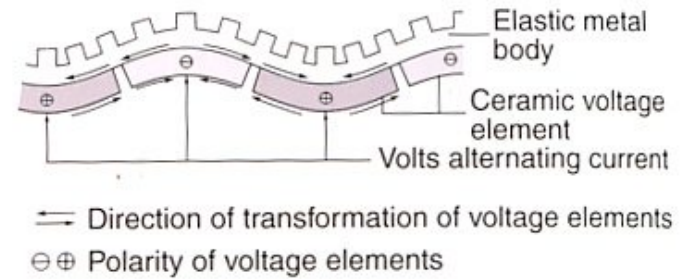
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- ◆ AI servo (Canon) / Continuous servo (Nikon)
  - predictive tracking so focus doesn't lag axially moving objects
  - continues as long as shutter is pressed halfway
- ◆ focusing versus metering
  - autofocus first, then meter on those points
- ◆ “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)
- ◆ all autofocus methods fail if object is textureless!

# Lens actuators

## ◆ Canon ultrasonic motor (USM)

Figure-41 Vibrations Generated by Piezoelectric Ceramic Element



(Canon)

© Marc Levoy

# Recap

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- ◆ active autofocus
  - *triangulation* between a sensor's view and active illumination
  - examples are sonar, laser, infrared light
- ◆ passive autofocus
  - *phase detection* uses *disparity* between views of a scene feature through left and right sides of aperture to judge misfocus
    - most SLRs use phase detection
    - permits direct jump to in-focus position
  - *contrast detection* uses *gradient* of pixel values from main sensor's view of a scene feature to judge misfocus
    - most DSCs use contrast detection
    - requires repeated measurements (hunting) as lens moves

## Questions?

# Slide credits

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- ◆ 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*.