# Optical image stabilization (IS)

CS 178, Spring 2014

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# Outline

- what are the causes of camera shake?
  - how can you avoid it (without having an IS system)
  - treating camera shake as a 2D convolution of the image
- image stabilization systems
  - mechanical
  - electronic, i.e. digital (among multiple shots)
  - optical
- optical image stabilization
  - lens shift
  - sensor shift
  - how much does stabilization help?

# Camera shake

- primary cause is neuro-muscular tremor
  - period = 8-12 cycles per second
  - amplitude increases with muscular contraction, fatigue, emotional state, cold temperatures, stimulants, time of day
- secondary causes
  - SLR mirror and shutter
  - lightweight tripod
  - wind and other sources of vibration
- exacerbating factors
  - long focal length lenses
  - long exposure time
  - heavy camera, light camera, poor grip, poking at the shutter

# Examples

(wildsight.co.uk)

(samgraphicdesign.com)

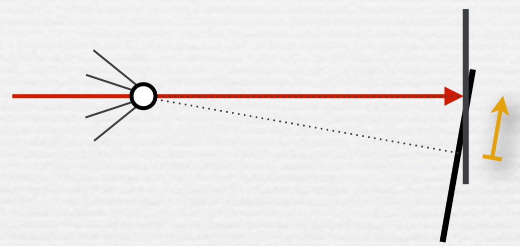
# Camera shake as convolution

- camera shake is camera translation (3 d.o.f.) + rotation (3 d.o.f.)
- for sufficiently distant objects, camera translation can be ignored
- camera rolling (around optical axis) is seldom a problem*
- assume pitching & yawing are around center of perspective
- these motions can be approximated as 2D translation of the scene

*recent research suggests otherwise [Levin 2009]

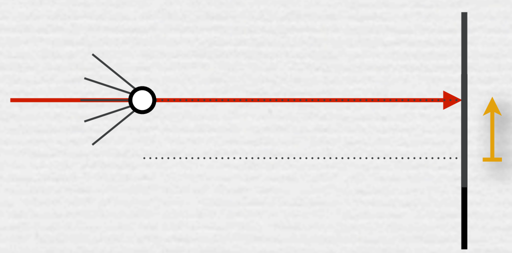
# Rotation around center of perspective can be approximated as 2D translation of the scene

as rotation



sensor rotates down,
features move up

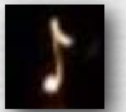
as translation



effect is nearly
the same

# Camera shake as convolution

- camera shake is camera translation (3 d.o.f.) + rotation (3 d.o.f.)
- for sufficiently distant objects, camera translation can be ignored
- camera rolling (around optical axis) is seldom a problem
- assume pitching & yawing are around center of perspective
- these motions can be approximated as 2D translation of the scene
- their effect over time is a 2D convolution of the scene $f(x,y)$ by a filter function $g(x,y)$ equal to the translation path

scene $f(x,y)$ $\otimes$  = 

# Avoiding camera shake

- hold the camera carefully, trigger the shutter slowly

- elbows in
- exhale first

- cradle the camera

- create a tripod

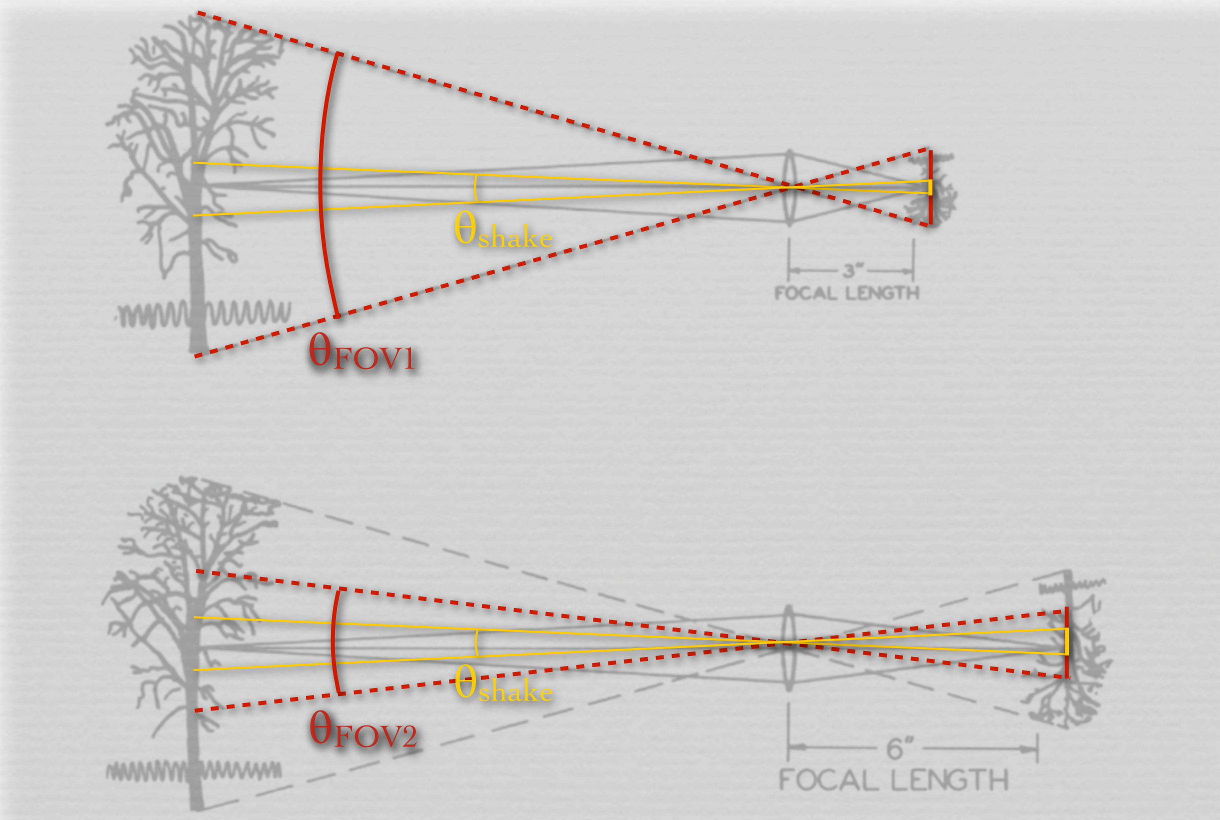
(http://digital-photography-school.com/how-to-avoid-camera-shake)

# Avoiding camera shake

- hold the camera carefully, trigger the shutter slowly
- as you increase focal length, reduce exposure time

# Effect of focal length on handshake

(Kingslake)




- as you increase focal length (for a fixed sensor size), handshake becomes a larger fraction of the angular FOV

# Avoiding camera shake

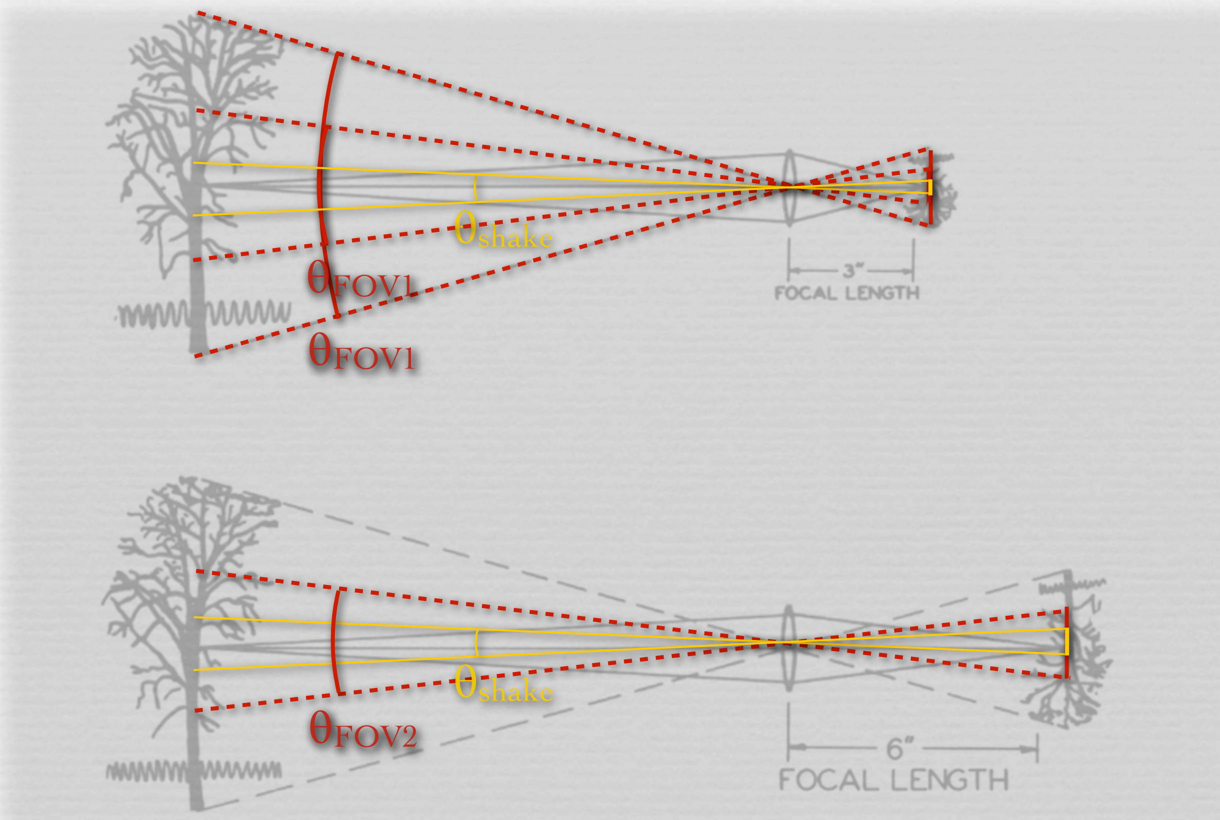
- hold the camera carefully, trigger the shutter slowly
- as you increase focal length, reduce exposure time
  - rule of thumb

$$T = \frac{1}{f}$$ e.g. 1/500 second for a 500mm lens

  - open the aperture or raise the ISO to compensate
  - or use flash

Q. Keep the shorter focal length and crop the image?

# Effect of cropping the image




(Kingslake)

- no, cropping the image is like increasing the focal length; handshake becomes a larger fraction of the angular FOV

Q. How does sensor size affect handshake?

# Effect of changing the sensor size

- as sensor shrinks, you typically decrease focal length to maintain the same angular FOV
- if you do this, then since handshake is a constant angular arc, it remains a constant fraction of the FOV

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- as sensor shrinks, total # of megapixels typically stays constant, and pixels get smaller
- since distance to sensor is smaller, and pixels are smaller, # of pixels covered by handshake stays constant

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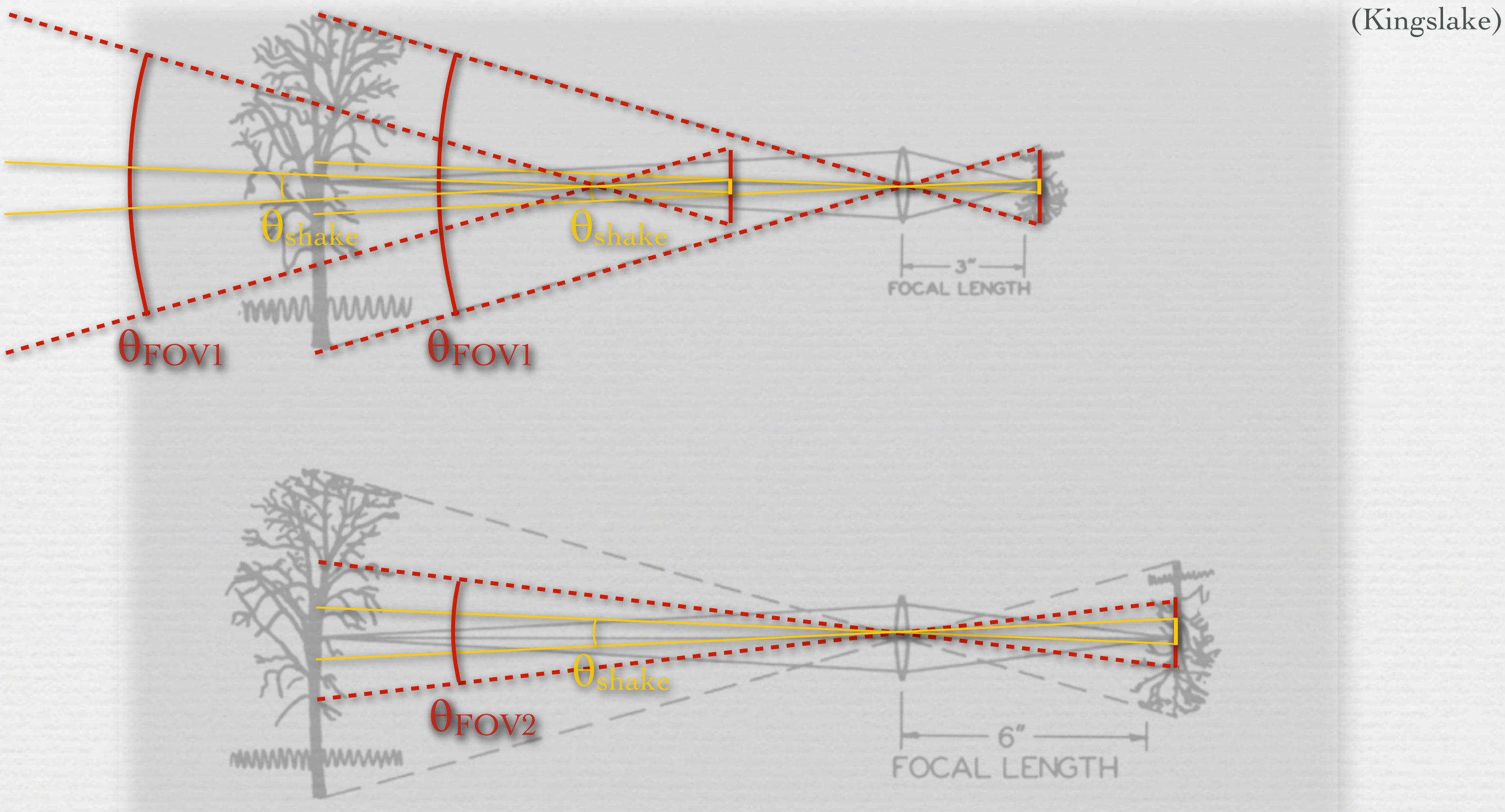
- under these assumptions, which are typical, changing sensor size has no effect on handshake
- for small sensors, use 35mm equivalent focal length in formula for minimum exposure time

# Effect of moving towards the object




- to avoid increasing focal length and suffering handshake, keep focal length constant and move towards the object
- perspective and occlusions will change

# Avoiding camera shake

- hold the camera carefully, trigger the shutter slowly
- as you increase focal length, reduce exposure time
  - rule of thumb

$$T = \frac{1}{f}$$

e.g. 1/500 second for a 500mm lens;
for small sensors, use 35mm equivalent

  - open the aperture or raise the ISO to compensate
  - or use flash
- keep the focal length constant and move towards the object
- lock up the mirror
- get a better tripod
- drink less coffee

# Recap

- camera shake can be modeled as a 2D convolution of the scene by a filter derived by treating handshake as translation
- the best way to avoid handshake is to hold the camera right
- as focal length increases, use a shorter exposure

$$T = \frac{1}{f}$$

- for small sensors, use 35mm equivalent focal length in formula

**Questions?**

# Image stabilization systems

- mechanical image stabilization
  - Steadicam
- electronic image stabilization - among multiple shots
  - for aligning & averaging bursts of still shots (Casio EX-F1)
  - for stabilizing video (Adobe Premiere, Deshaker, etc.)
  - reduces the field of view
  - hot research topic
- optical image stabilization - during a single exposure
  - shift the lens, or
  - shift the sensor

# Image stabilization systems

- mechanical image stabilization
  - Steadicam


# Biological image stabilization

(http://www.youtube.com/watch?v=_dPlkFPowCc)

# Poor man's steadicam

built by Benjamin Levoy
material: welded steel
camera: Canon DSC

# Image stabilization systems

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  - shift the lens, or
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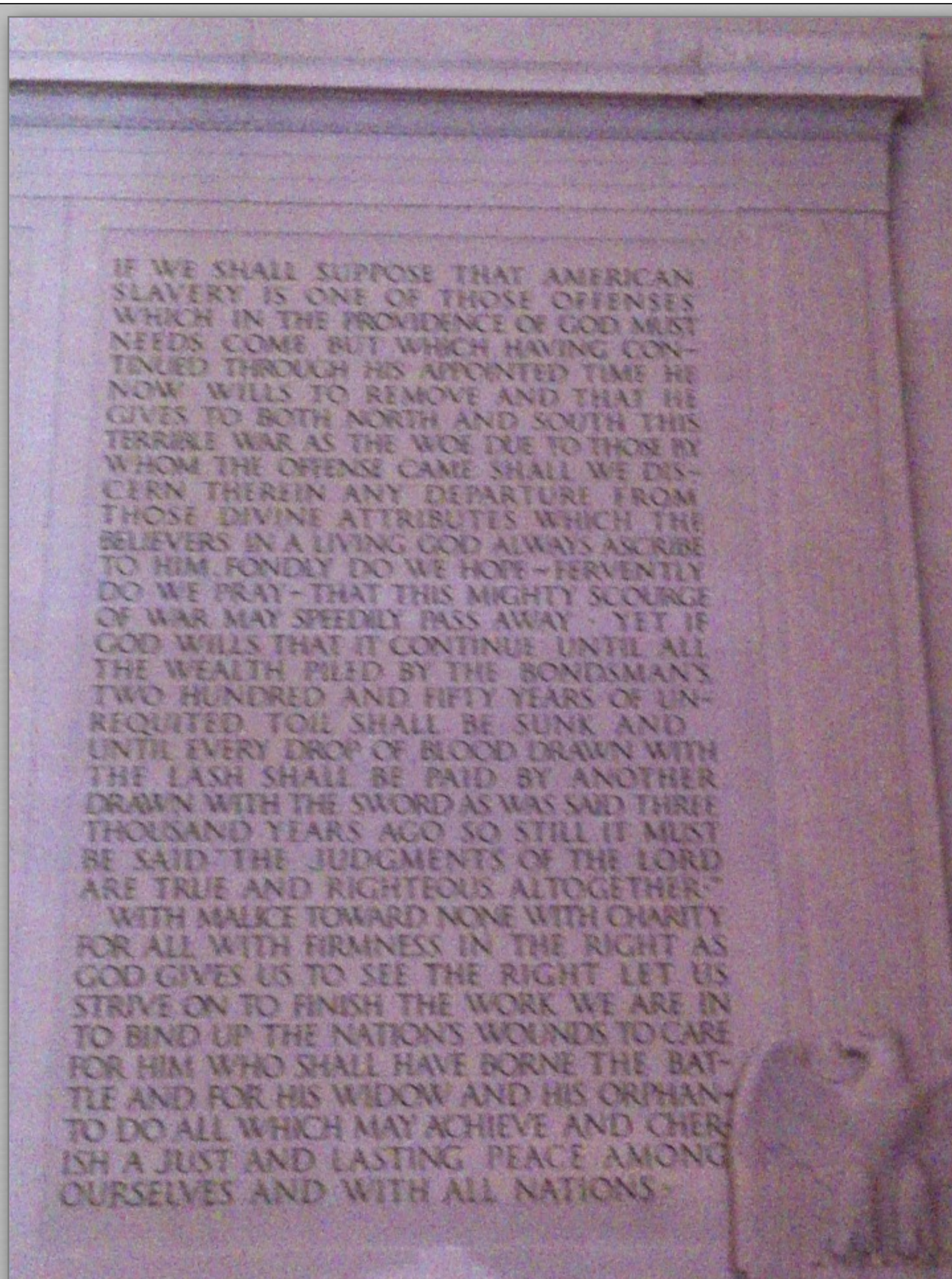
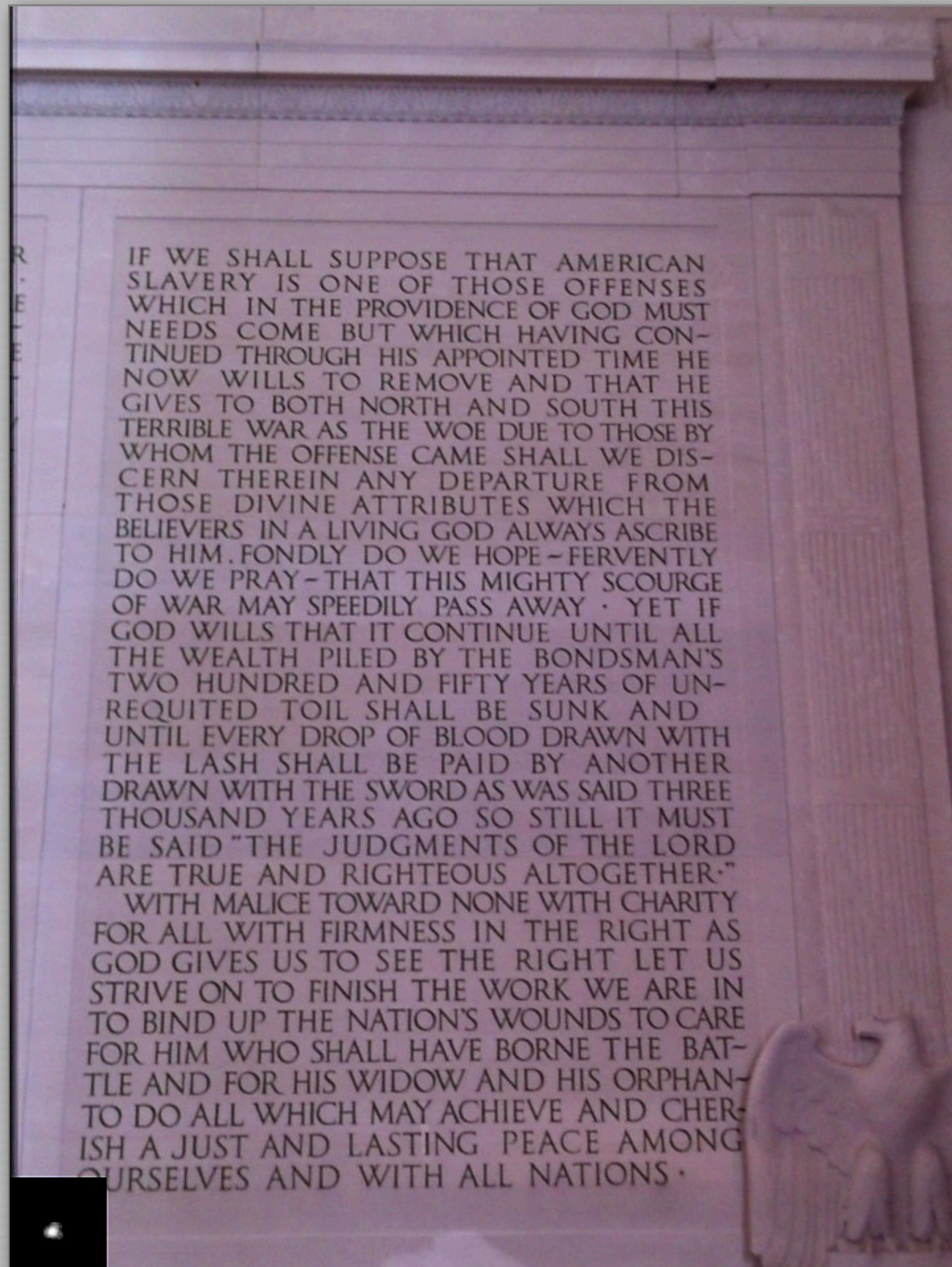
iPhone 4,
single HD
video frame

blurry due to long exposure time and handshake; noisy nevertheless



Synthcam,
average of
~30 frames



iPhone 4,
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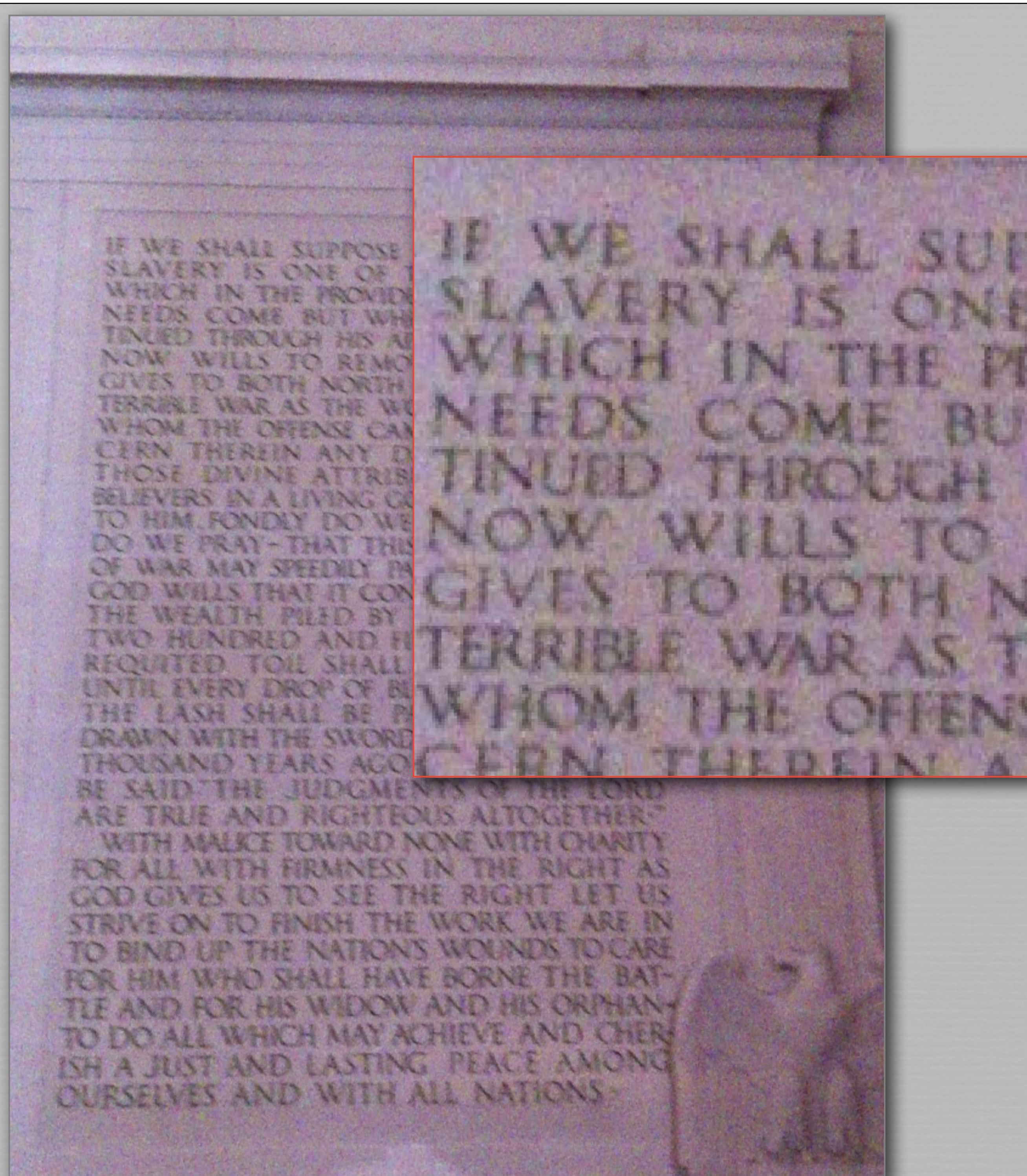
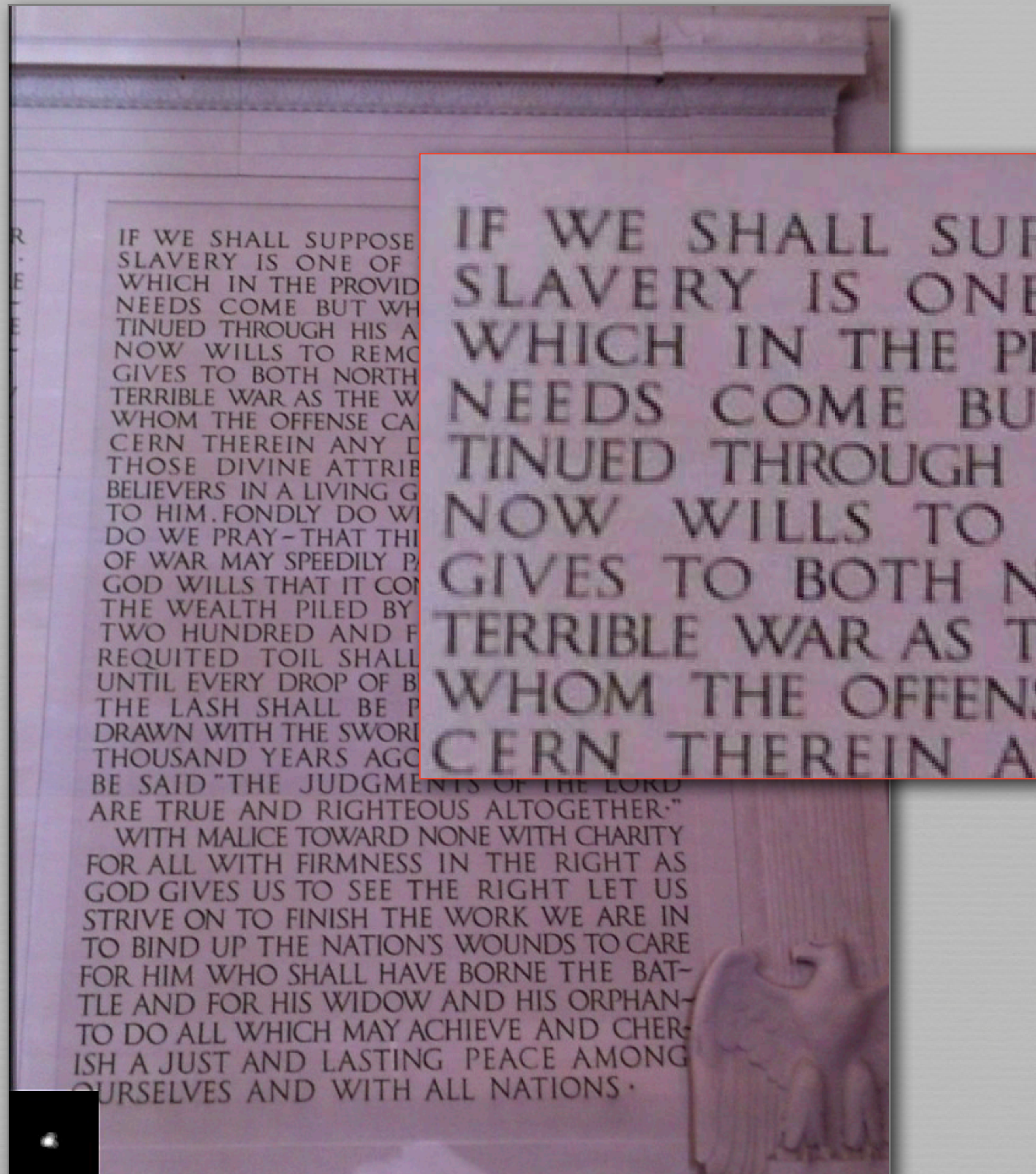


Synthcam,
average of
~30 frames

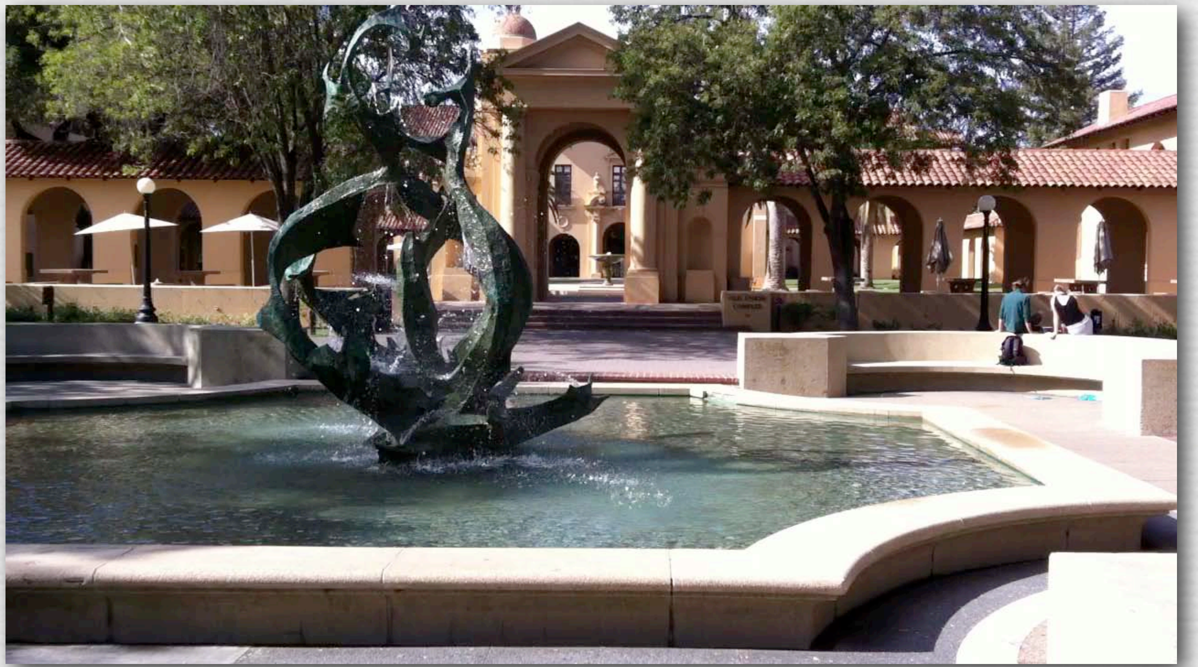
SNR increases as
sqrt(# of frames)



# 2D video stabilization

[Karpenko 2011]

- gyro-based
- also corrects for rolling shutter
- real-time on iPhone 4



- can correct for rotation of camera, but not for translation

# 3D video stabilization

[Agarwala 2011]

- image-based
- warps imagery to infill disocclusions

- corrects for translation as well as rotation
- not real-time

(http://web.cecs.pdx.edu/~fliu/project/subspace_stabilization/demo.mp4)

# Optical image stabilization

- lens-shift

| | |
|---|---|
| Canon | IS (Image Stabilization) |
| Nikon | VR (Vibration Reduction) |
| Panasonic, Leica | MegaOIS |
| Sigma | OS (Optical Stabilization) |
| Tamron | VC (Vibration Compensation) |

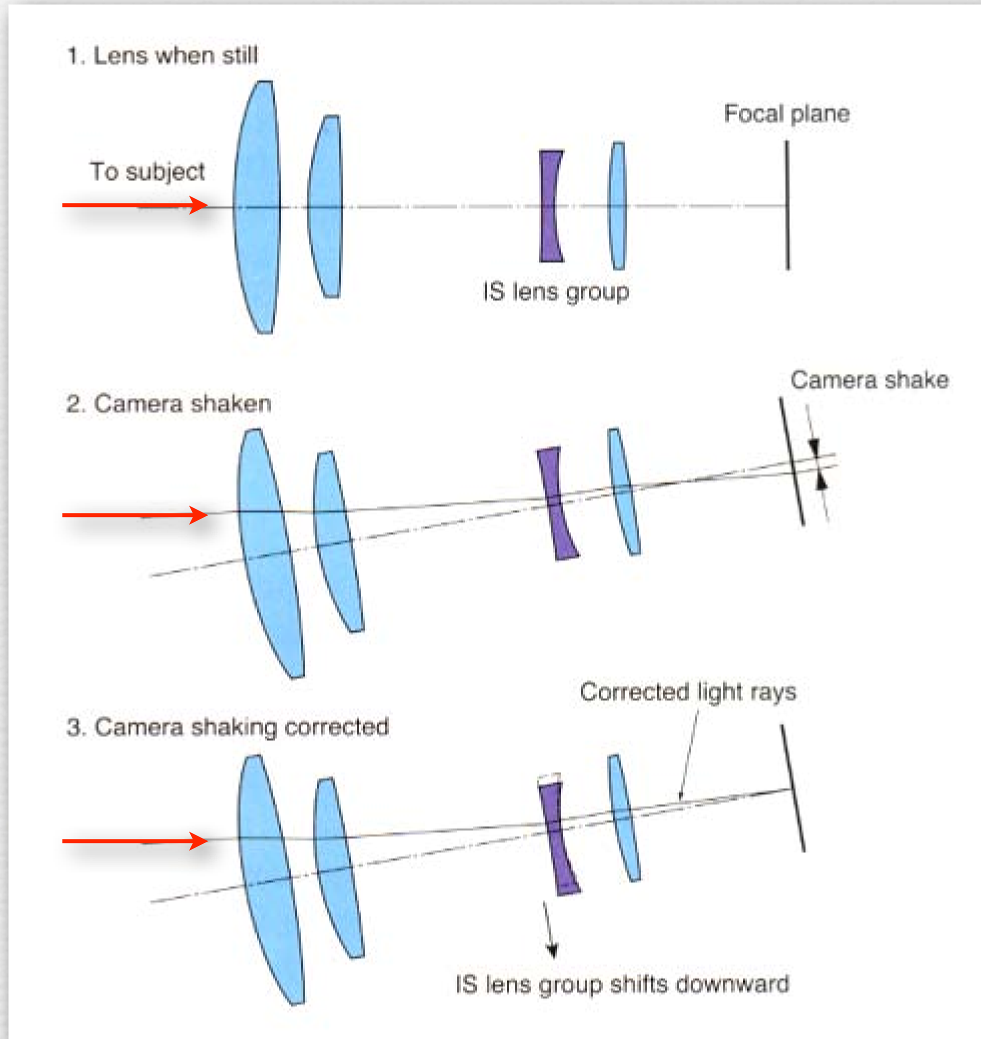
- sensor-shift

| | |
|---|---|
| Konica Minolta | AS (Anti Shake) |
| Sony | SSS (Super Steady Shot) |
| Pentax | SR (Shake Reduction) |
| Olympus | IS (Image Stabilization) |

# Lens-shift stabilization

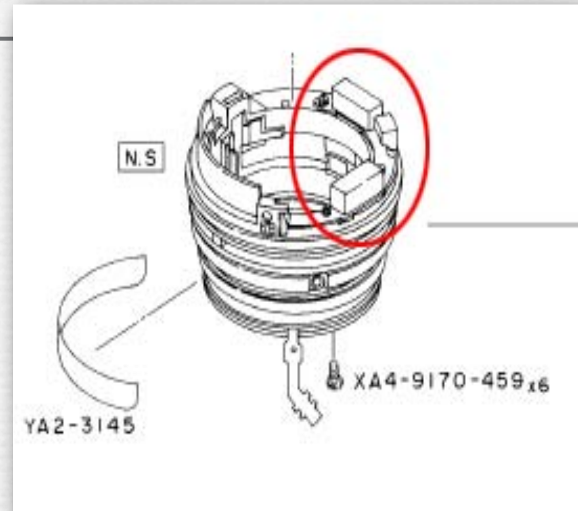
- camera shake is treated as rotation around the center of perspective
- can be offset by translating a lens the other way
- must be done at the same instant in time!

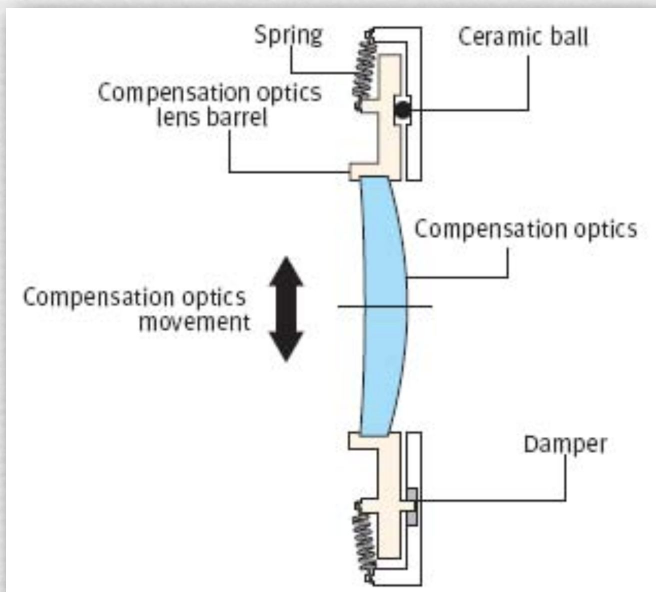
(Canon)

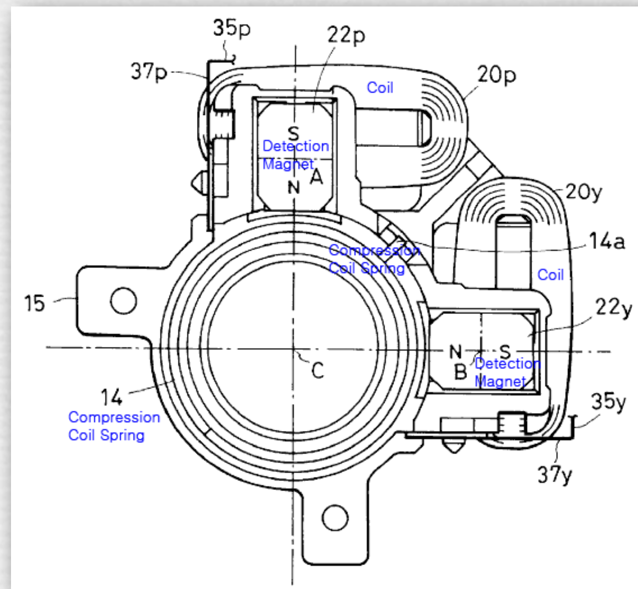


# Lens-shift stabilization

- detect pitching and yawing using two gyroscopes at 90°
- move spring-mounted lens laterally using two electromagnets at 90°

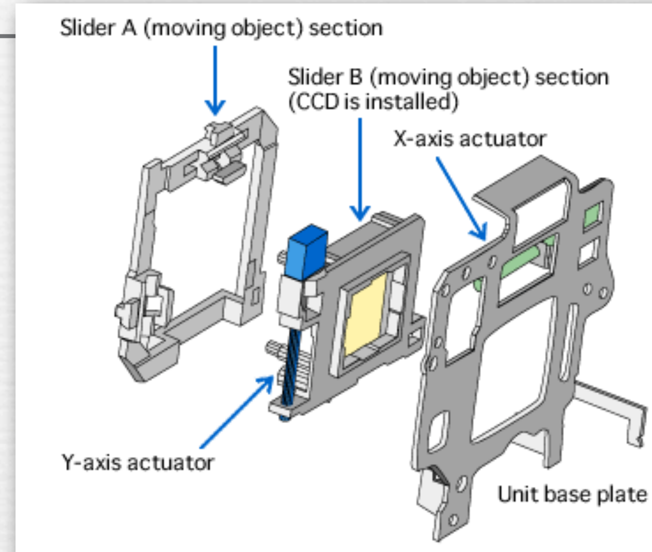


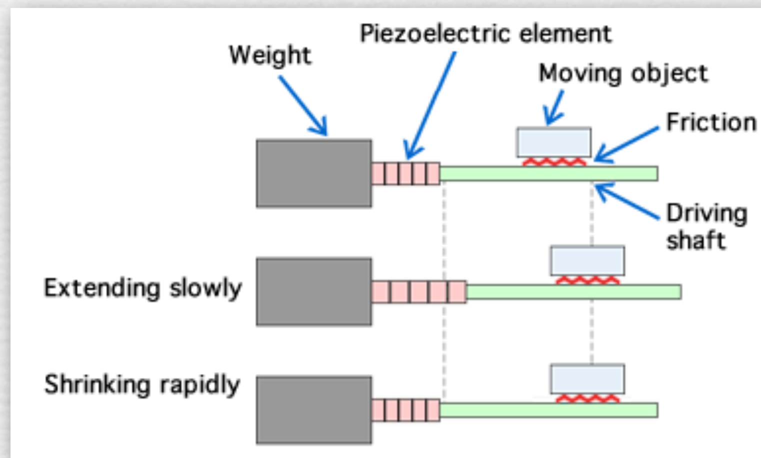



# Sensor-shift stabilization

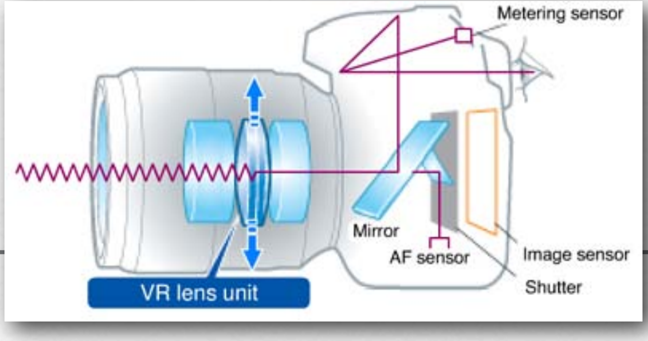
- detect pitching and yawing using two gyroscopes, as before
- move sensor laterally on sliders using two piezo actuators at 90°







# Which is better?

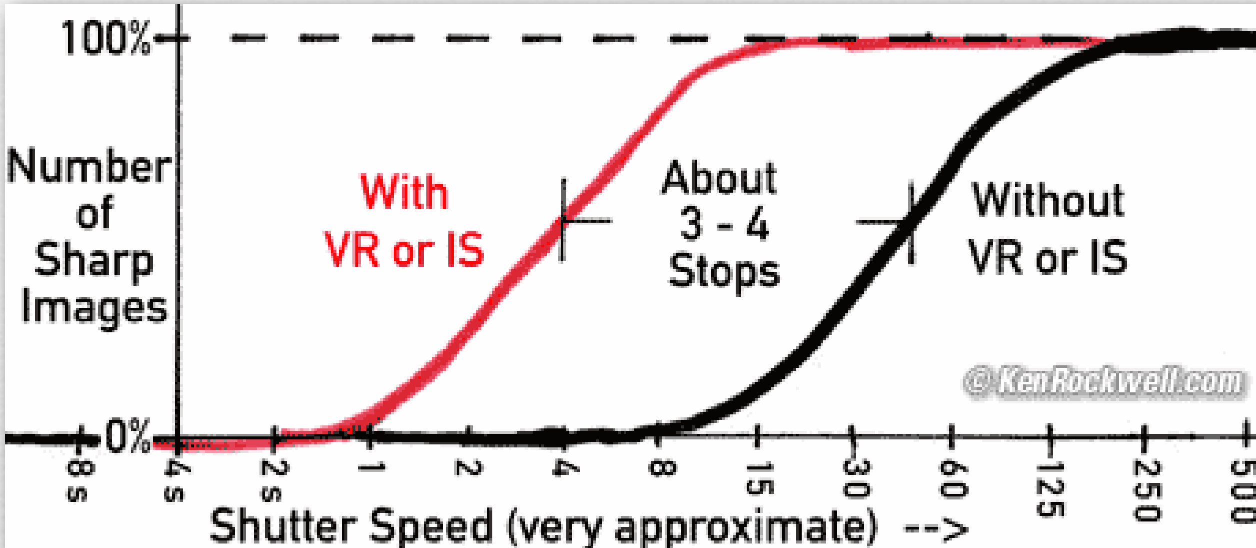



- lens-shift
  - stable viewfinder
  - better autofocus and metering for SLRs than sensor-shift
  - optimized for each lens
- sensor-shift
  - works for every lens, so cost effective
  - stabilizes autofocus and metering for mirrorless cameras, but not for SLRs
  - reduces size and weight of lenses
  - better optical performance?

# Example of image stabilization

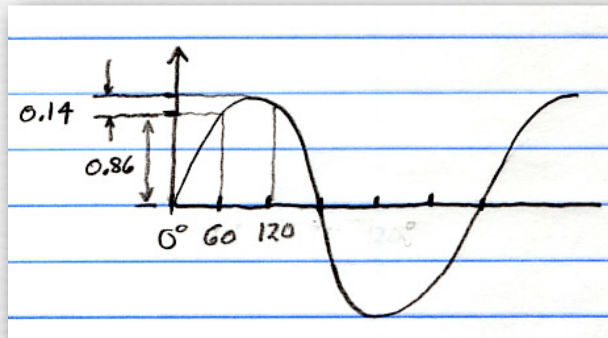
(Canon)

# How much does stabilization help?



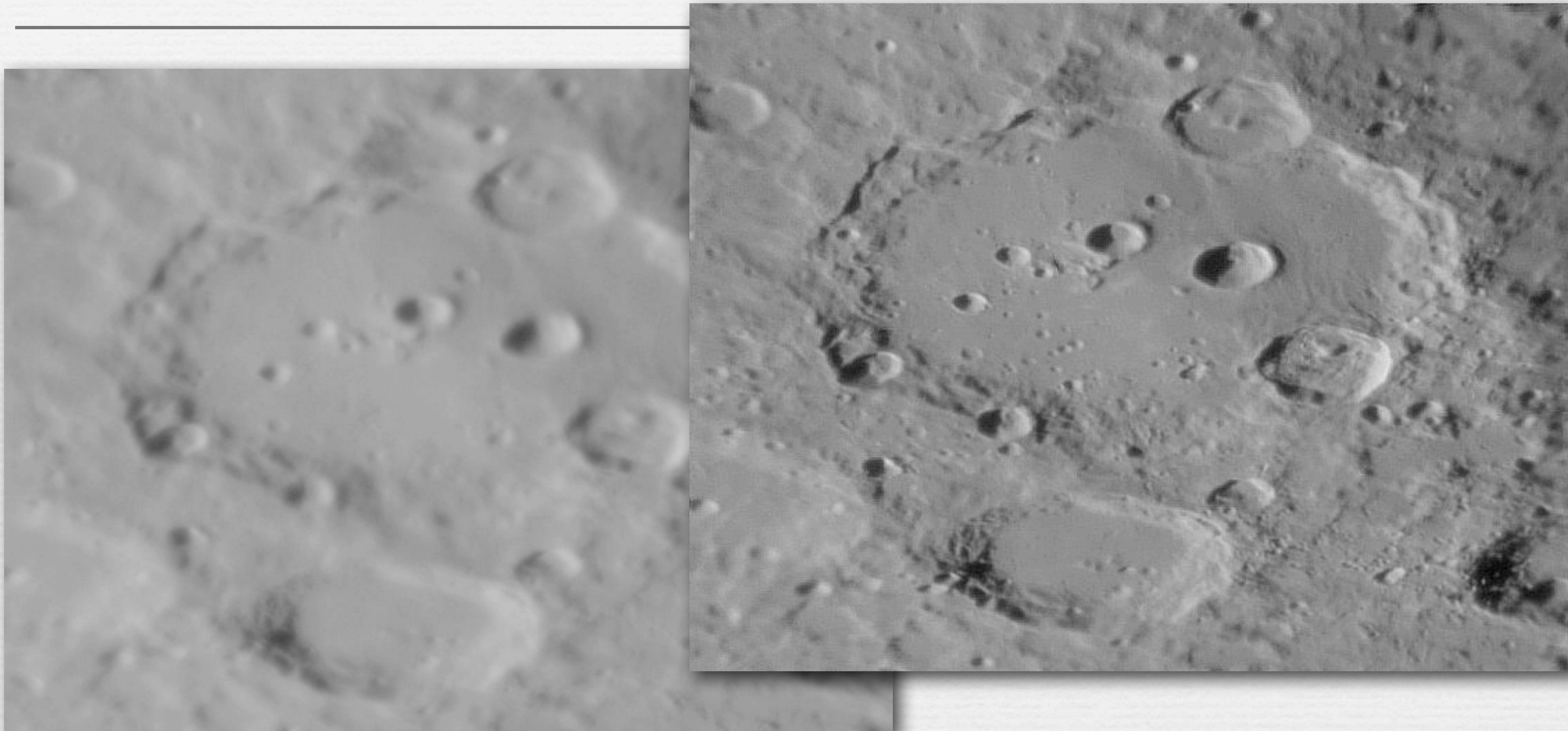

- if you don't have image stabilization (IS), take lots of shots
  - some of them will be sharp, due to sinusoidal nature of camera shake
  - without IS, half your shots at 1/60 sec will be sharp (black curve)
  - with IS, half your shots at 1/4 second will be sharp (red curve)
- between these exposure times, stabilization helps a lot
  - 3-4 stops seems optimistic; your mileage may vary

# Sinusoidal nature of camera shake (contents of whiteboard)




- muscle tremor is sinusoidal, at about 10 cycles per second
- this means 1/10 sec per sine wave period, or 1/60 sec per 60°
- change in y over first 60° is sin(60) - sin(0) = 86% of maximum
- change over second 60° is sin(90) - sin(60) = 14% of maximum
- so some shots are definitely luckier than others

# Lucky imaging in astronomy



(http://www.ast.cam.ac.uk/~optics/Lucky_Web_Site/LI_Amateur.htm)

- quality of "seeing" varies with atmospheric turbulence
- select sharpest parts of sharpest frames, align and average

# Aligning on a foreground object using the Casio EX-F1

# Recap

- camera shake can be stablized optically by moving a lens or the sensor laterally during the exposure, in response to sensed motion of camera body
- optical stabilization allows longer exposures, by 3-4 f/stops
- also, take lots of shots and hope you're lucky

**Questions?**

# Slide credits

- Sung Hee Park


- Canon, *EF Lens Work III: The Eyes of EOS*, Canon Inc., 2004.
- http://KenRockwell.com
- Levin, A., et al., "Understanding and evaluating blind deconvolution algorithms," *Proc. CVPR 2009.*