Optical image stabilization (IS)

CS 178, Spring 2011

Marc Levoy
Computer Science Department
Stanford University

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
  - optical
  - electronic (i.e. digital)
- 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

(samgraphicdesign.com)

(wildsight.co.uk)

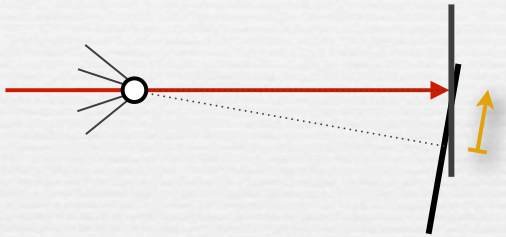
Camera shake as convolution

- 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]

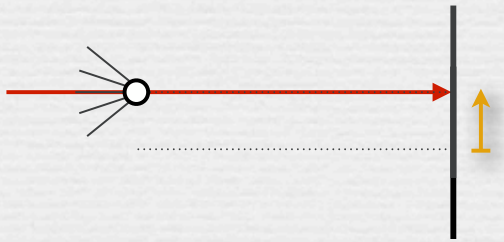
Rotation around center of perspective can be approximated as 2D translation of the image

as rotation



sensor rotates down, features move up

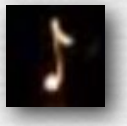
as translation



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

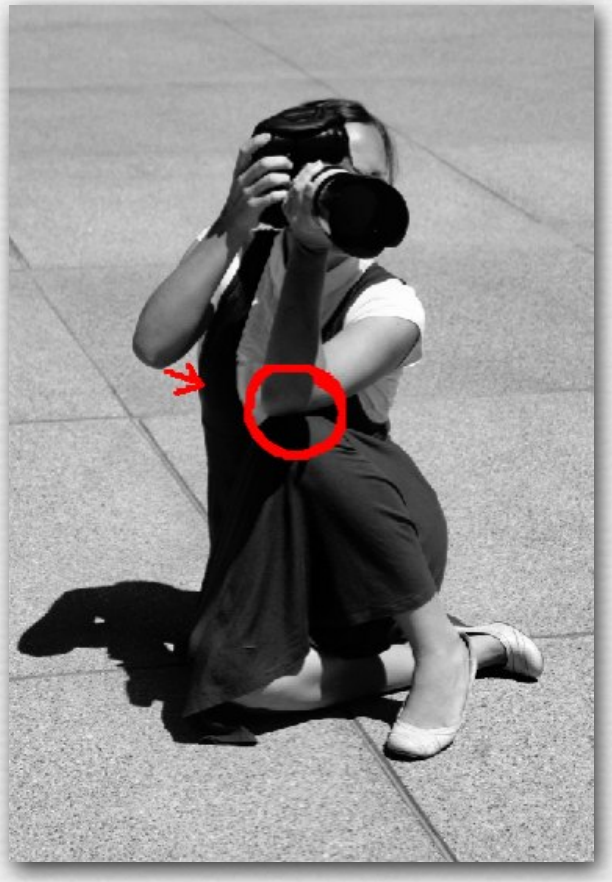
scene $f(x,y)$ $\otimes$  =

Avoiding camera shake

- hold the camera carefully, trigger the shutter slowly

- elbows in
- exhale first

- cradle the camera



- create a tripod

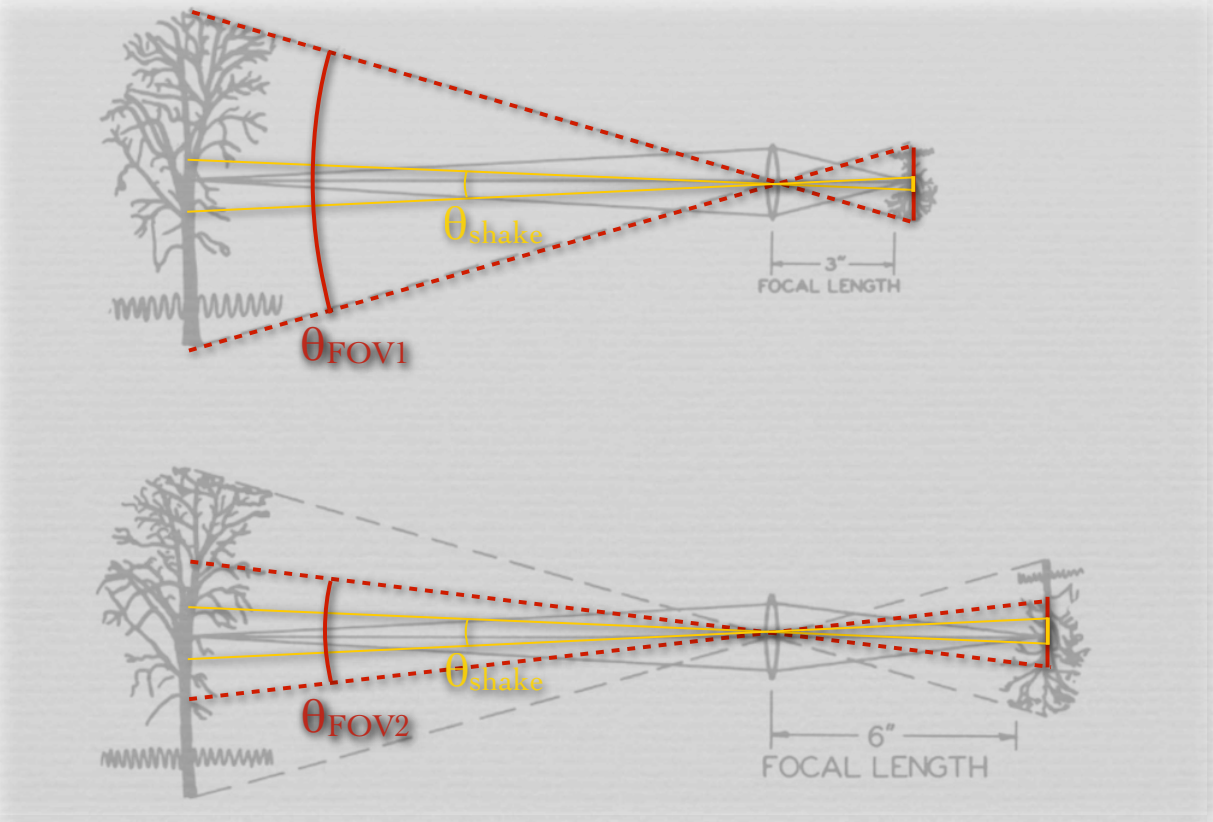
(http://digital-photography-school.com/how-to-avoid-camera-shake)

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

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

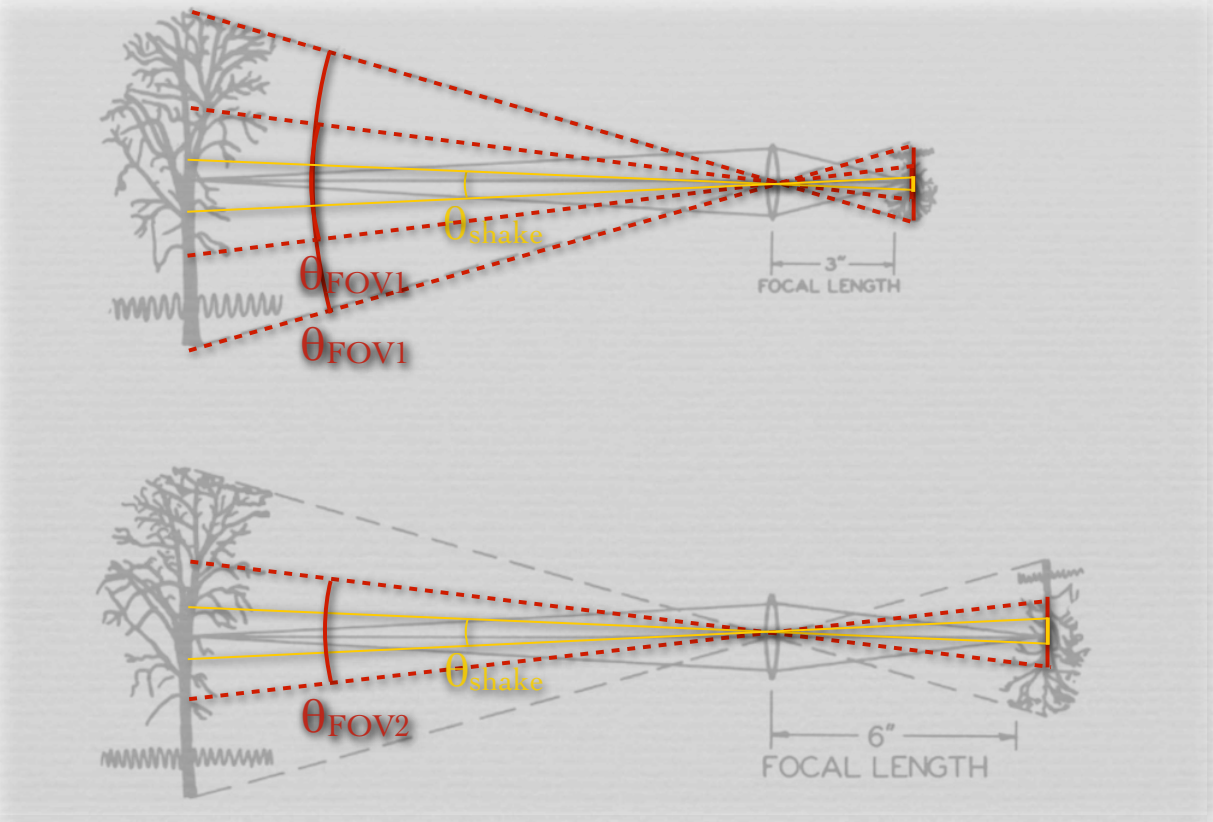
e.g. 1/500 second for a 500mm lens

  - 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)



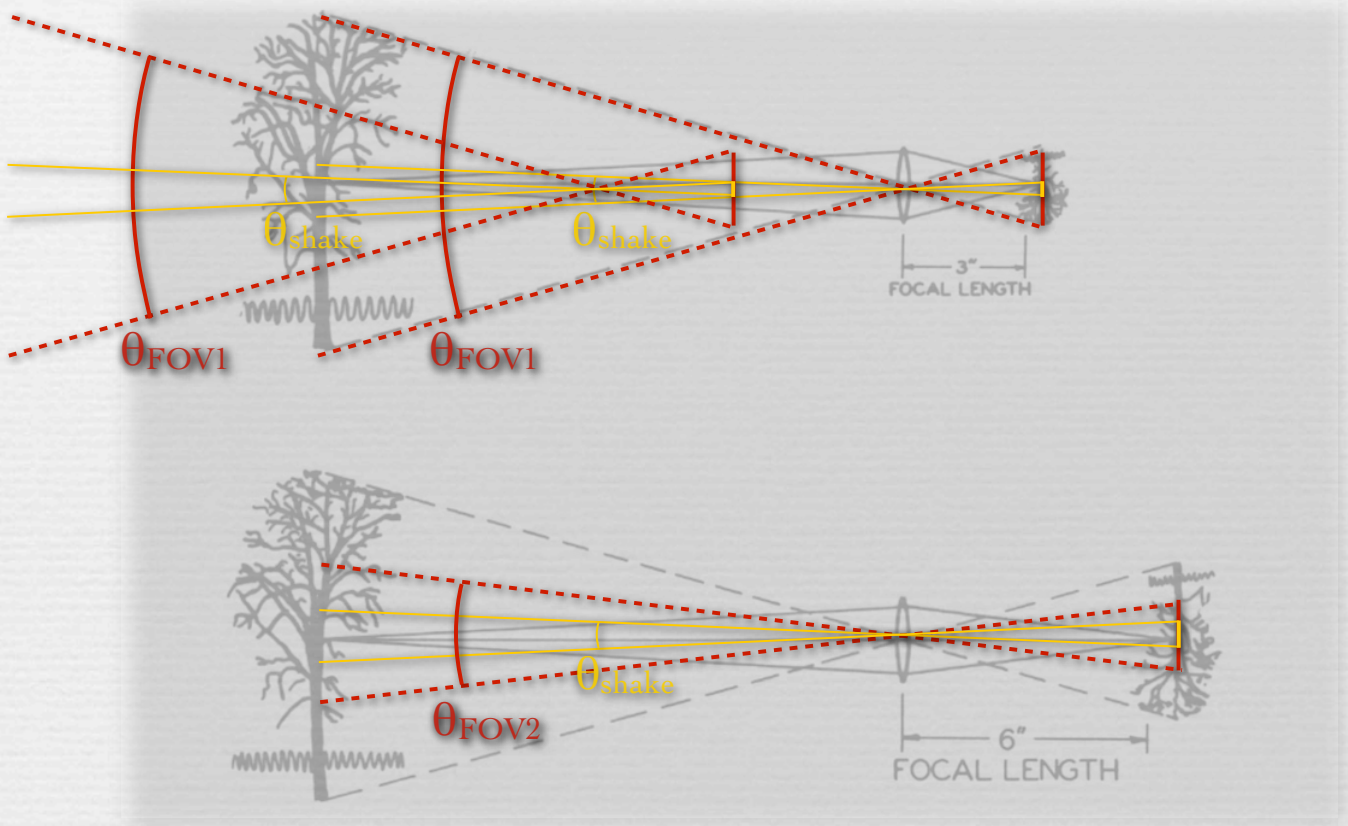
- no, cropping the image is like increasing the focal length; handshake becomes a larger fraction of the angular FOV

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
- 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
- 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



(Kingslake)

- 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

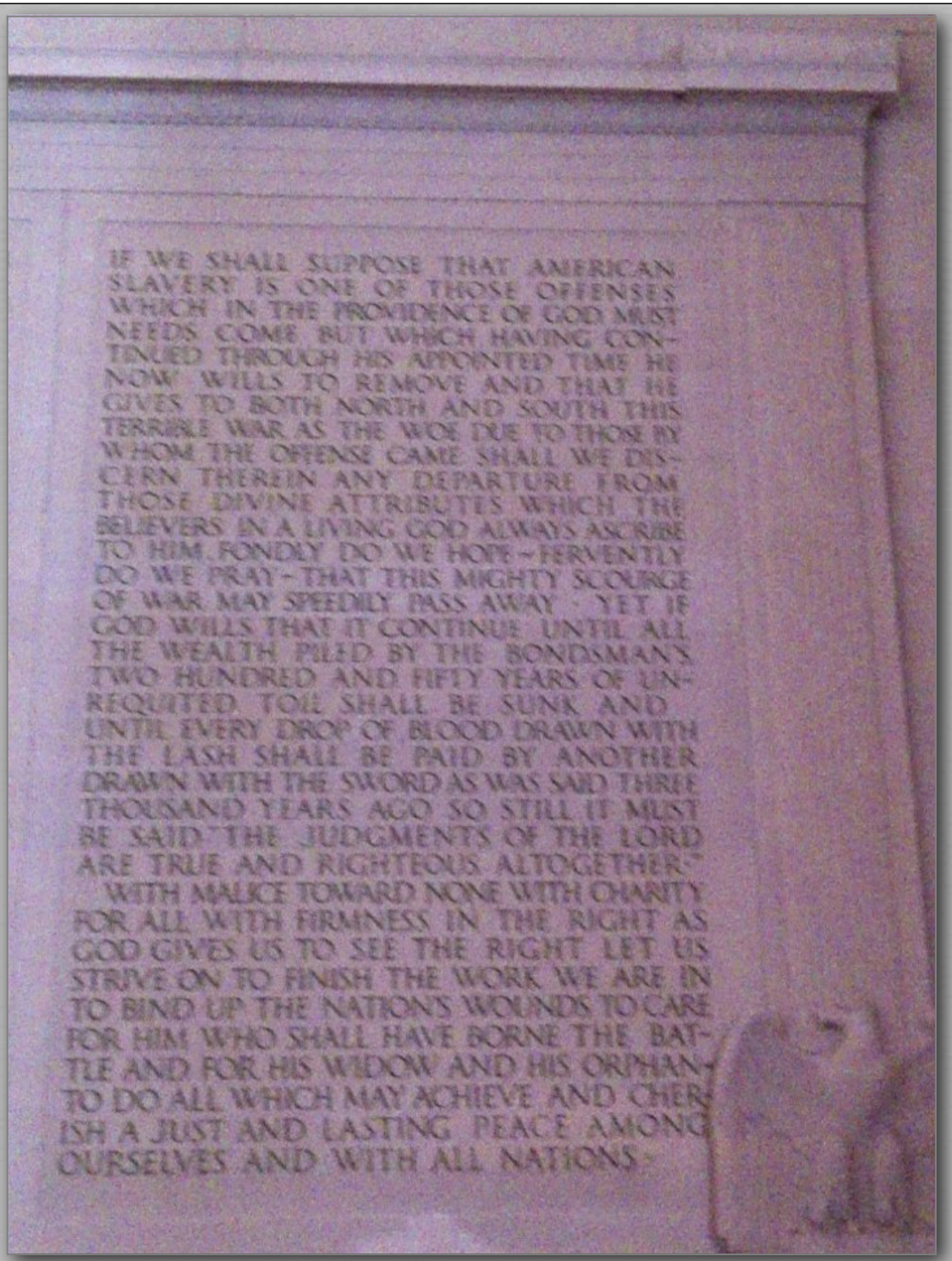
Image stabilization systems

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

The outline slide I presented in class failed to emphasize that optical image stabilization operates during a single exposure, while electronic stabilization aligns multiple shots. I've fixed that bug here.

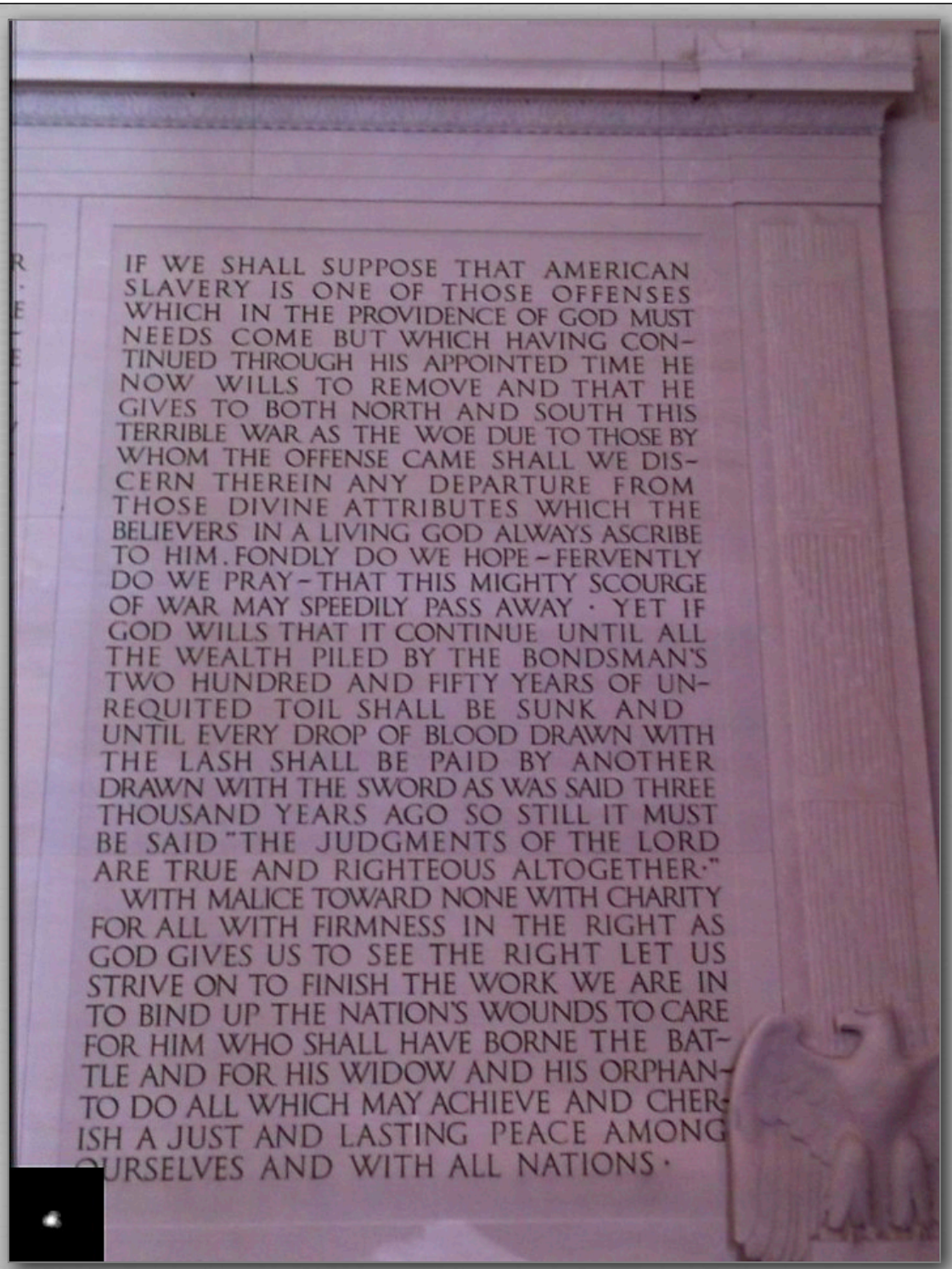
iPhone 4,
single HD
video frame

blurry due to long exposure time and handshake; noisy nevertheless



Synthcam, average of ~30 frames

SNR increases as sqrt(# of frames)



Research in video stabilization

[Agarwala 2011]

(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)

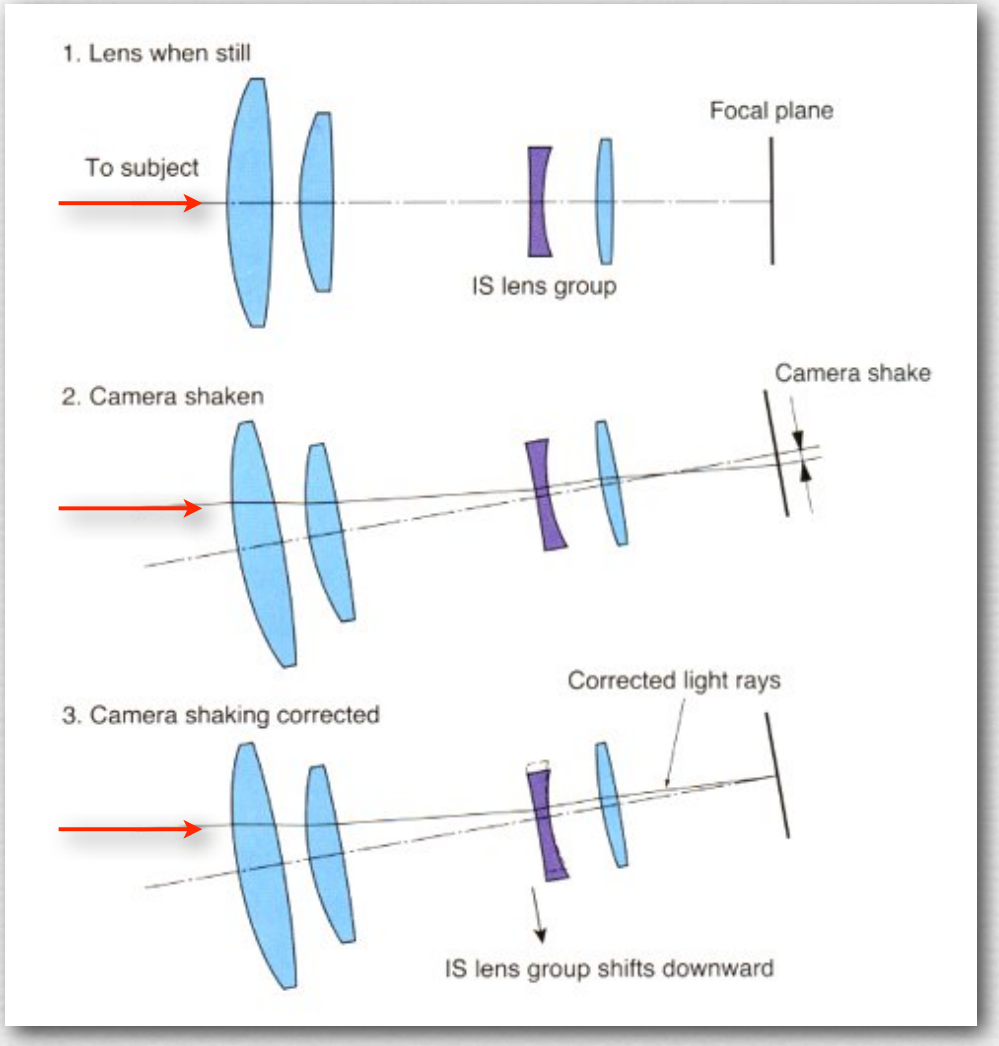
- sensor-shift

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

Lens-shift stabilization

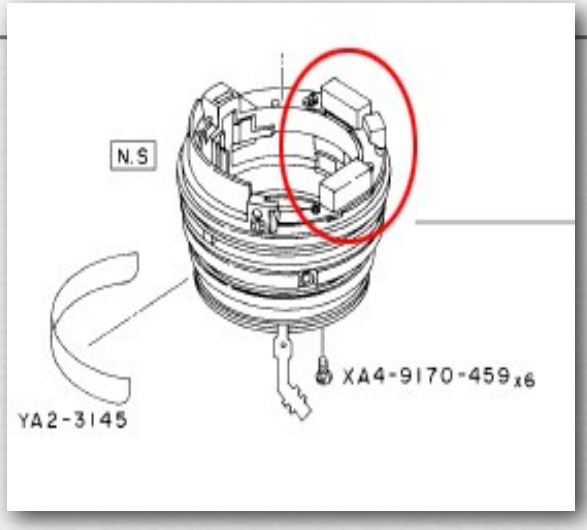
- camera shake is treated as rotation around the center of perspective
- can be offset by translating a lens the other way
- must be done at the same instant in time!

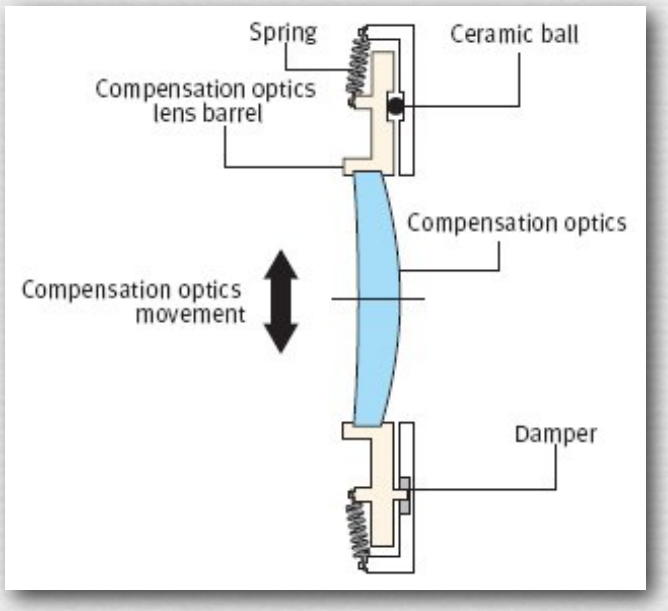
(Canon)

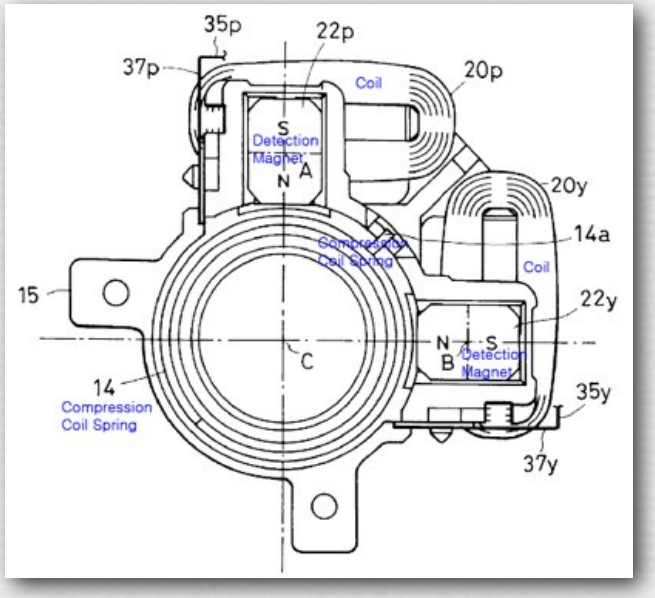


Lens-shift stabilization

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

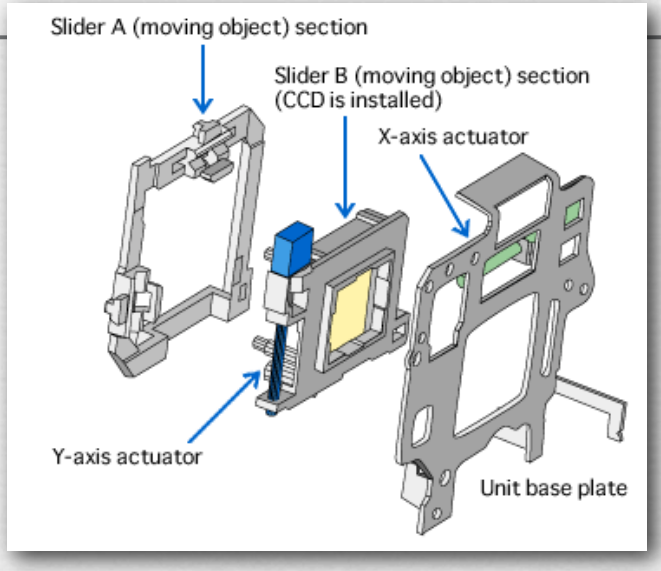


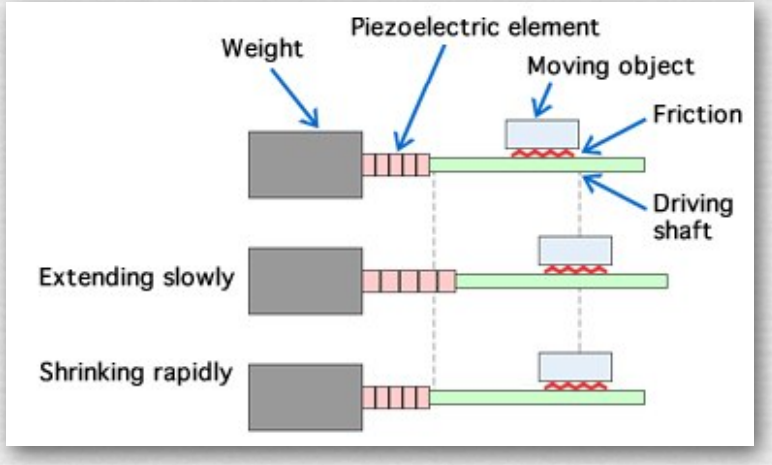




Sensor-shift stabilization

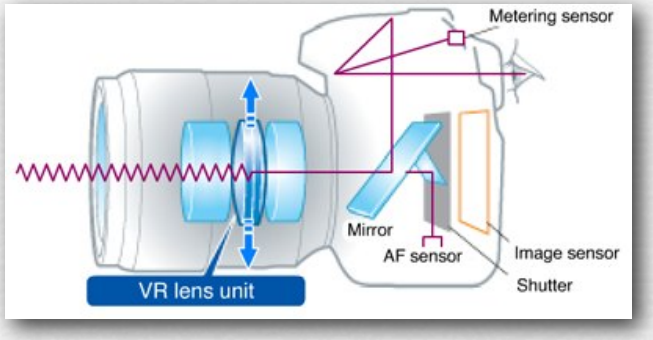
- detect pitching and yawing using two gyroscopes, as before
- move sensor laterally on sliders using two piezo actuators at 90°





Which is better?

- lens-shift
  - stable viewfinder
  - better autofocus and metering
  - optimized for each lens



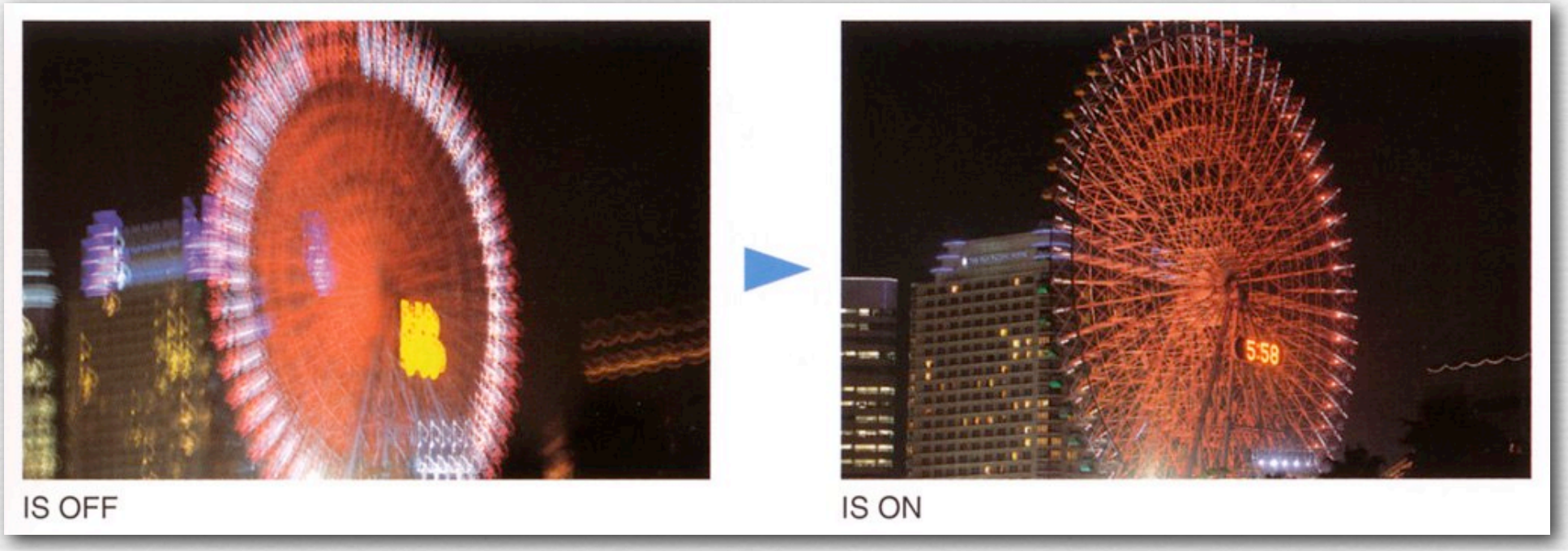
- sensor-shift
  - works for every lens, so cost effective
  - reduces size and weight of lenses
  - better optical performance

Additional features

- panning detection
  - some systems have an alternative IS mode for panning
- tripod detection
  - turn off stabilization when camera is stationary on a tripod
- re-centering prior to exposure (Nikon)
  - to maximize IS movement range during exposure

Examples of image stabilization

(Canon)



Examples of image stabilization

Nikon D200, 18-200mm at 28mm at 1/4s (77% crop)

Nikon D70, 18-200mm at 28mm at 1/4s (100% crop)

- lesson: fancy camera body doesn't matter if you can't hold it still!

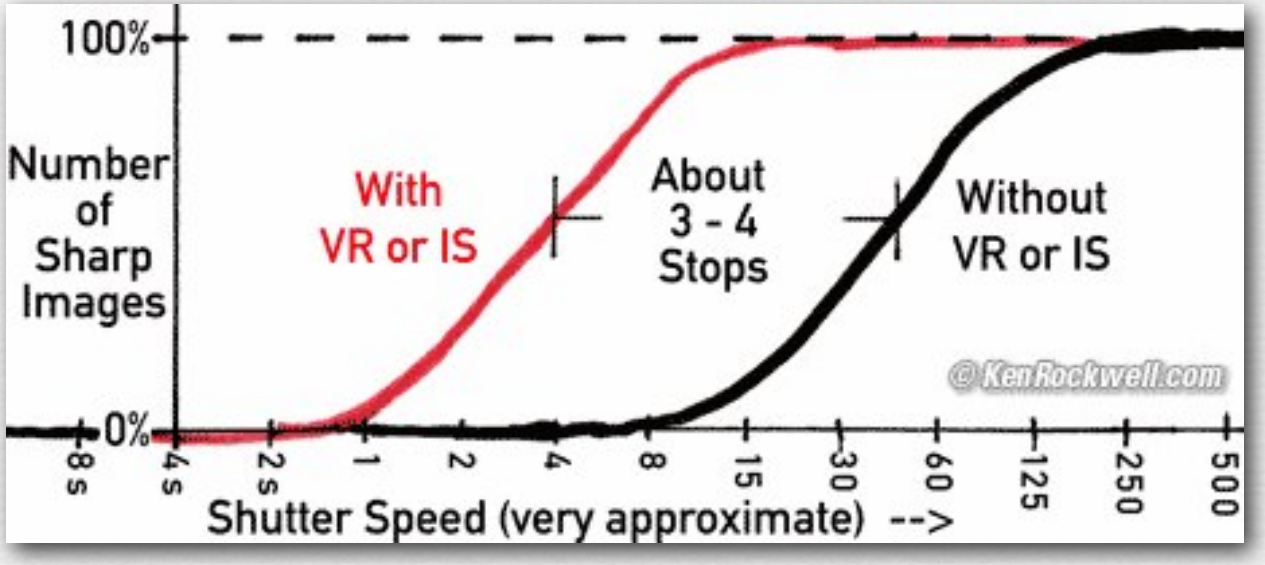
Examples of image stabilization

Nikon D200, 18-200mm at 28mm at 1/4s (77% crop)

Canon SD700 IS at 1/4s (100% crop)

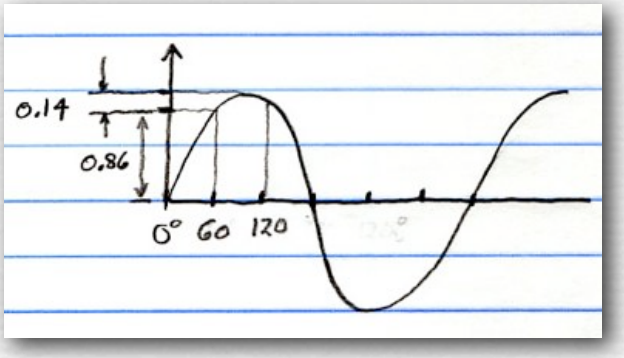
- lesson: SLR no better than DSC if you can't hold it still!

How much does stabilization help?



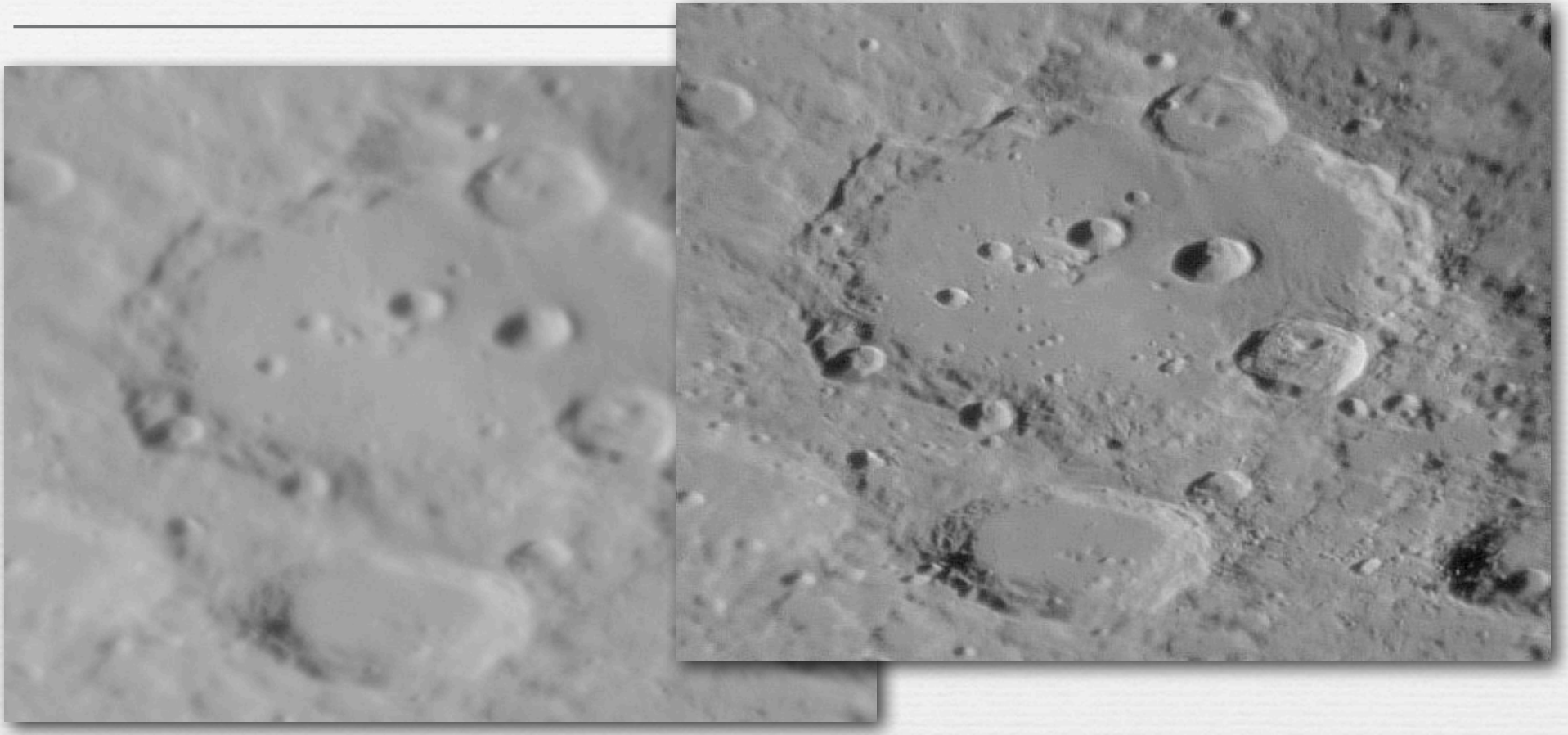
- if you don't have image stabilization (IS), take lots of shots
  - some of them will be sharp, due to sinusoidal nature of camera shake
  - without IS, half your shots at 1/60 sec will be sharp (black curve)
  - with IS, half your shots at 1/4 second will be sharp (red curve)
- between these exposure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

Sinusoidal nature of camera shake (contents of whiteboard)



- muscle tremor is sinusoidal
- 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

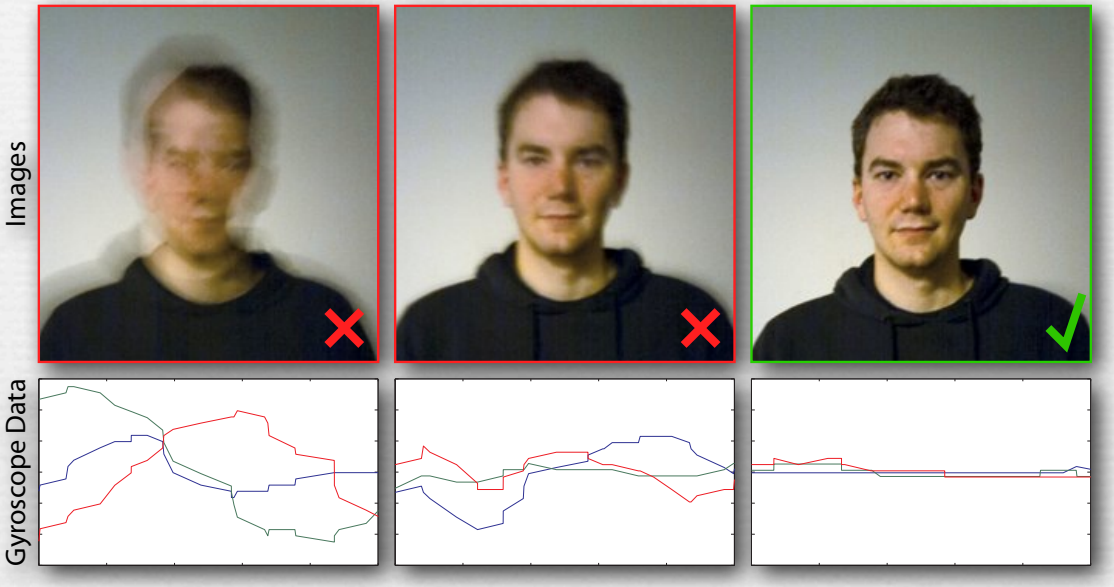


(http://www.ast.cam.ac.uk/~optics/Lucky_Web_Site/LI_Amateur.htm)

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

Lucky imaging using the N900 "F"

- 3-axis gyroscope on N900
- burst of 1/2-sec exposures
- save image if little motion



- could alternatively combine multiple lucky 1/8-sec exposures
- future: deconvolve using gyro trace as initial guess of kernel
- also: deconvolve from multiple moderately lucky images

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*.