Optical image stabilization (IS)

CS 178, Spring 2014

Begun 4/29/14, finished 5/1.



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Outline

• what are the causes of camera shake?

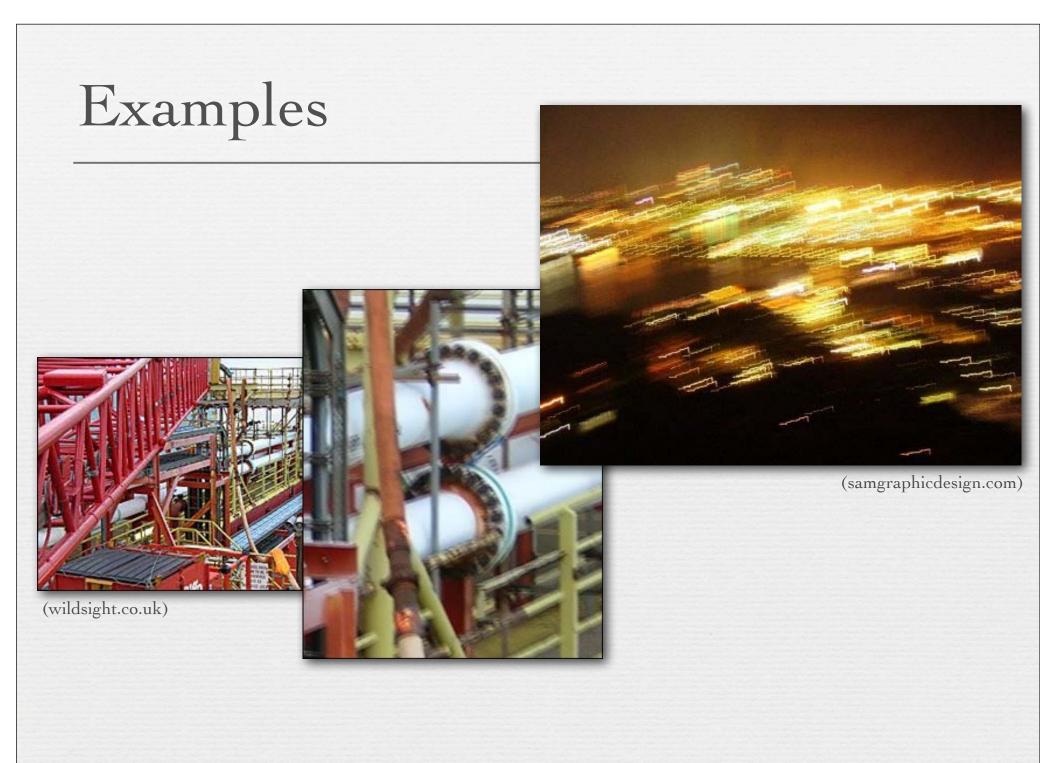
- how can you avoid it (without having an IS system)
- treating camera shake as a 2D convolution of the image
- image stabilization systems
 - mechanical
 - electronic, i.e. digital (among multiple shots)
 - optical
- optical image stabilization
 - lens shift
 - sensor shift
 - how much does stabilization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





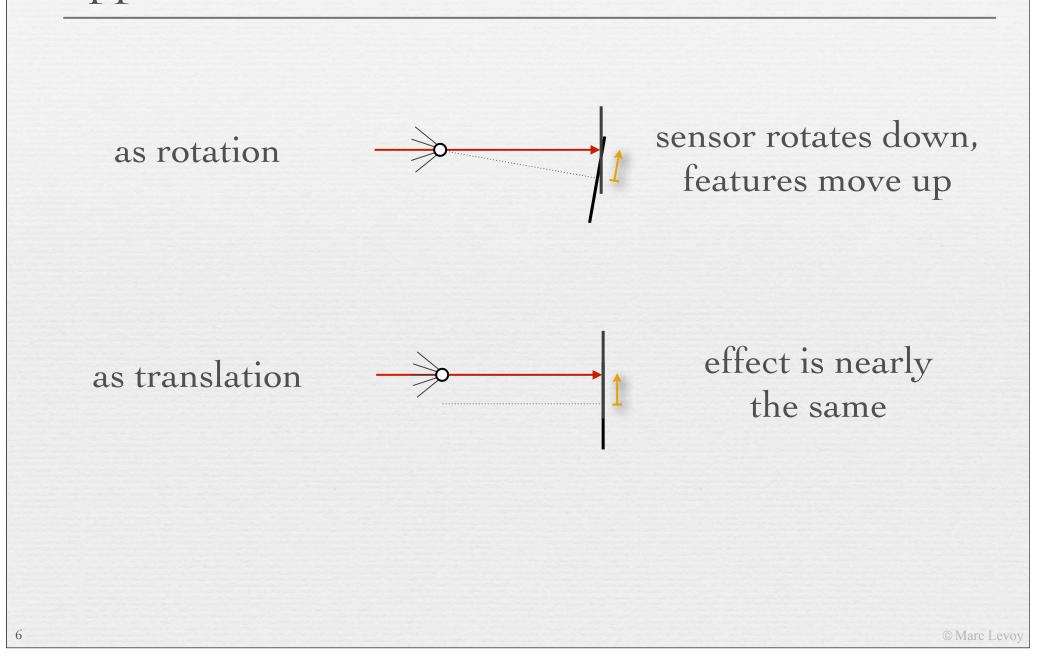
Camera shake as convolution

- 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]

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



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

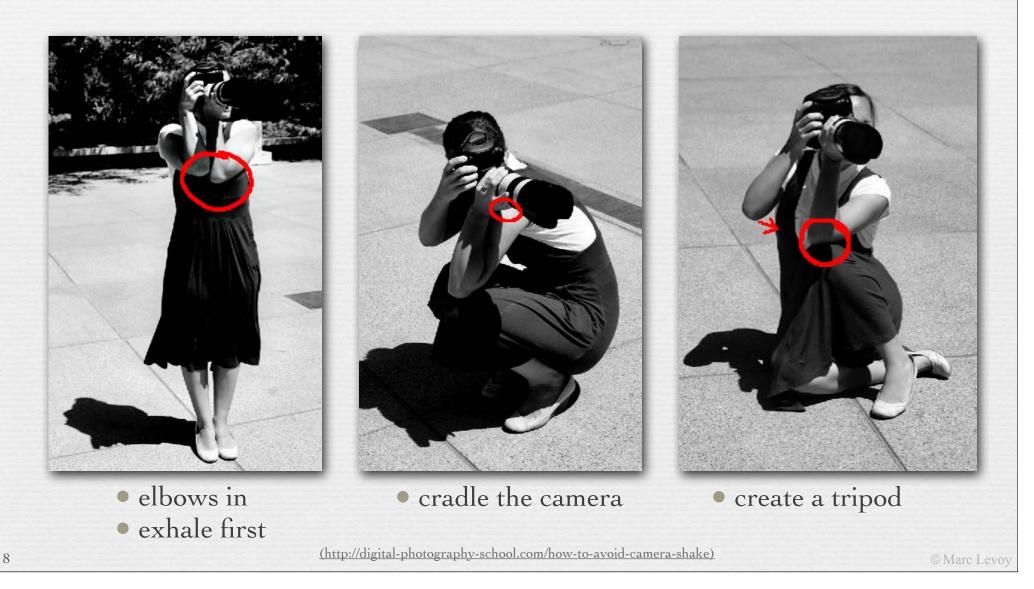
scene f(x,y) \otimes





Avoiding camera shake

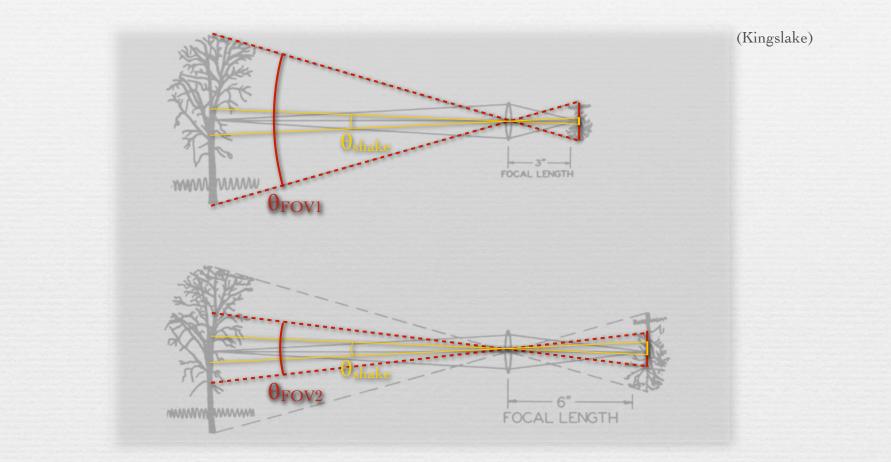
hold the camera carefully, trigger the shutter slowly



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



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

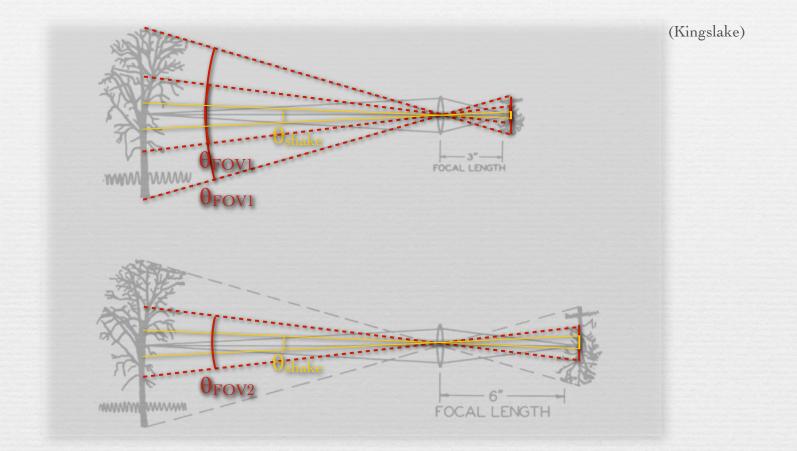
Avoiding camera shake

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- 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 compensateor use flash

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

Effect of cropping the image



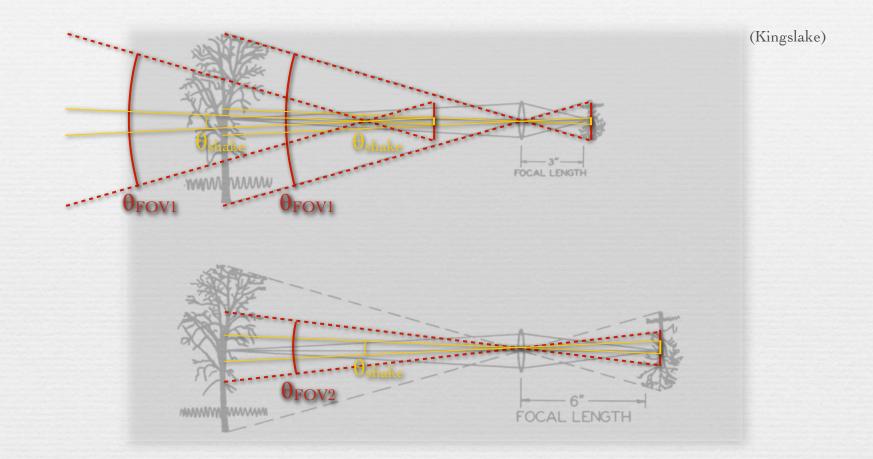
 no, cropping the image is like increasing the focal length; handshake becomes a larger fraction of the angular FOV

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



- 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

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

- 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

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



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



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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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iPhone 4, single HD video frame

blurry due to long exposure time and handshake; noisy nevertheless

IF WE SHALL SUPPOSE THAT AMERICAN SLAVERY IS ONE OF THOSE OFFENSES WHICH IN THE PROVIDENCE OF GOD MUST NEEDS COME BUT WHICH HAVING CON-TINCED THROUGH HIS APPOINTED TIME NOW WILLS TO REMOVE AND THAT GIVES TO BOTH NORTH AND SOUTH TERRIERE WAR AS THE WON DUE TO THOSE BD WHOM THE OWENESS CAME SHALL WE I CERN THEREIN ANY DEPARTURE FROM THOSE DIVINE ATTRIBUTES WHICH THE SELEVERS IN A LIVING COD ALWAYS AS TO HIM FONDLY DO WE HOPE - FERVEN DO WE PRAY-THAT THIS MIGHTY SCC WAR MAY SPEEDILY PASS AWAY O WILLS THAT IT CONTINUE UNTIL THE WEALTH PILED BY THE BONDSMAN'S TWO HUNDRED AND HIFTY YEARS OF UN-RECUTED TOIL SHALL BE SUNK AND THE EVERY DROP OF BLOOD DRAWN WITH LASH SHALL BE PAID BY ANOTHER DRAWN WITH THE SWORD AS WAS SAND THREE USAND YEARS AGO SO STILL IT MUS RE SAID THE JUDGMENTS OF THE LORD ARE TRUE AND RIGHTEOUS ALTOGETHER WITH MALKE TOWARD NONE WITH CHARIT ROR ALL WITH FERMINESS IN THE RICHT COD GIVES US TO SEE THE RIGHT STRIVE ON TO FINISH THE WORK WE ARE TO BIND UP THE NATIONS WOUNDS FOR HIM WHO SHALL HAVE BORNE THE BAT-TEF AND FOR HIS WILXIN AND HIS ORPHAN DO ALL WHICH MAY ACHIEVE AND ISH A JUST AND LASTING PEACE AMONG OURSELVES AND WITH ALL NATIONS

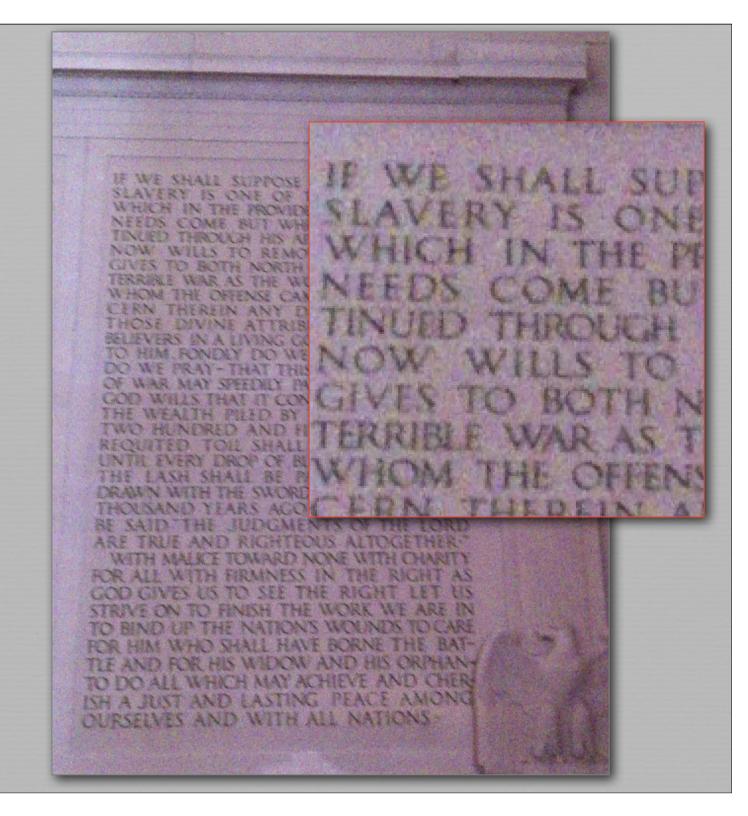
Synthcam, average of ~30 frames

IF WE SHALL SUPPOSE THAT AMERICAN SLAVERY IS ONE OF THOSE OFFENSES WHICH IN THE PROVIDENCE OF GOD MUST NEEDS COME BUT WHICH HAVING CON-TINUED THROUGH HIS APPOINTED TIME HE NOW WILLS TO REMOVE AND THAT HE GIVES TO BOTH NORTH AND SOUTH THIS TERRIBLE WAR AS THE WOE DUE TO THOSE BY WHOM THE OFFENSE CAME SHALL WE DIS-CERN THEREIN ANY DEPARTURE FROM THOSE DIVINE ATTRIBUTES WHICH THE BELIEVERS IN A LIVING GOD ALWAYS ASCRIBE TO HIM. FONDLY DO WE HOPE ~ FERVENTLY DO WE PRAY - THAT THIS MIGHTY SCOURGE OF WAR MAY SPEEDILY PASS AWAY . YET IF GOD WILLS THAT IT CONTINUE UNTIL ALL THE WEALTH PILED BY THE BONDSMAN'S TWO HUNDRED AND FIFTY YEARS OF UN-REQUITED TOIL SHALL BE SUNK AND UNTIL EVERY DROP OF BLOOD DRAWN WITH THE LASH SHALL BE PAID BY ANOTHER DRAWN WITH THE SWORD AS WAS SAID THREE THOUSAND YEARS AGO SO STILL IT MUST BE SAID "THE JUDGMENTS OF THE LORD ARE TRUE AND RIGHTEOUS ALTOGETHER. WITH MALICE TOWARD NONE WITH CHARITY FOR ALL WITH FIRMNESS IN THE RIGHT AS GOD GIVES US TO SEE THE RIGHT LET US STRIVE ON TO FINISH THE WORK WE ARE IN TO BIND UP THE NATION'S WOUNDS TO CARE FOR HIM WHO SHALL HAVE BORNE THE BAT-TLE AND FOR HIS WIDOW AND HIS ORPHAN-TO DO ALL WHICH MAY ACHIEVE AND CHER-

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URSELVES AND WITH ALL

iPhone 4, single HD video frame



Synthcam, average of ~30 frames

SNR increases as sqrt(# of frames)

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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

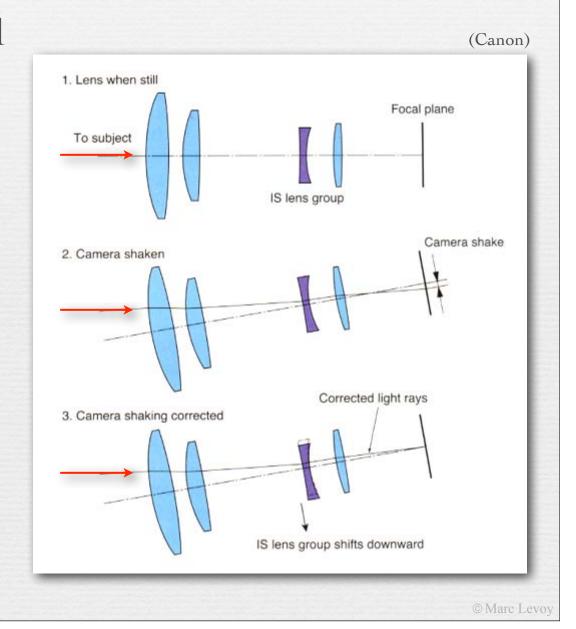
Canon	IS (Image Stabilization)
Nikon	VR (Vibration Reduction)
Panasonic, Leica	MegaOIS
Sigma	OS (Optical Stabilization)
Tamron	VC (Vibration Compensation)

★ sensor-shift

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

Lens-shift stabilization

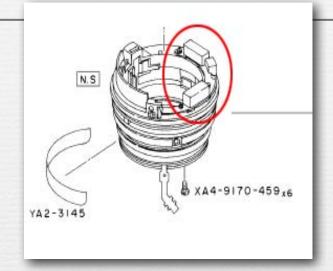
- camera shake is treated as rotation around the center of perspective
- can be offset by translating a lens the other way
- must be done at the same instant in time!



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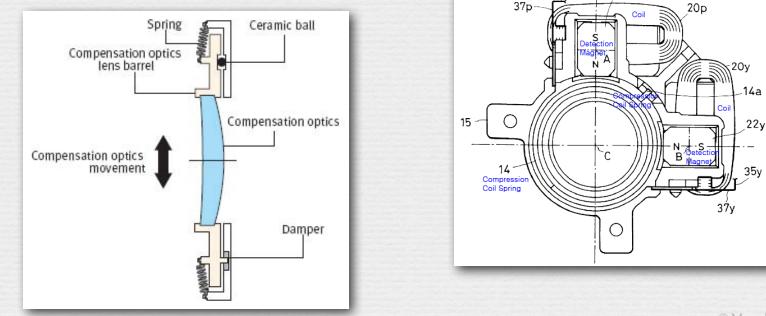
Lens-shift stabilization

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



35p

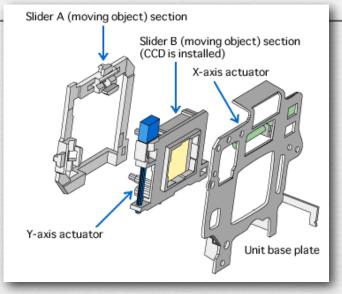
22p

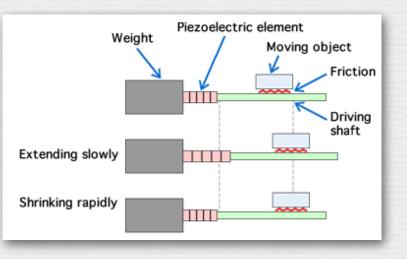


Sensor-shift stabilization

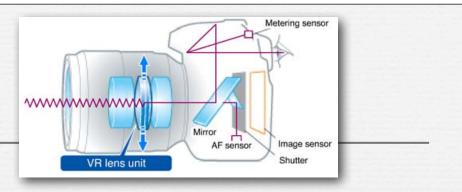
- detect pitching and yawing using two gyroscopes, as before
- move sensor laterally on sliders using two piezo actuators at 90°





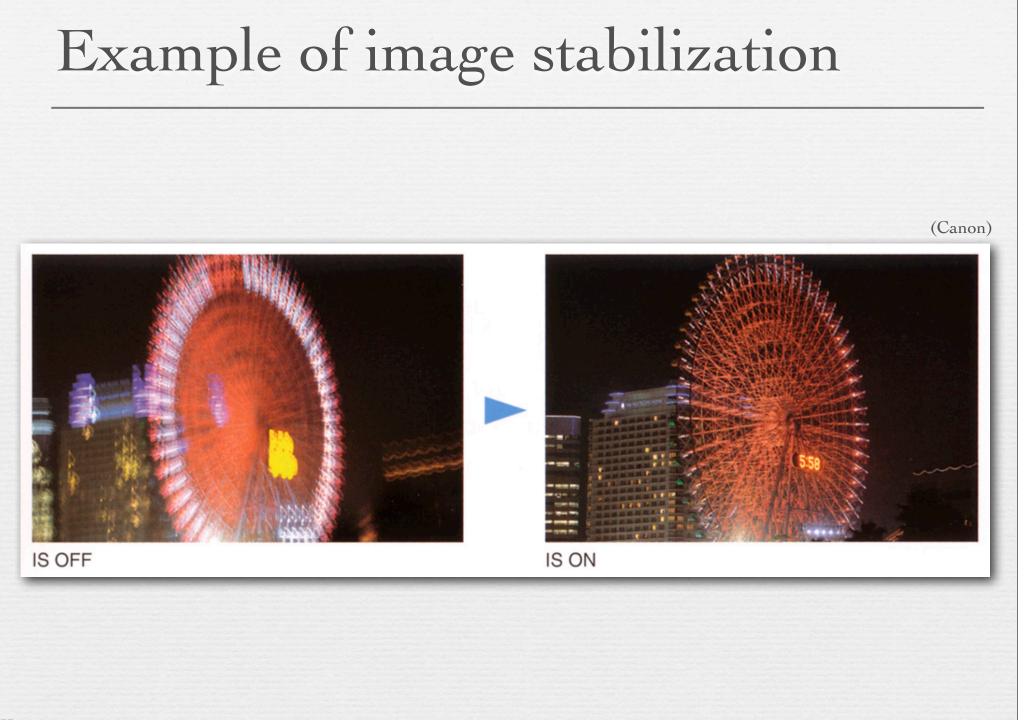


Which is better?

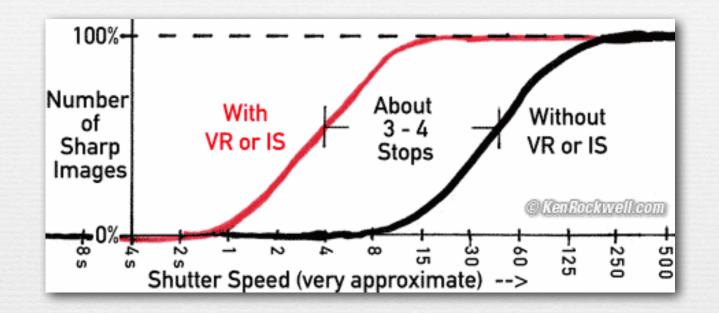


- ✦ lens-shift
 - stable viewfinder
 - better autofocus and metering for SLRs than sensor-shift
 - optimized for each lens
- sensor-shift
 - works for every lens, so cost effective
 - stabilizes autofocus and metering for mirrorless cameras, but not for SLRs
 - reduces size and weight of lenses
 - better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





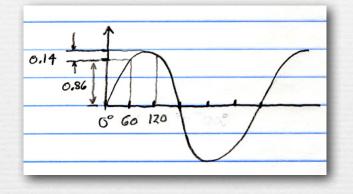
How much does stabilization help?



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

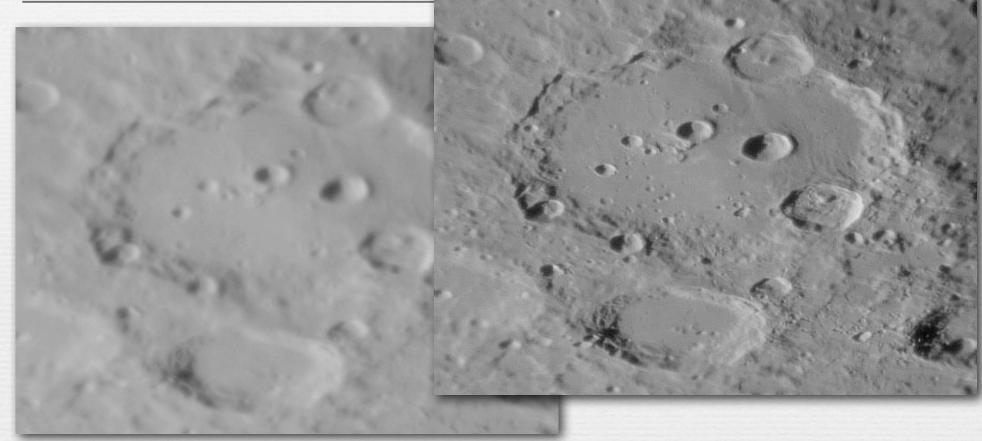
Sinusoidal nature of camera shake (contents of whiteboard)



- 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

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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



Slide credits

Sung Hee Park

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