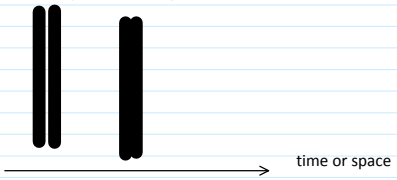
09.Resolution

Sunday, January 23, 2011 3:27 PM

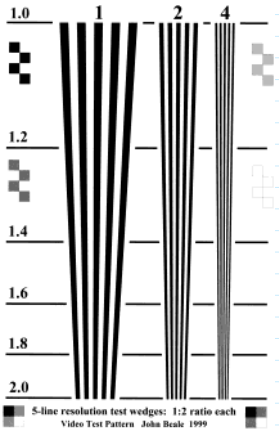
Today:
Spatial and temporal resolution
Bring input device for next 3 classes

Resolution: Spatial and Temporal

Can two adjacent things be resolved?



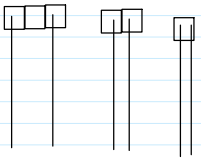
Resolution = minimum distance between two objects for them to be recognized as separate.
Applies to objects (spatial resolution)
and events (temporal or time resolution)



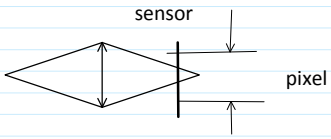
"Large resolution" = meaningless
"Fine resolution" or "Highly resolved"
= well - resolved.

Spatial resolution can be DEGRADED by

- Bad focus
- Rastering, pixelation
- Diffraction effects
- Low contrast
- Compression artifact (in jpegs)
- Motion blur



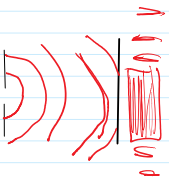
- Bad focus: is circle of confusion > pixel?



- Diffraction effects if lens aperture or pixel size < λ wavelength of light

λ < d
tweeters,
Beamy effect, sharp focus

λ >d
woofers, relatively
small aperture



fuzz from interference effects

Example : http://www.luminous-landscape.com/tutorials/understanding-series/u-diffraction.shtml. Moral of the story: high f number has better depth of field, but sharpness can be defeated by diffraction effects.

Current sensor sizes range 35 - 3 mm. For 3k px wide, 1 pixel = 10 -1 µm.
Red λ = 0.7 µm. Pretty close!

"Canon Develops 35 Mm Full-frame CMOS Sensor for Video Capture."
Accessed March 5, 2013.
http://www.opli.net/magazine/imaging/2013/canon_35_mm_full_frame_CMOS.aspx.

How much resolution is needed?
Consider range of scales:
3000 px wide image, can see 1:1000 = 3 decades of scales

What is a decade? 10x; AKA order of magnitude
O(x)
Largest scale = whole frame, takes 3000 px.
Smallest resolvable scale = feature that takes up 3 px or so.
3→30 One decade
30 → 300 2nd decade
300→3000 3rd decade.
We can resolve features that range across 3 decades of scales.

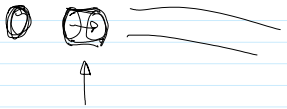
In flow, scales can be 3 minimum,
For turbulence need 4 or 5 decades minimum
Same scale considerations as for CFD:
If resolution is increased, is new information seen?
Is it important information?
In CFD, could have different physics; even large scale results could be wrong
In Flow Vis, missing small scales could lead to misinterpretation of physics

Minute paper: In your GW image, how many decades of length scale was in your flow?
How many did your image capture?
Was your flow spatially resolved?

Examples from GW images; resolved vs not resolved. What if there aren't two things close together, how to estimate from an edge gradient?

Human eye resolution, 74 to >500 Mpx, depending on how you count.
http://www.clarkvision.com/articles/eye-resolution.html

Time resolution



Other considerations of shutter speed:
Short enough to 'freeze' flow= TIME RESOLVED
VS long enough to get desired particle tracks
or long enough to be TIME AVERAGED.
Calculate motion blur. If unacceptable, increase time resolution= shorter exposure time

Increase shutter speed
Max is 1/10,000? 0.1 msec, 100 µsec? At best.
High speed camera 30,000 fps ~ 3 x 10-5 sec = 30 µsec

Freeze the flow with short light source (won't work for light emitting fluids, i.e. flames)
Strobe, camera flash ~ 10-5 or -6 sec = 1-10 µsec
Pulsed laser 3x10-9 sec = 3 nsec or less
Good resource for high speed photography: http://www.hiviz.com/index.html

If long shutter is needed, might be too much light, even at low ISO.
Try a
NDF = Neutral Density Filter. Neutral = all wavelengths equally. Gray.
NDF 1 = 1 /10 light transmission, 3 stops
NDF 2 = 1/100 etc. Log scale. 7 stops
http://en.wikipedia.org/wiki/File:Strickland_Falls_Shadows_Lifted.jpg
30 seconds. NDF 8x = 1/100,000,000 = 27 stops

$10^8 = 2^x$
$8 \ln 10 = x \ln 2$
$x = 8 \frac{\ln 10}{\ln 2}$
$= 26.6$

= 26.6

Need a tripod for macros, or shutters > 1/30 sec
Full size start at $25. Highly recommended.

Several available for checkout.

Estimate motion blur *in pixels* to guide choice of shutter speed.

Example:
Field of view = 10 cm
Fluid moving at 0.5 m/s
10 Mpx sensor

Minute paper: what shutter speed will 'freeze' this flow?

Can tolerate maybe 5 px blur?
10 Mpx ~ 3750 X 2750
0.1 m / 3750 = 2.6 e-5 = 0.000026 m/px = 26 μm/px
5 px = 1.3 e-4 m = 0.00013 = 0.13 mm estimated acceptable object displacement *x*
time *t = x/velocity*
1.3e-4 m / (0.5 m/s) = 2.6e-4 seconds
2.6e-4 sec = 1/3750 Very short. Can your camera do this?
5/3750 = 0.0013 = 0.13% of image width

Do this analysis for each image. Motion blur is surprisingly common and annoying.