

Today:

Review exposure

Resolution

- Spatial
- Temporal

Friday will talk about Measurand, aka Dynamic range, then on to Specific Flow Vis Techniques, starting with Dyes

Clouds First Report Due today

Dear ME Students,

We're hosting a big alumni event on Friday, November 9th and are looking for students interested in participating in a project showcase. This is a good opportunity to connect with alumni and maybe even get some feedback on next steps for your project.

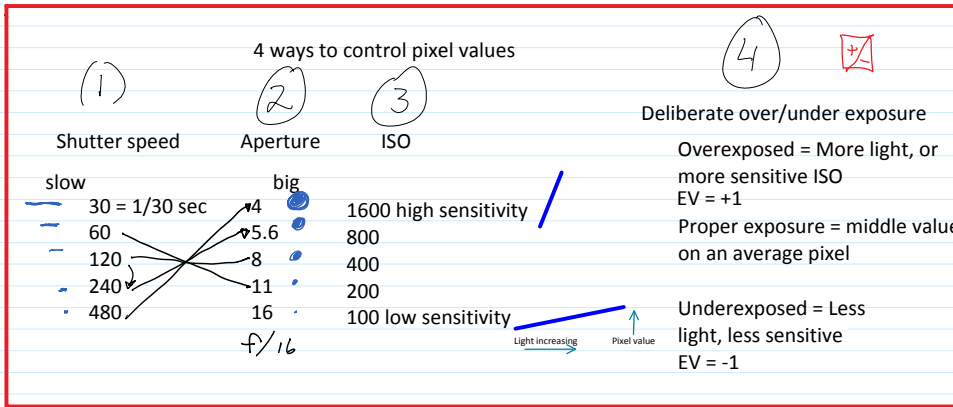
Ideas of projects that would be a good fit include:

- A class project that you're excited about or that is unique in some way.
- A project that you're working on as part of a student group.
- A self-directed project that you've been working on outside of class.

Projects don't need to include a physical build, but you will need to have something visual and/or tactile to showcase what you've been working on. There will be prizes, with details TBD. The application to participate is due on Friday, October 26th and is available [here](https://cuboulder.qualtrics.com/jfe/form/SV_d13KBF13flh3fl).

https://cuboulder.qualtrics.com/jfe/form/SV_d13KBF13flh3fl

Review of Exposure Choices



Side effects of each method, beyond the effect on exposure:

$$f\# = \frac{f}{D}$$

Shutter speed: motion blur at slow speeds

Aperture: low depth of field at large aperture. Diffraction will reduce sharpness at small apertures

ISO: Noise at high ISO

Deliberate under/over: Camera will change one or more of the other three settings, with attendant side effects. With underexposures, get loss of detail in shadows. Worse, at high overexposure, lose detail in highlights.

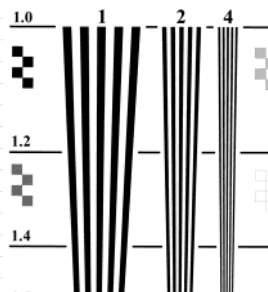
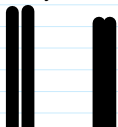
Resolution

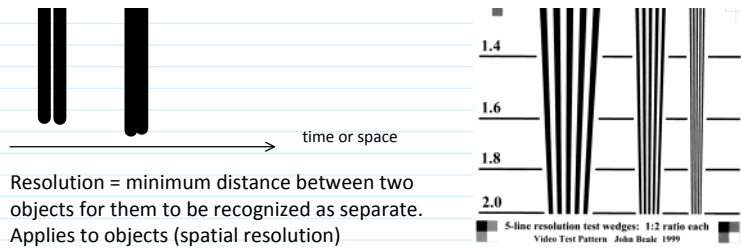
Any measurement requires 3 types of resolution: spatial, temporal, measurand (dynamic range)

Making an image is equivalent to making a measurement of light (measurand)

Resolution: Spatial

Can two adjacent things be resolved?



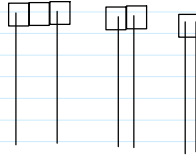


Resolution = minimum distance between two objects for them to be recognized as separate. Applies to objects (spatial resolution) and events (temporal or time resolution) and any quantity being measured (measurand)

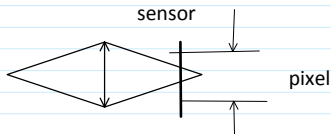
"Large resolution" = meaningless
 "Fine resolution" or "Highly resolved" = well - resolved.

Spatial resolution can be DEGRADED by

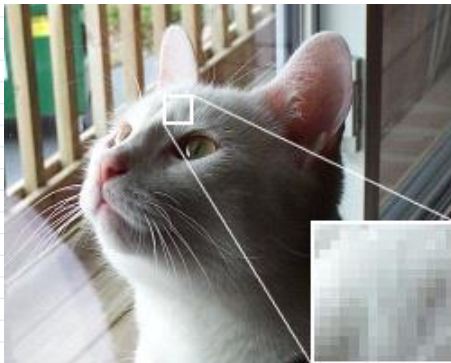
- Bad focus
- Rastering, pixelation
- Diffraction effects
- Low contrast
- Compression artifact (in jpegs)
- Motion blur



- **Bad focus: is circle of confusion > pixel?**

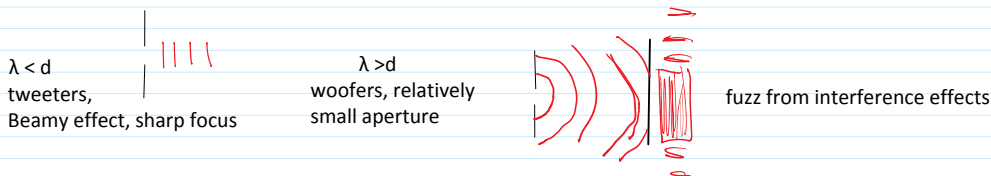


- **Rastering, pixelation**



<https://en.wikipedia.org/wiki/Pixelation>

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



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 μ m.
 Red λ = 0.7 μ m. Pretty close!

'Full Frame' DSLR: sensor size is ~35 mm
<http://www.whatdigitalcamera.com/roundup/camera-roundups/best-full-frame-dslrs-2016-9263>.

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?

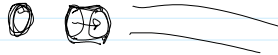
How many did your image capture?

Was your flow spatially resolved?

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. How many pixels long? 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 ~ 3×10^{-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 10⁻⁶ 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

$$\begin{aligned} 10^8 &= 2^x \\ \ln 10^8 &= x \ln 2 \\ x &= 8 \frac{\ln 10}{\ln 2} \\ &= 26.6 \end{aligned}$$



≈ 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.

Resolution Homework for Monday: Write short answers and submit in Canvas

1) In your Get Wet image, are all the scales of interest in the flow well-resolved in the image?

Is there a sharp boundary in the flow that only takes up one or two pixels in the image? What was the major effect that degraded the resolution?

2) At what $f/$ does your lens produce the sharpest image? Take an object that you can easily focus on (a ruler?), and image it with a range of $f/$. Then zoom in and check the focus. Try to minimize the effects of motion blur and ISO noise so your testing is valid. Submit at least three images illustrating your results.