

Today:

Finish spatial resolution

Temporal resolution

Dynamic Range

Learning objectives: you will be able to analyze the spatial and temporal resolution of your images. You will be able to manipulate dynamic range of color channels in an editor.

Admin: Resources for reports

Guidebook on Flowvis.org website

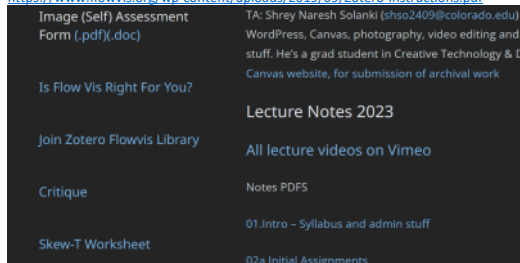
Zotero library

Zotero is an open-source citation management database system, like Endnote and Mendeley. Has web, phone and computer app versions, but app for your computer is best. Interfaces with both your browser and word processor. We have a group library: Fluid Physics for Flow Vis. Has references (including PDFs) for many common Flow Vis topics: vortexes, splashes, clouds, ferrofluid, etc.

Zotero is the best-ever browser bookmark system. Stores snapshot of web pages, plus pdfs and any other document. Many ways to organize; folders, tags, related docs. Can even be used to organize your Google Drive nondestructively.

Borrero-Echeverry, Daniel, Christopher J. Crowley, and Tyler P. Riddick. "Rheoscopic Fluids in a Post-Kalliroscope World." *Physics of Fluids* 30, no. 8 (August 1, 2018): 087103. <https://doi.org/10.1063/1.5045053>.

<https://www.flowvis.org/wp-content/uploads/2019/09/Zotero-Instructions.pdf>



Spatial Resolution Continued

- 1) How many decades of scales were in your flow
- 2) How many decades of scales were in your image?

Part 1)

Are you prepared to answer the following:

- A) Yes
- B) No, but give me a few minutes
- C) No, no idea how to proceed

In your Get Wet image, how many decades of length scale were in your flow? Meaning

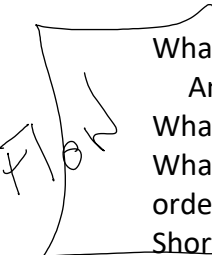
What was the smallest feature of interest, whether you were able to capture it or not?

An edge, a boundary, a vortex, a filament, a bubble...

What was the largest feature of interest, also whether you were able to capture it or not?

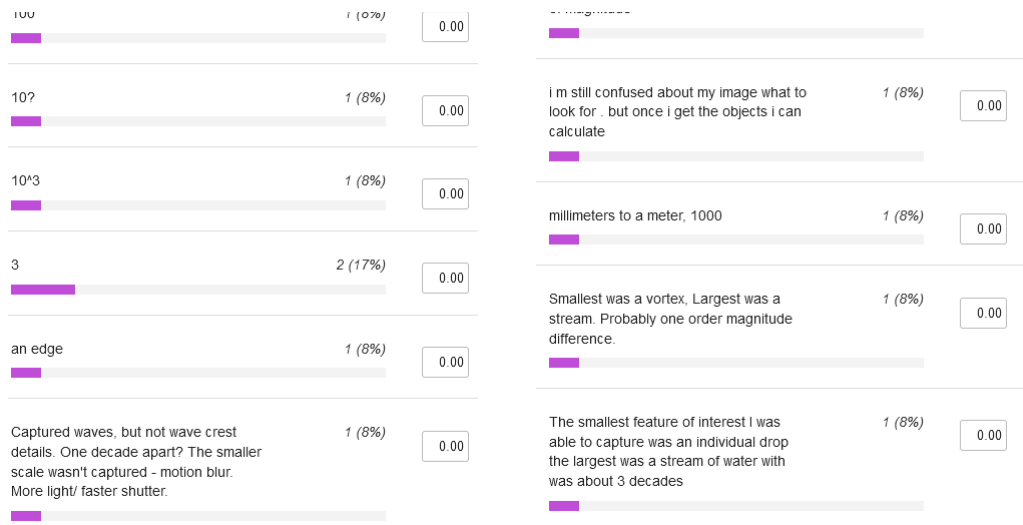
What is the difference in order of magnitude (decades) between these two? A factor of 10 = one order of magnitude = one decade.

Short answer clicker:



Response	Count	Points
foam bubbles 1/10 mm, did not capture. full glass 100mm. I did capture. 3 orders of magnitude	1 (8%)	0.00
i m still confused about my image what to look for, but once i get the objects i see	1 (8%)	0.00





IMAGE

Groups/Breakout rooms; share your image and discuss scales in everybody's image.

1. Is there a sharp boundary in the flow that only takes up one or two pixels in the image.
2. Are all the scales of interest in the flow well-resolved in the **image**? In other words, was your flow spatially resolved?
3. If there's time, what was the major effect that degraded the resolution?

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

DSLR max = 1/4000 sec, = 250 μsec

Max on cell phone is 1/23000= 0.043msec, 43 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

Best at low power

Good resource for high speed photography: <http://www.hiviz.com/index.html>

Strobes and Speedlights

The most common type of strobe (or Speedlight, if you are a Nikon enthusiast) is an 'electronic' flash; a xenon flash tube (Figure 3). On-camera integrated flash units and standalone studio strobes are of this type. A charged capacitor dumps current into a small quartz tube filled with xenon gas. The high current ionizes the xenon, and the resulting spectrum is a broadband white light, centered on green [12]. This provides a bright, short burst of light. Unfortunately, brightness and duration are related: the brighter the flash, the longer it lasts. Typical durations are 1 to 10 μsec (1/100,000 to 1/10,000 seconds). Strobe duration specifications are often given as $T_{.5}$, the time it takes the intensity to decay to 1/2 the maximum, although the tail of the curve (Figure 4) can last well beyond that, causing ghostly motion blur in an image. A more useful specification for flow visualization is thus $T_{.1}$.

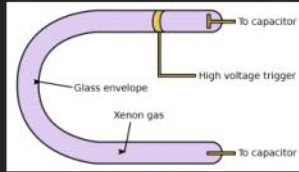


Figure 3: Xenon flash tube. Riffemann-commonswiki CC BY-SA 3.0, via Wikimedia Commons.

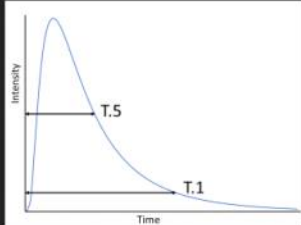


Figure 4: Flash duration is specified by $T_{.1}$ and $T_{.5}$. Hertzberg 2022.

Photographic strobes require significant battery power (4 to 6 AA batteries) and take several seconds to recharge. In contrast, a stroboscope, used for studying rotating machinery, flashes continuously. LED stroboscopes provide low-intensity light bursts at frequencies up to 1600 Hz, and xenon stroboscopes up to 600 Hz.

Strobe units need to be triggered to fire when the shutter on your camera is fully open, i.e., in sync. Triggering can be done either optically (the strobe will fire when it sees the flash on your camera go off), or wirelessly using a trigger device that fits on the hot shoe of your camera. Controlling

Pulsed laser 3×10^{-9} sec = 3 nsec or less typically.

\$600 will get you a 10-ns, 532-nm (green) pulse at up to 2000 mJ. Used for micromachining. Special lasers go to femtoseconds (10^{-15} , a millionth of a billionth of a second), often low power and infrared.

Picosecond lasers (10^{-12} ; seconds), red or blue, for tattoo removal, < \$200 but only 7 mJ.

Not much info out there on LED flash units. Yes, requires only low power and has good repetition rate, but intensity and pulse rate depend on circuit details. A few professional photography units are on the market so far. Godox FV200 (watts), combination flash and continuous. High speed sync at $1/8000 = 0.0001$ sec = 100 μsec and 10 hz. \$500.

Time averaged images. Other end of the scale from time-resolved.

If long shutter is needed, might be too much light, even at low ISO and small aperture.

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



Need a tripod for macros, or shutters $> 1/30$ sec
Full size start at \$17. Highly recommended.

Estimate motion blur *in pixels* to guide choice of shutter speed.
Alternately, use length of motion blur streak and shutter speed
to estimate flow speed

Motion Blur Example:

Field of view = 10 cm

Fluid moving at 0.5 m/s

18 Mpx sensor

Groups/Breakout rooms: will $1/1000$ sec shutter speed 'freeze'
this flow? How many pixels will motion blur be? Calculate on
group whiteboard please. Save for discussion; available from
annotate tools.

