CSCI 4550/6550 Interactive Visualization

https://www.cs.rpi.edu/~cutler/classes/visualization/S24/

Lecture 14: Streamlines & Intro to Volume Visualization

http://imgur.com/TRJonQk

http://i.imgur.com/ZcjC9KP.jpg

Today

- Final Project Ideas
  - How to brainstorm and foster novel or radical ideas?
- Readings for Today
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  - "Image Based Flow Visualization"
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- Readings for Next Time

Brainstorming Final Project Ideas

- Two Different Final Project Ideas
  - Who (audience), why (research question), & what (the visualization)
  - One technical challenge: What makes it difficult?
    What is a potential "risk" for completion? For example:
    - acquiring the data,
    - working with very large data,
    - implementing a new visualization design,
    - implementing a novel interaction scheme, or
    - revising the visualization design to validate your hypothesis.
  - Do you already have a partner?
- Make Submitty forum post by Thursday 2/29
- Read & *reply* to 3 other students by Monday 3/11 (after break)

Novel Inspiration for Final Project?

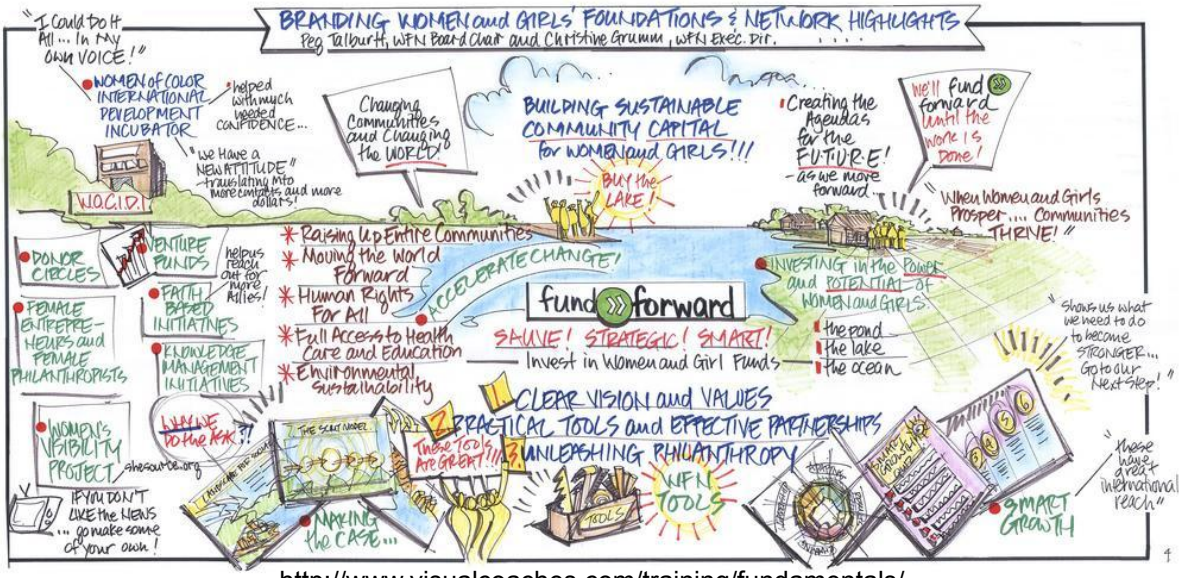
- Unusual interaction
  - What could you do with touch-based interaction?
  - What could you do with direct object manipulation?
    (rather than sliders or buttons spatially separate from your data)
- Layers/Levels/Level of Detail/Complexity of your visualization?
- Formal Evaluation
  - How would you measure, in a controlled setting,
    the effectiveness of your visualization?

Drawing for Communication

http://arterior-motives.blogspot.com/

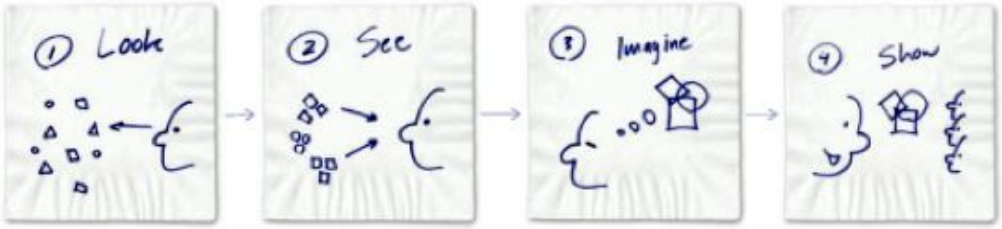
http://idcminnovations.com/facilitation/facilitation-services

Drawing for Communication



http://www.visualcoaches.com/training/fundamentals/

Drawing for Communication

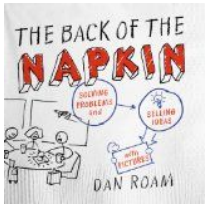


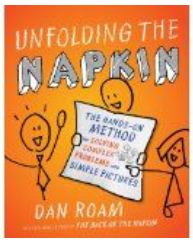
What is out there?
What am I looking at?
What are the limits?
Which way is up?

What do I see?
Have I seen this before?
What patterns emerge?
What stands out?
What seems to be missing?

How can I manipulate these patterns?
Can I fill in the gaps?
Have I seen enough – or do I need to go back and look at more?

This is what I saw, and this is what I think it means.
Is this what I expected... or not?
When you look at this, do you see the same things?





http://www.danroam.com/the-back-of-the-napkin/

How to Brainstorm Ideas?

Do:

- Say whatever comes to mind
- No idea is a bad idea, write everything down, keep good notes/record
- When you run out of ideas, revisit the list and expand previous points, what's good about each item?
- Highlight ideas that keep returning
- Make everyone talk
- Keep scope of project, keep on relevant topics
- Revise ideas that might be out of scope, rather than eliminating
  - 80 / 20 it: 80% of the outcome, for 20% of the input
- Draw connections between ideas
- Start with what you like and know, try to bring that to what's relevant

Don't: (or do later)

- Don't cross anything out, nothing is 'stupid', goal is to generate lots of things
- Don't get too attached to one idea
- Resist convergence -- don't converge too early, don't limit the conversation to one topic/idea
- Don't let the loudest person be only voice
- Don't waste time on ideas that are not feasible

How to encourage/foster/recognize new ideas?

- Be open-minded
- Brainstorming rule: generate ideas, no negativity, no early criticism/rejection
- Be a "Paper/Idea Champion", not a "Paper/Idea Killer"
- Suggest other applications/datasets
- Don't say what's wrong, say how to improve it
- Really specific comments, not general criticism
- Use "I" statements (Say "I think…" or "I feel")
  - Not "your paper is bad" but instead
    "I feel your paper could be better if you do… "

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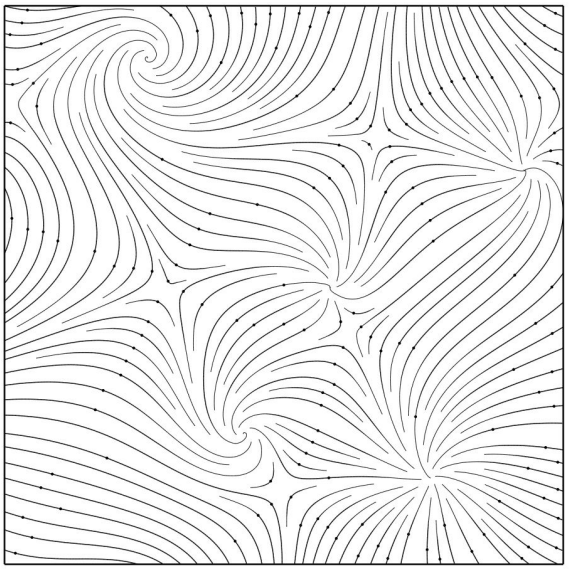
Reading for Today

- "Farthest Point Seeding for Efficient Placement of Streamlines", Mebarki, Alliez, & Devillers, IEEE Visualization 2005



- Start at the furthest away
- Favors long streamlines
- Retain uniformity with increasing density
- 200X Faster, but comparable quality to previous techniques
- Streamline:
  - curve that is everywhere tangent to the vector/flow field,
  - path traced by a massless particle dropped into a steady flow field
  - Stops at boundary or when it gets too close to another streamline
  - Streamlines are better if they uniform, of desired density, and longer rather than shorter
  - Termination points of streamline will be inferred as flow field singularities (source & sink), so avoid misinterpretations…

How to choose seedpoints for streamline placement?

- Uniform grid: streamlines won't be evenly placed & will form undesirable patterns
- Randomly placed: Does not improve upon uniform
- Turk & Banks use "streamlets" & energy decreasing optimization to combine, delete, create, lengthen, & shorten streamlets
  - High quality but slow
- Jobard & Lefer seed new streamlines near existing streamlines
  - Faster, but can have empty spaces
- Verma et al. seed streamlines near critical points
  - Good capture of flow features, but poor density control

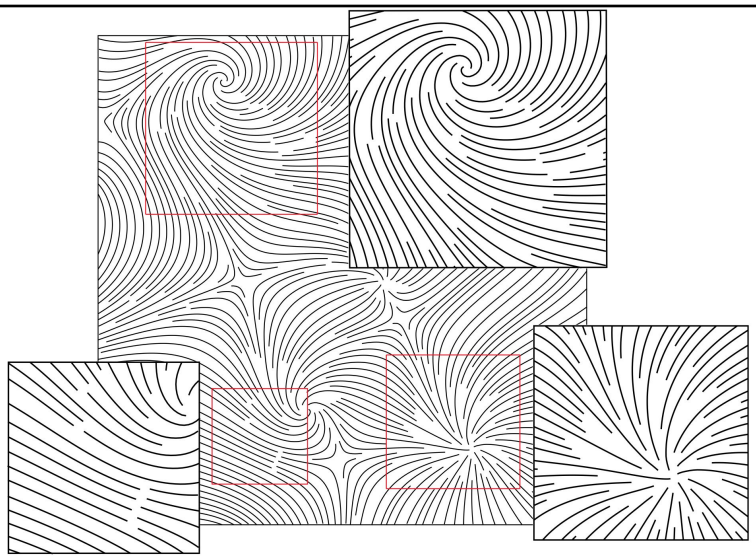
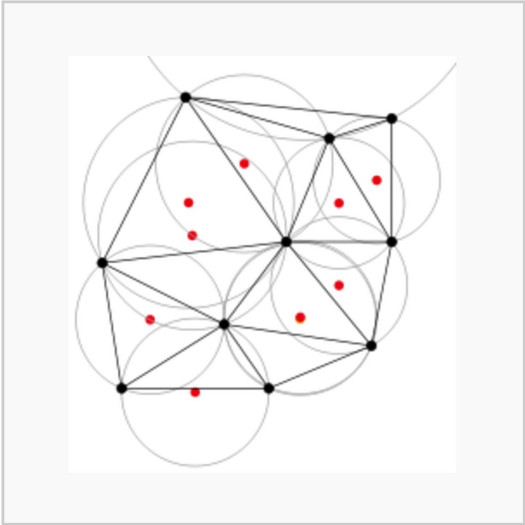
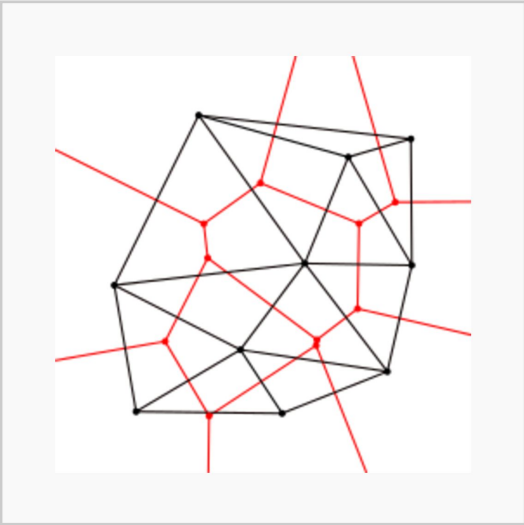


Figure 2: Local seeding strategy produces empty spaces due to the consecutive stopping of a series of streamlines (bottom right closeup). Some discontinuities also appear near singularities (top right closeup) and in laminar areas (bottom left closeup). Figure reproduced from [12].

Delaunay / Voronoi Duality



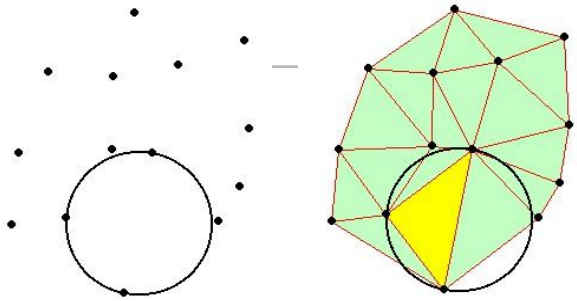


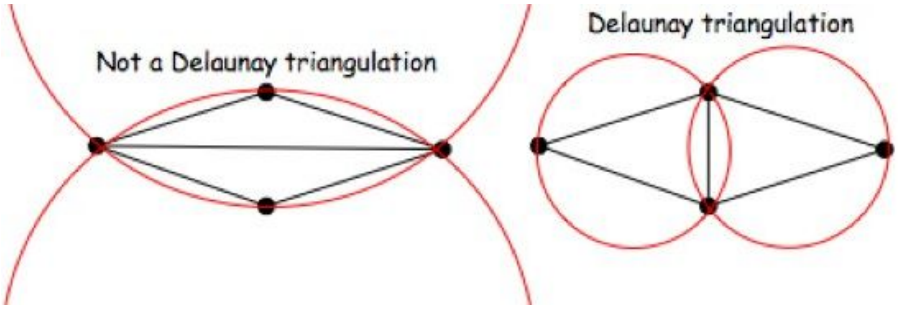
https://en.wikipedia.org/wiki/Delaunay_triangulation

http://www.ian-ko.com/resources/triangulated_irregular_network.htm

Delaunay Triangulation

- Contains a triangle connecting 3 points if and only if the circumcircle does not contain any other points from the set





- Data structures are important for streamline computation!
- Implemented in C++! Open source (CGAL)!
- Amazing results
  - fast,
  - looks pretty good, but not perfect when zoomed in, those artifacts not discussed in paper
  - Curious about adding color, texture, or animation
  - How could it extend to 3D?
- Detailed writing
  - Great Diagrams
  - Pseudocode: “confident I could implement it” “even a data structures student could implement it!”
- Good comparison to prior work
- Motivation could be presented more compellingly
- How is the step size chosen?

- Choose seedpoints that are furthest away from ALL existing streamlines (center of biggest void)
  - Favors long streamlines
  - Amenable to multiresolution placement (each streamline placed increases density)
- Use Delaunay Triangulation
  - Find (approximate?) biggest cavities
  - add point to triangle with largest circumcircle diameter
  - Integrate forward & backward to trace curve through flow (steady state flow only?)
  - Only re-add triangles to priority queue if their circumcircle is bigger than threshhold for density & saturation.
- Ok to be somewhat sloppy/inaccurate about the Delaunay triangulation
  - when streamlines form tight curls
  - Use local maximum circumcircle
- Advanced Features
  - Variable density, Multiresolution

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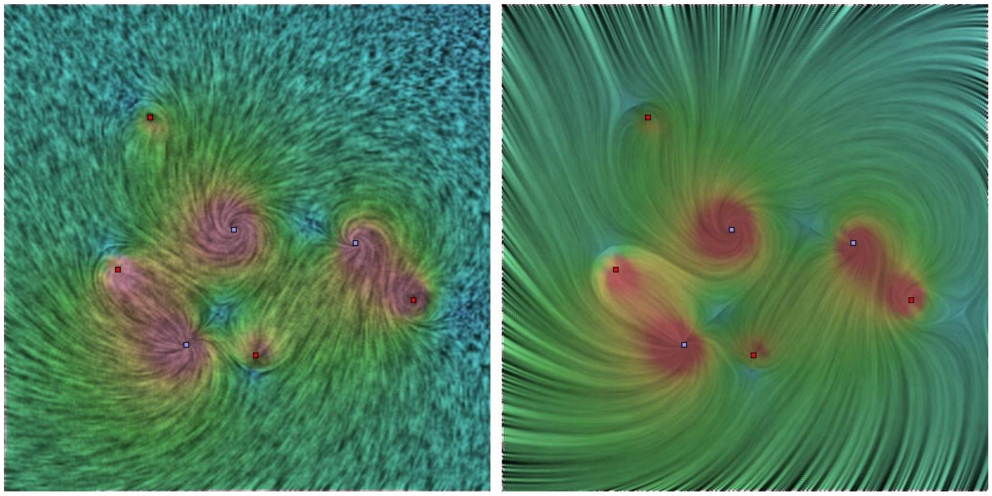
- "Image Based Flow Visualization", Jarke J. van Wij, SIGGRAPH 2002.



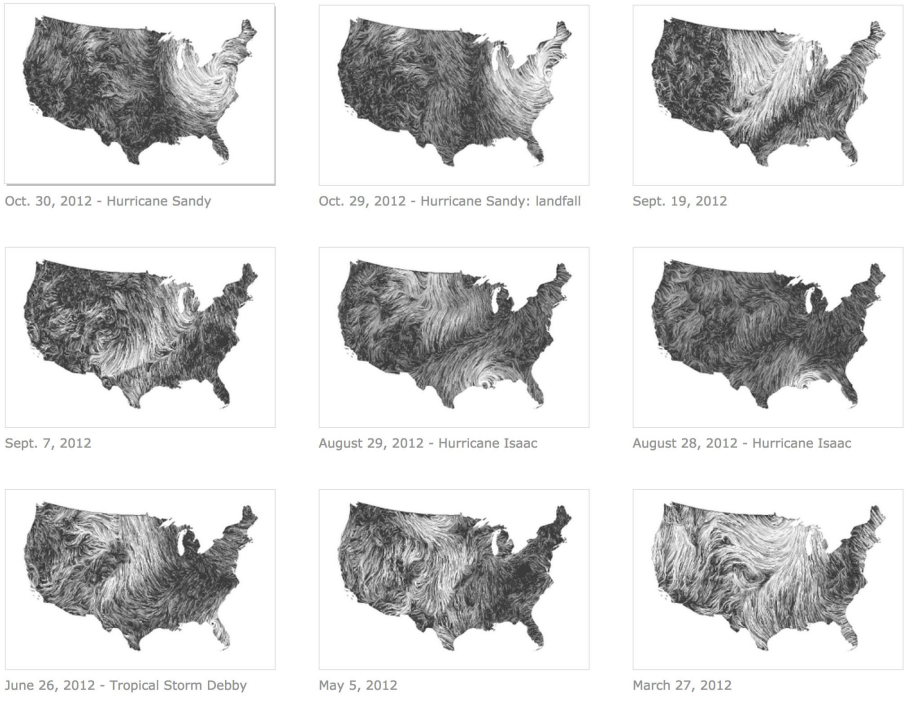
- Advection: "the transfer of heat or matter by the flow of a fluid, especially horizontally in the atmosphere or the sea"
- Blend warped previous frame w/ a selected background image
- Applications: Weather, climate, industrial processes, cooling, heating
- Moving particles, streamlines, moving textures, topological images
- Handles unsteady flow
  - With prior work it is hard to reconstruct flow
- Efficient
  - Best performance to date (50 fps) by using graphics card features
- Easy to implement
  - Other techniques need user to place particles (with poor placement, important features can be missed)
  - Small amount of code!

- White noise vs. Pink noise
  - Pink noise: remove high frequency from white noise, both in space & time
- Pathline: position of a particle in a dynamic flow field
- Streamline: same as pathline, but for single point in time (or a constant/steady flow field)
- Particle & streamline tracking: focus on world space coordinates
- Line integral convolution: focus on screen space coordinates
- Image Based Flow Visualization: focus on images as basic primitive
- Data structures are essentially irrelevant for image based flow visualization!
- Implemented in Object Pascal (??)

- Frequency analysis (yeah “Signals & Systems”!) to understand & create background images to minimize artifacts from undersampling
- If G changes over time, then texture will “move with the flow”
  - not new random image, but spots that appear & disappear (cosine, square, exponential decay, sawtooth)
- Computation
  - Distorted mesh calculated on CPU
  - Rendering & blending on GPU
- Lots of control over results
  - Background image choice
  - Dye injection
  - Alpha values choice (decay)

- Good attempt to compare running time of different algorithms from different eras on different hardware
- Great discussion/comparison of results
- Method was unintuitive (author should take that as a compliment, right?) & really clever
  - "Work smarter not harder"
- How does resolution affect quality?
- What is coarse vs fine texture?
- Produces a visual result, but can't be used other than to "look at" (results can't be fed back into simulation/computation)
- Somewhat confused about "dye" and "decay of dye"
- What is the motivation for this paper?
- Use of gradient/color to help reader understand direction of flow is very important

Wind Map
Fernanda Viégas &
Martin Wattenberg
http://hint.fm/wind/



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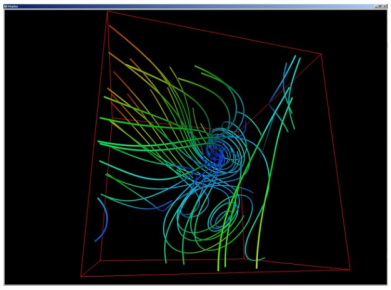
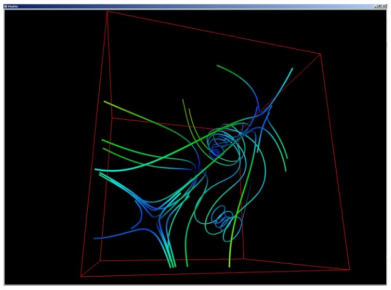
Reading for Today

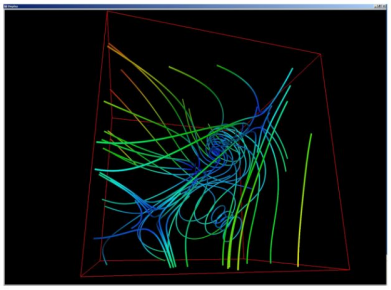
- "Strategy for Seeding 3D Streamlines",
  Ye, Kao, & Pang, IEEE Visualization 2005



(a) Poisson seeding with 50 streamlines.

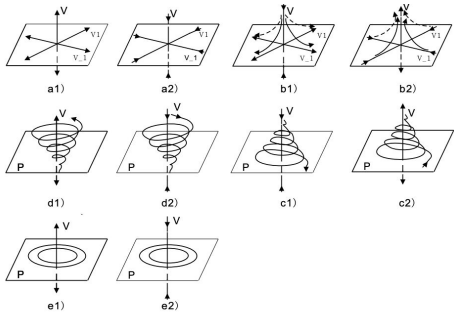


(b) Template seeding with 28 streamlines.

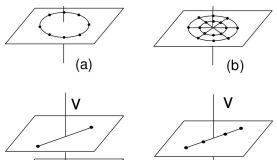


(c) Template then Poisson seeding.

- Want to highlight the important flow features and reduce clutter
- Analyze the flow field before trying to visualize it
- Identify the critical points of the flow (critical point = zero velocity)
  - Use a template to place streamlines near these points (different templates based on different class of critical point)
  - Highlight transitions between different critical points



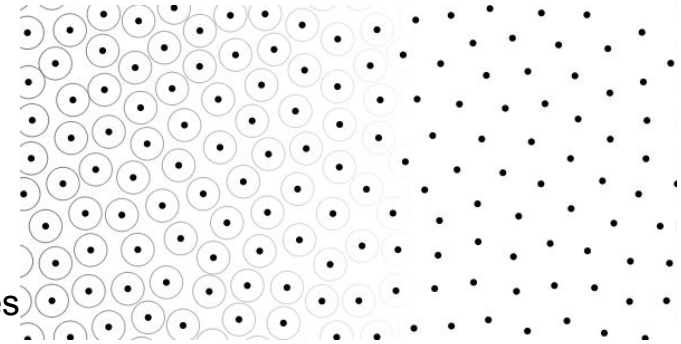
- Post process to revise the streamlines
  - Add additional streamlines using poisson disk sampling
  - Reduce visual clutter
  - Filter to remove short streamlines
  - More uniform coverage
- Challenge/limitation: scaling to many control points



Poisson Disk Sampling

Dart throwing algorithm:

- Places the samples randomly
- Check if points are too close: *Discard new point if circles of radius r drawn around every point overlap*
- End result is even but random distribution of samples



NOTE: This algorithm is slow. But there are faster algorithms to get same result!

https://en.m.wikipedia.org/wiki/File:Poisson_disk_sampling.svg

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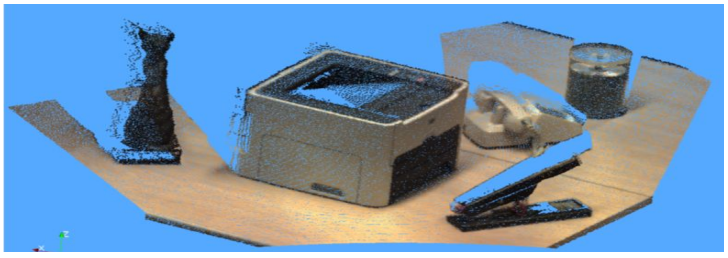
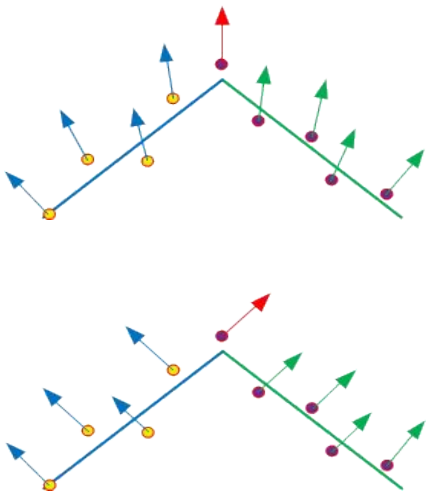
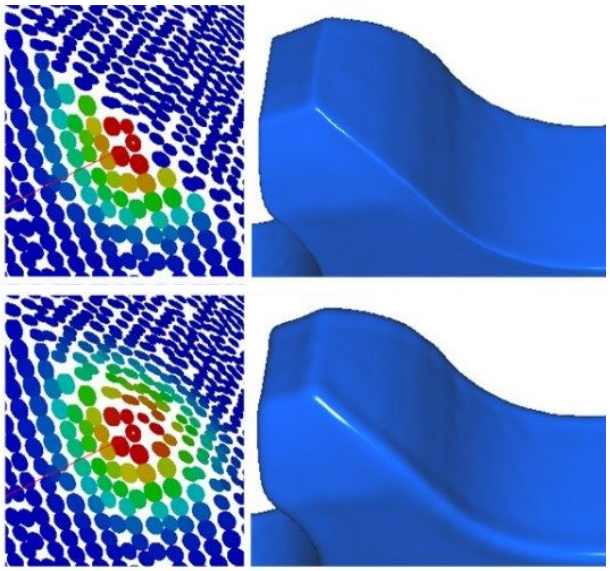
Motivation for Spatial Data Structures

- Closest Point
  - Collision detection
  - Surface normal estimation
- Line-Polygon Intersection
  - Ray casting (& recursive ray tracing)
  - Shadow calculation
- Want to do significantly better than linear *O(n) n = # of objects* brute force solution!



Surface Normal Estimation

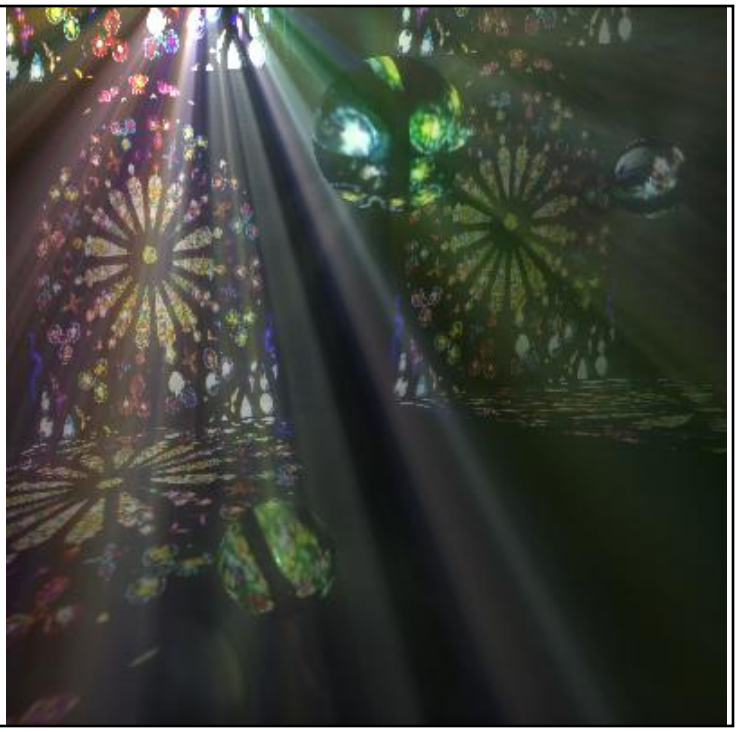




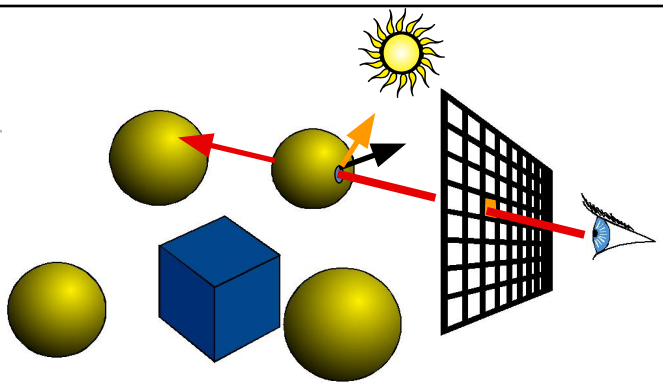
http://taylorwang.wordpress.com/

Light Rays in Dusty Room

Annie Ding, MIT
6.837 Final Project
December, 2004



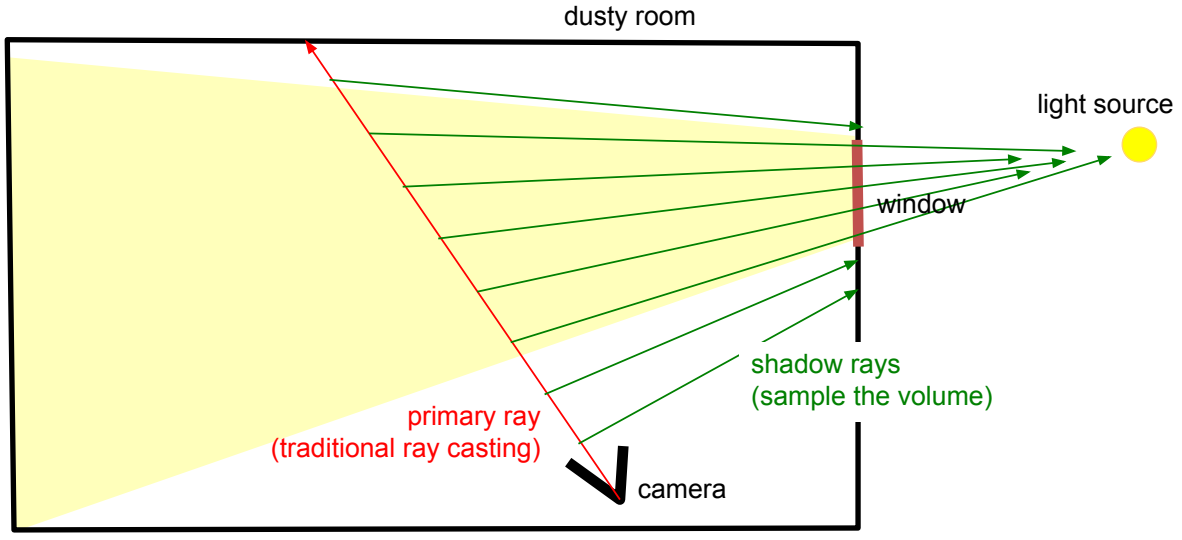
Ray Casting



```
For every pixel
   Construct a ray
   from the eye
   For every object
   in the scene
      Find intersection with the ray
      Keep if closest
   Shade depending on light
   and normal vector
```

Finding the intersection and normal is the central part of ray casting

Ray Tracing Participating Media



Volume Rendering

- Try to display a 3D data set (the whole thing, not just a surface)
- Must determine the opacity of every pixel (voxel)
- Often called the “transfer function”
- Almost always medical images

http://idav.ucdavis.edu/~okreylos/ResDev/VolVis/LinkSupersampling.html

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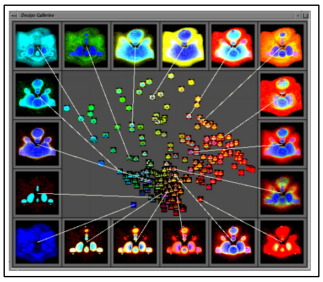
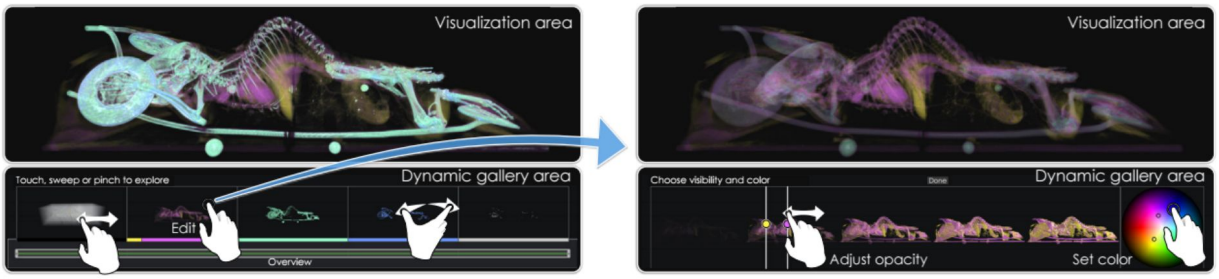
Reading for Next Time (after break!) *pick one*

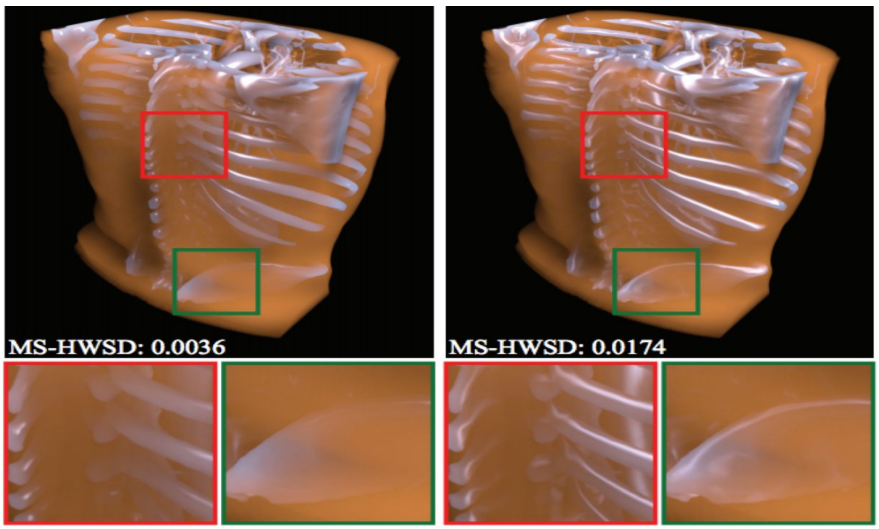
- "Intuitive Exploration of Volumetric Data Using Dynamic Galleries" Jönsson, Falk, & Ynnerman IEEE Visualization 2015





Reading for Next Time (after break!) *pick one*

- "Anisotropic Ambient Volume Shading" Ament & Dachsbacher, IEEE Visualization 2015



Reading for Next Time (after break!) *pick one*

- "Interactive Dynamic Volume Illumination with Refraction and Caustics" Magnus & Bruckner, IEEE TVCG 2017

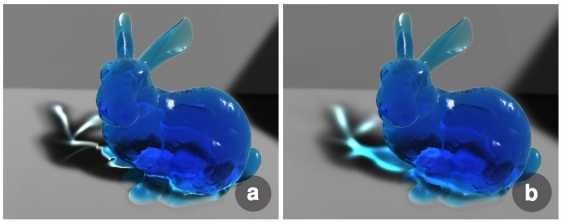


Fig. 3: Effects of light filtering. (a) No filtering. (b) Filtering of light and light direction.

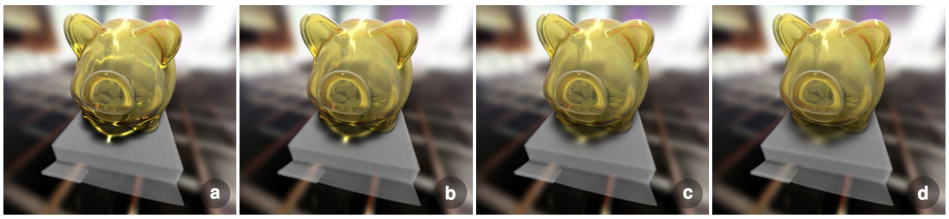


Fig. 7: CT scan of a piggy bank with refraction and combination of transmissive and reflective material properties and increasing light source softness from (a) to (d).