Streamlines (& Volume Vis Motivation)

http://imgur.com/TRJonQk

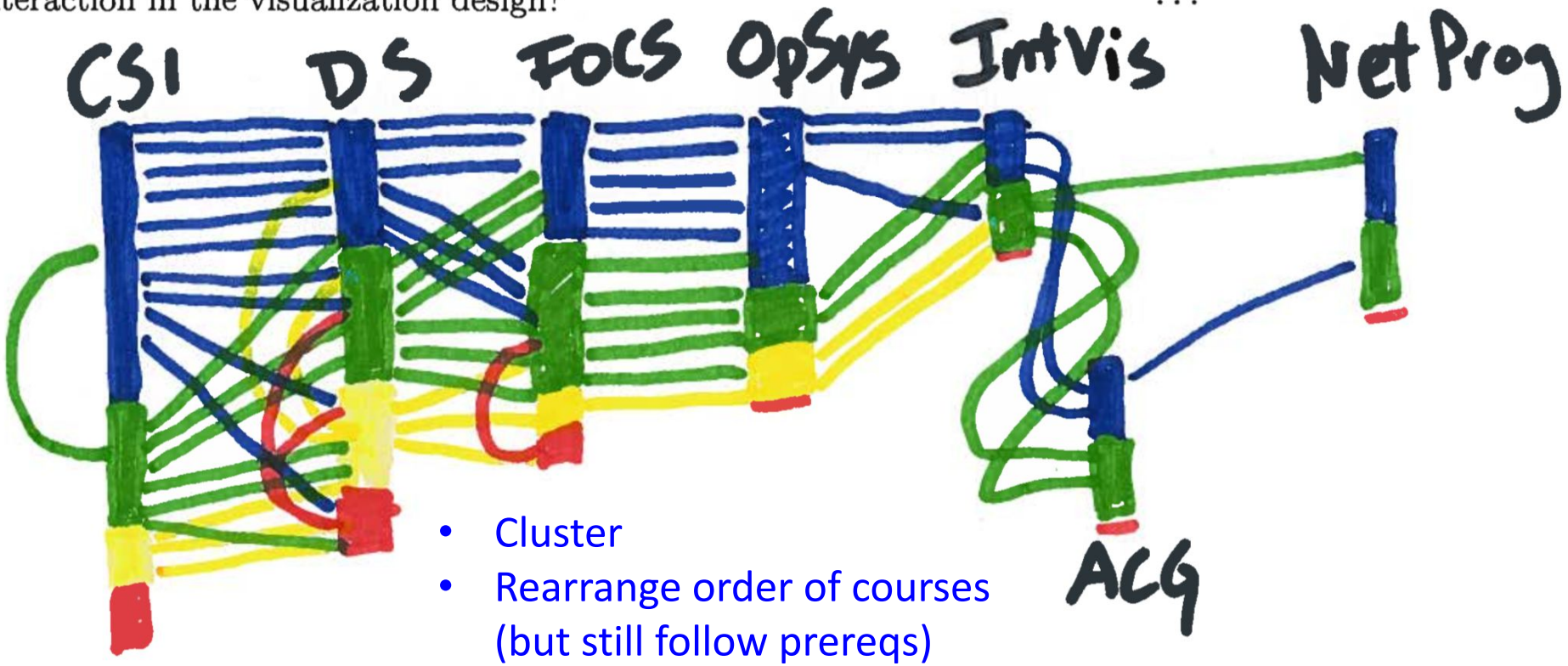
http://i.imgur.com/ZcjC9KP.jpg

Today's Class

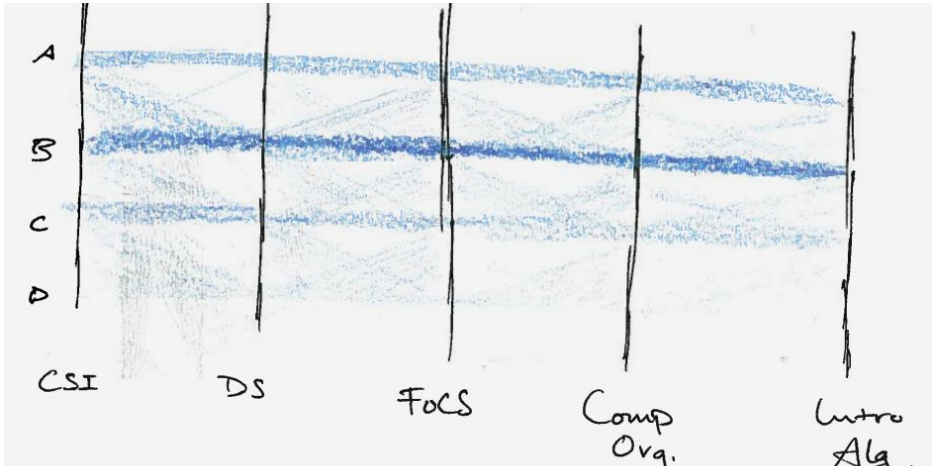
- Last Week's Worksheet
  - Final Project Ideas
  - How to brainstorm/foster radical ideas?
- Readings for Today
  - "Farthest Point Seeding for Efficient Placement of Streamlines"
  - "Image Based Flow Visualization"
- Spatial Data Structures Motivation / Volume Visualization Challenges
- Readings for Tuesday

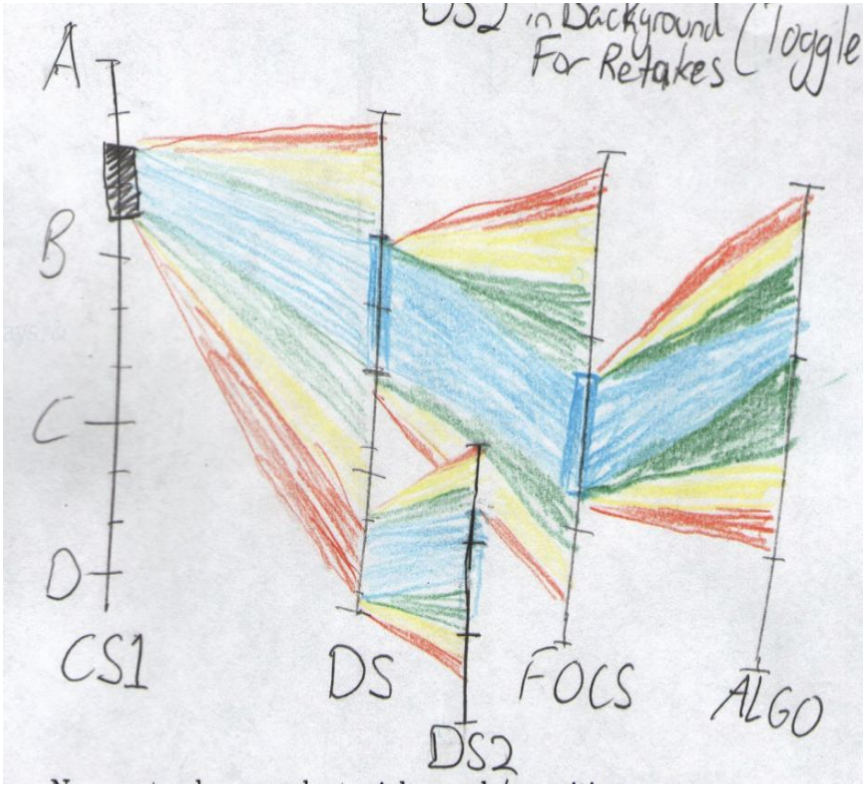
Say you have the final semester grades for 10 years of RPI classes. Sketch an anonymized visualization that explores the correlation in performance/final grade between courses. Let's assume that all offerings of each course are equivalent (no variation between terms/instructors). This visualization can advise students whether immediately repeating a course to improve their understanding of the material and course grade will positively impact their success at RPI in future terms. How would you leverage interaction in the visualization design?

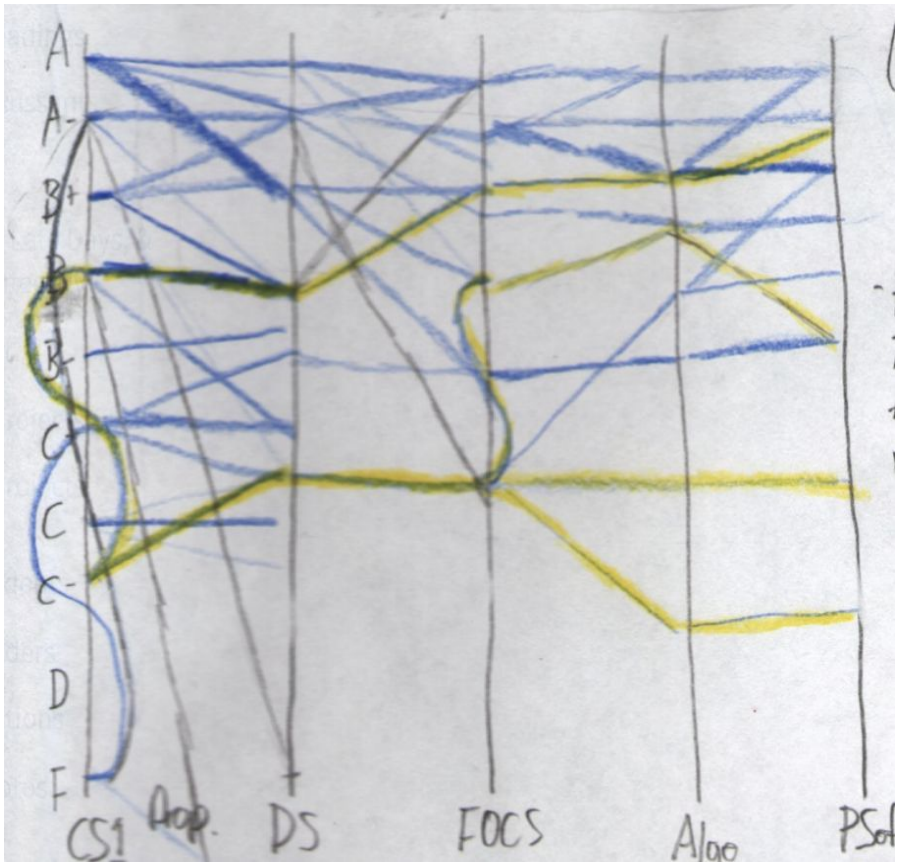
```
F15 John Doe CS1 A
F15 Bob Smith DS A-
...
S16 John Doe DS B-
S16 Bob Smith FOCS A
...
F16 John Doe FOCS B+
...
```



- Cluster
- Rearrange order of courses (but still follow prereqs)
- Brush/Filter by students who have taken certain courses, achieved certain grades, retaken specific course


A
B
C
D
CSI
DS
FoCS
Comp Org.
Intro Alg


DS2 in Background For Retakes (Toggle
A
B
C
D
CS1
DS
FOCS
ALGO
DS2


A
A-
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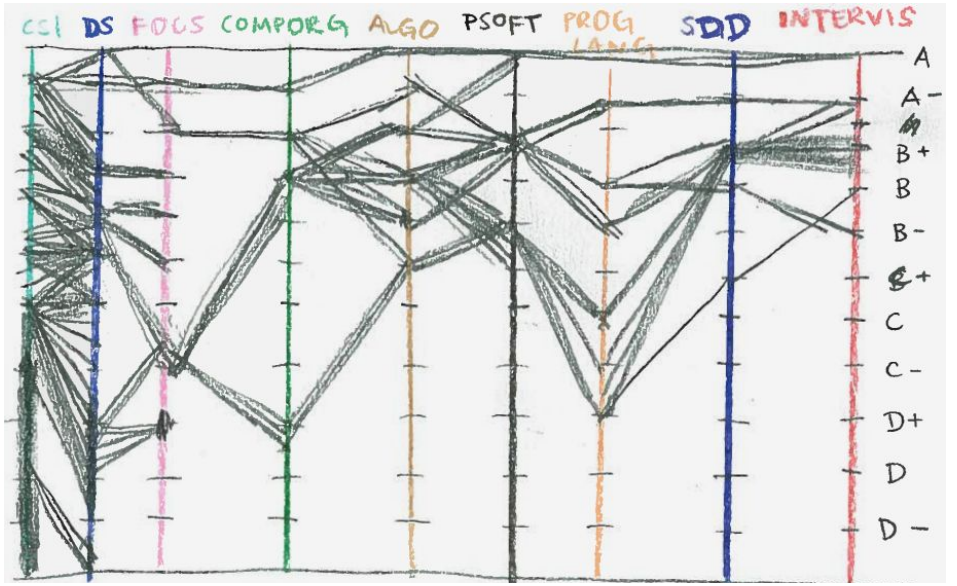
CS1
DS
FOCS
Algo


CS1
DS
FOCS
COMPORG
ALGO
PSOFT
PROG LANG
SDD
INTERVIS
A
A-
B+
B
B-
C+
C
C-
D+
D
D-

Now pretend you work at a job search/recruiting company and only have access to the above anonymized visualization and publicly-available data of courses using Piazza (don't worry, it doesn't include your final grade). Note: Most students unknowingly "opt-in" to sharing this data.

```
Jennifer Brown F14 CS1
Jennifer Brown F15 CompOrg
Jennifer Brown S18 DatabaseSystems
...
```

Can the job search/recruiting company reverse engineer students' GPA and grades without their permission? Can they automatically discard without human review the applications from students with any blemish on their record? How? Give a specific example. Is this a problem?

- May reveal (at least with high probability) the identity of some students
  - Small # of students who taken a specific unusual set of courses
  - Risk increases when applied to other majors/dual majors that have fewer total students with that selection of courses
- Applying repeated filtering, the viewer (or a computer crunching the extracted results) may find patterns. E.g.,
  - Students with weak GPAs select specific electives that have a reputation for being less difficult and/or have more grade inflation (GPA boosters)
  - Often when screening applications for a job or graduate school or papers submitted to for publication, the reviewer is looking for a reason to reject
- Assignment of grades in later courses, and hiring decisions should be made on current performance and current abilities *NOT* just on historical performance

Radical Inspiration for Final Project?

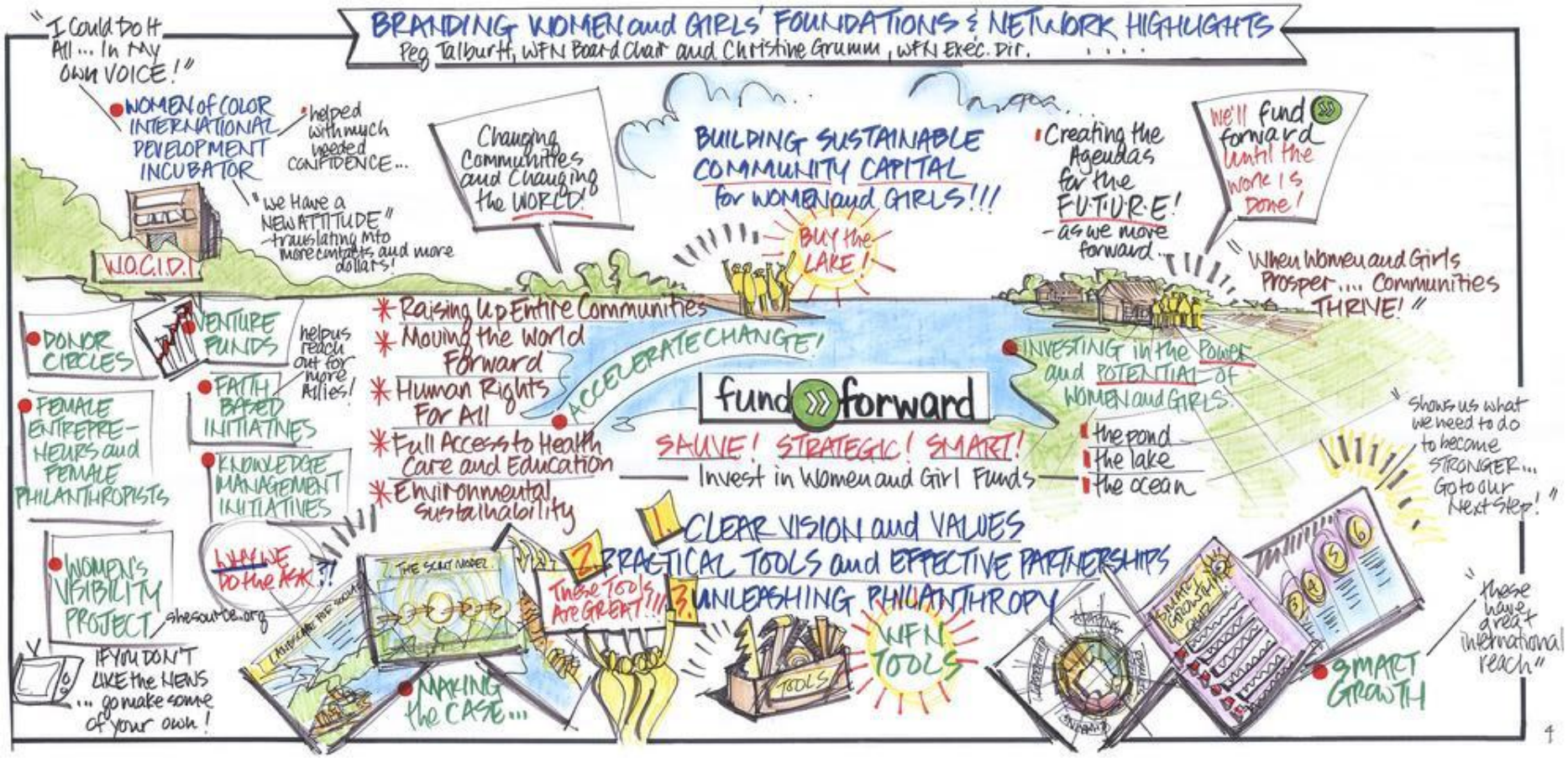
- Unusual interaction
  - What could you do with touch-based interaction?
  - What could you do with direct object manipulation? (rather than sliders or buttons spatially separate from your data)
- Layers/Levels/Level of Detail/Complexity of your visualization?
- Formal Evaluation
  - How would you measure,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

Drawing for Communication

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

http://idcminnovations.com/facilitation

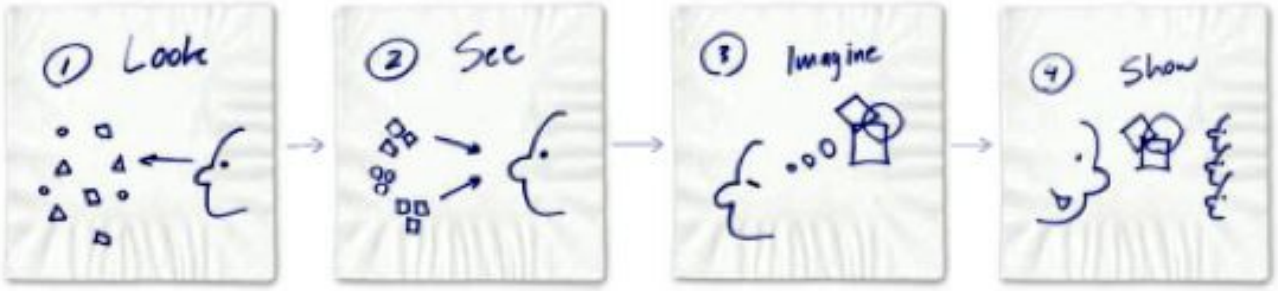
Drawing for Communication



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

Drawing for Communication

The 4 steps of visual thinking:



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?

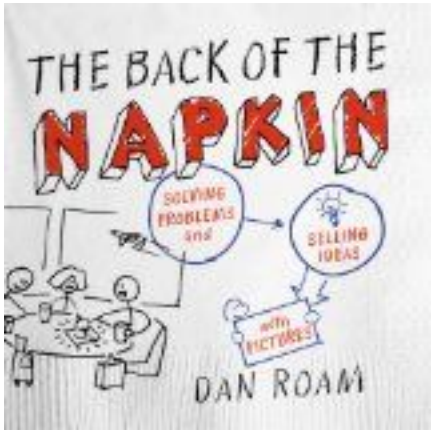
Can I fill in the gaps?

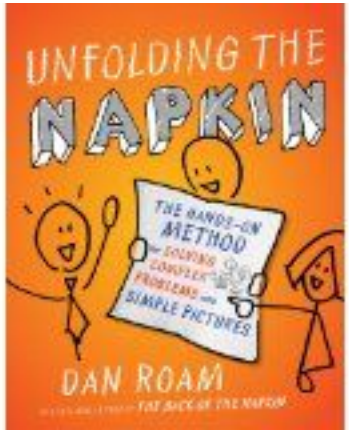
Have I seen enough – or do I need to go back and look at more?

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?





https://www.youtube.com/watch?v=ri8E8cNf2Bw

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, whats good about them
- 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, nothings stupid, 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 radical new ideas?

- Be open-minded
- Brainstorming rule: generate ideas, no negativity, no early criticism/rejection
- Be a “Paper Champion”, not a “Paper 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 “I feel your paper could be better if you do… “

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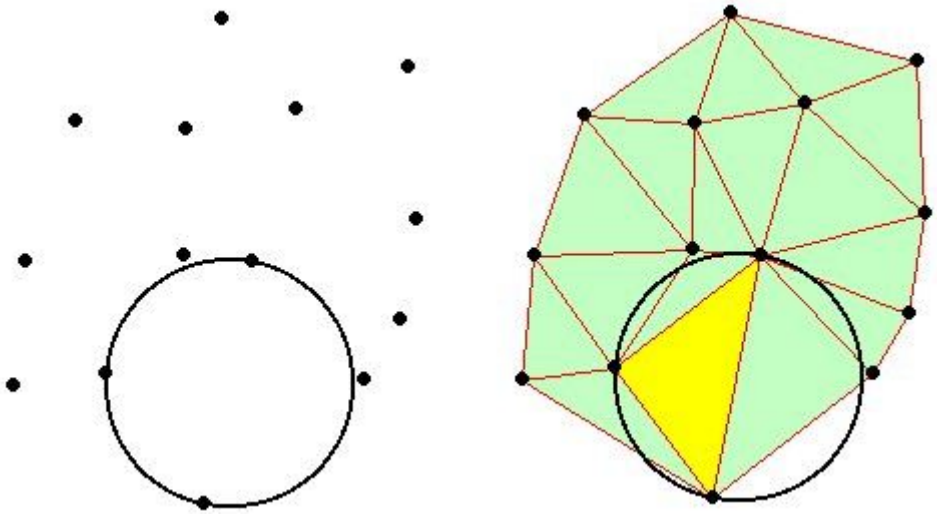
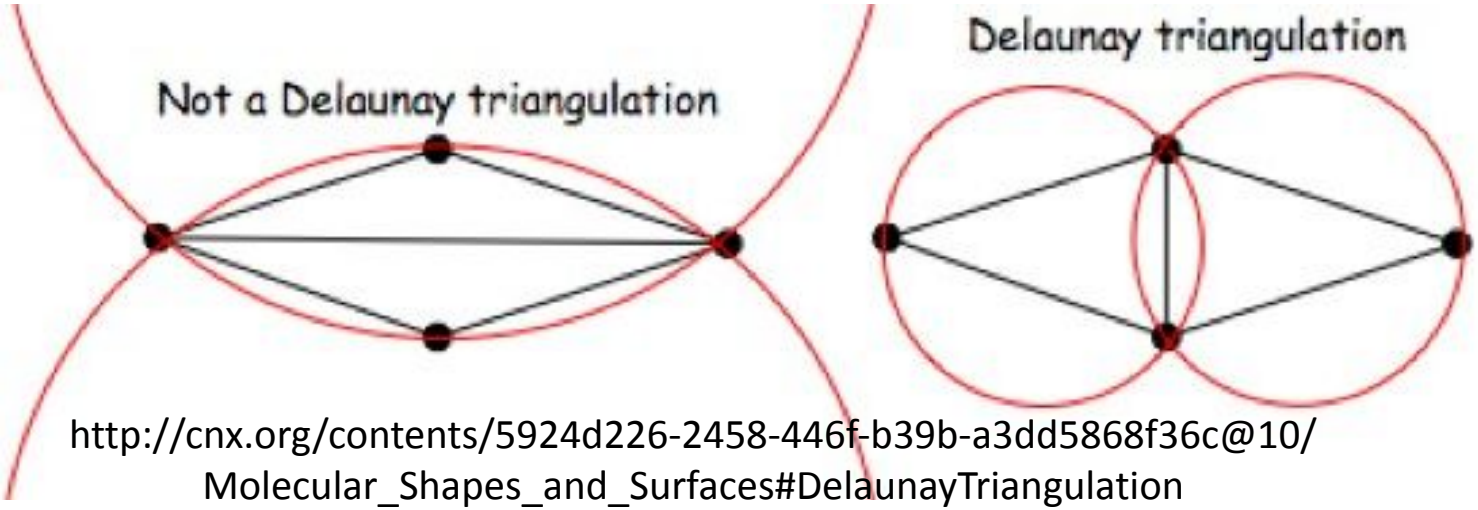
Delaunay Triangulation

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

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

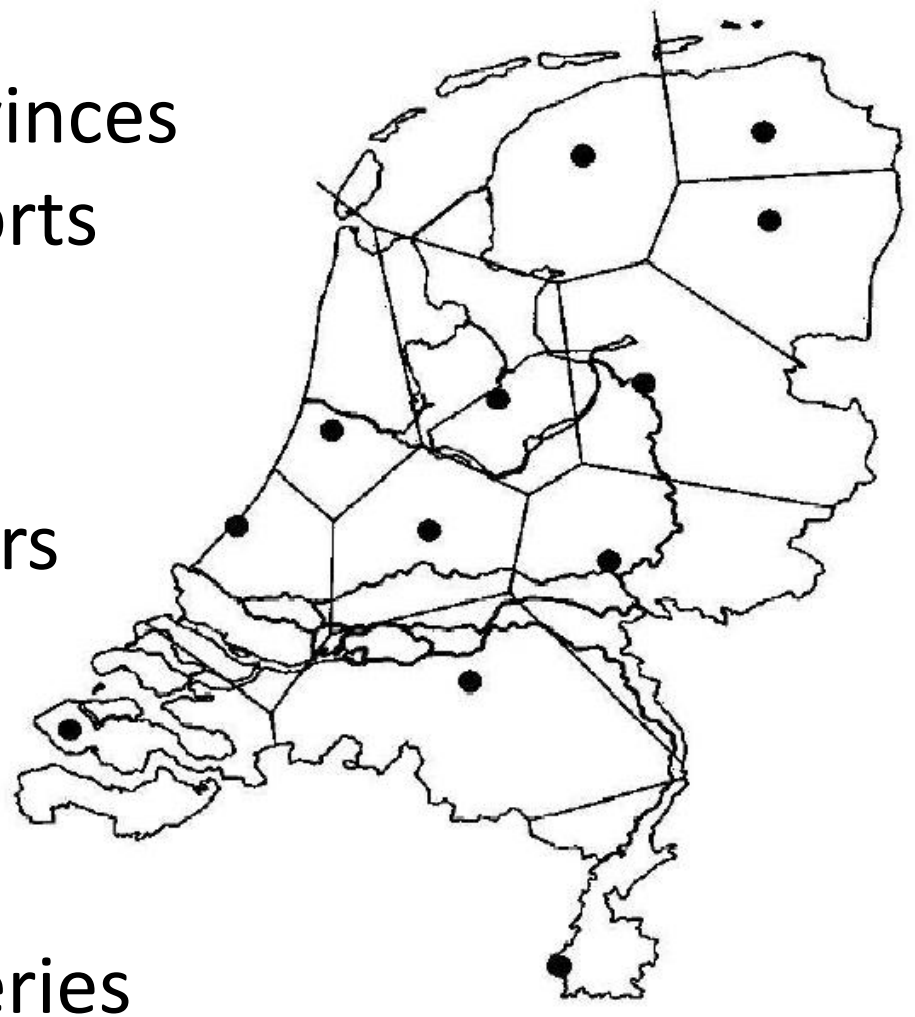




http://cnx.org/contents/5924d226-2458-446f-b39b-a3dd5868f36c@10/Molecular_Shapes_and_Surfaces#DelaunayTriangulation

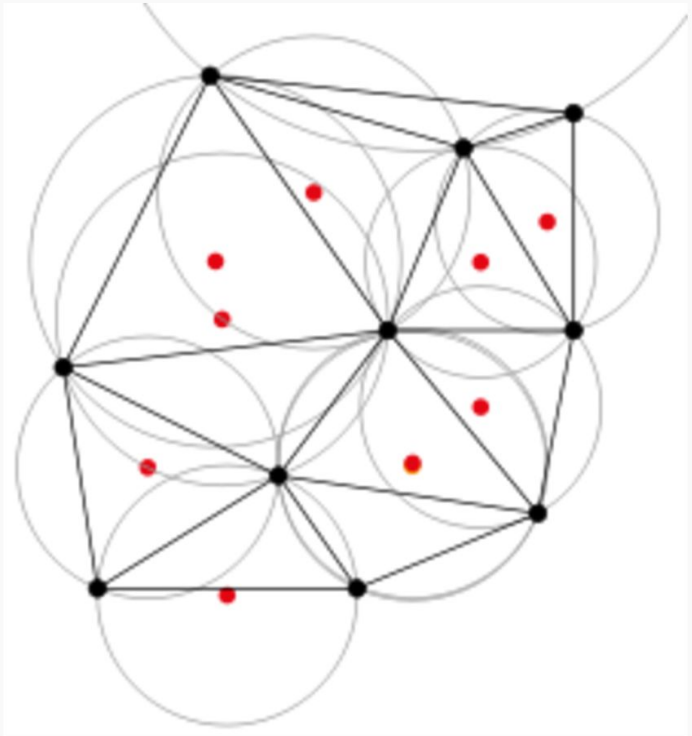
Voronoi Diagram/Cells/Regions

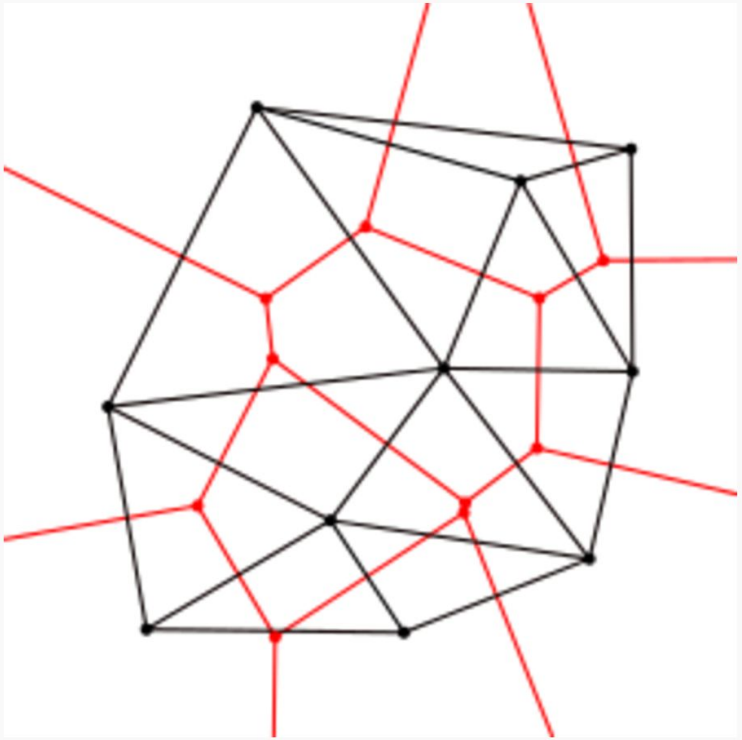
- How to re-district the Netherlands into provinces so that everyone reports to the closest capital
- Cell edges are the perpendicular bisectors of nearby points
- 2D or 3D
- Supports efficient *Nearest Neighbor* queries



http://ccc.inaoep.mx/~rodrigo/robotica/Trigui.pdf

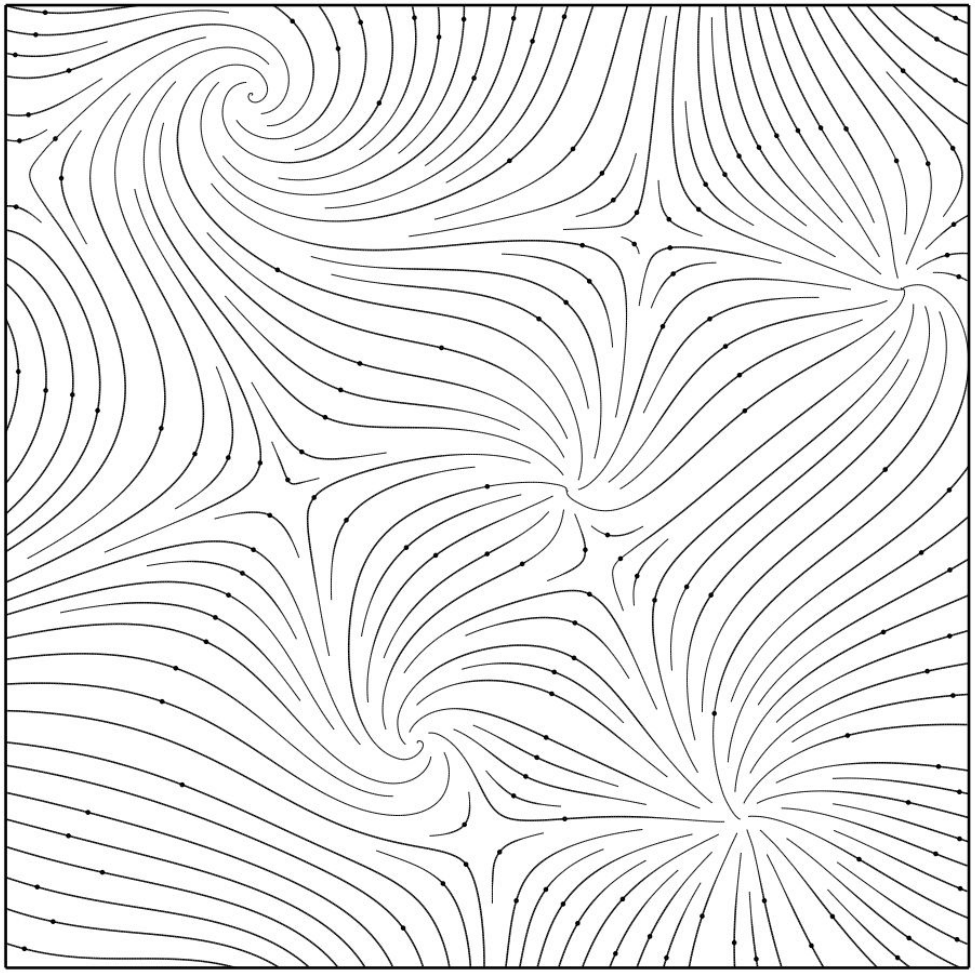
Delaunay / Voronoi Duality





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

- "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

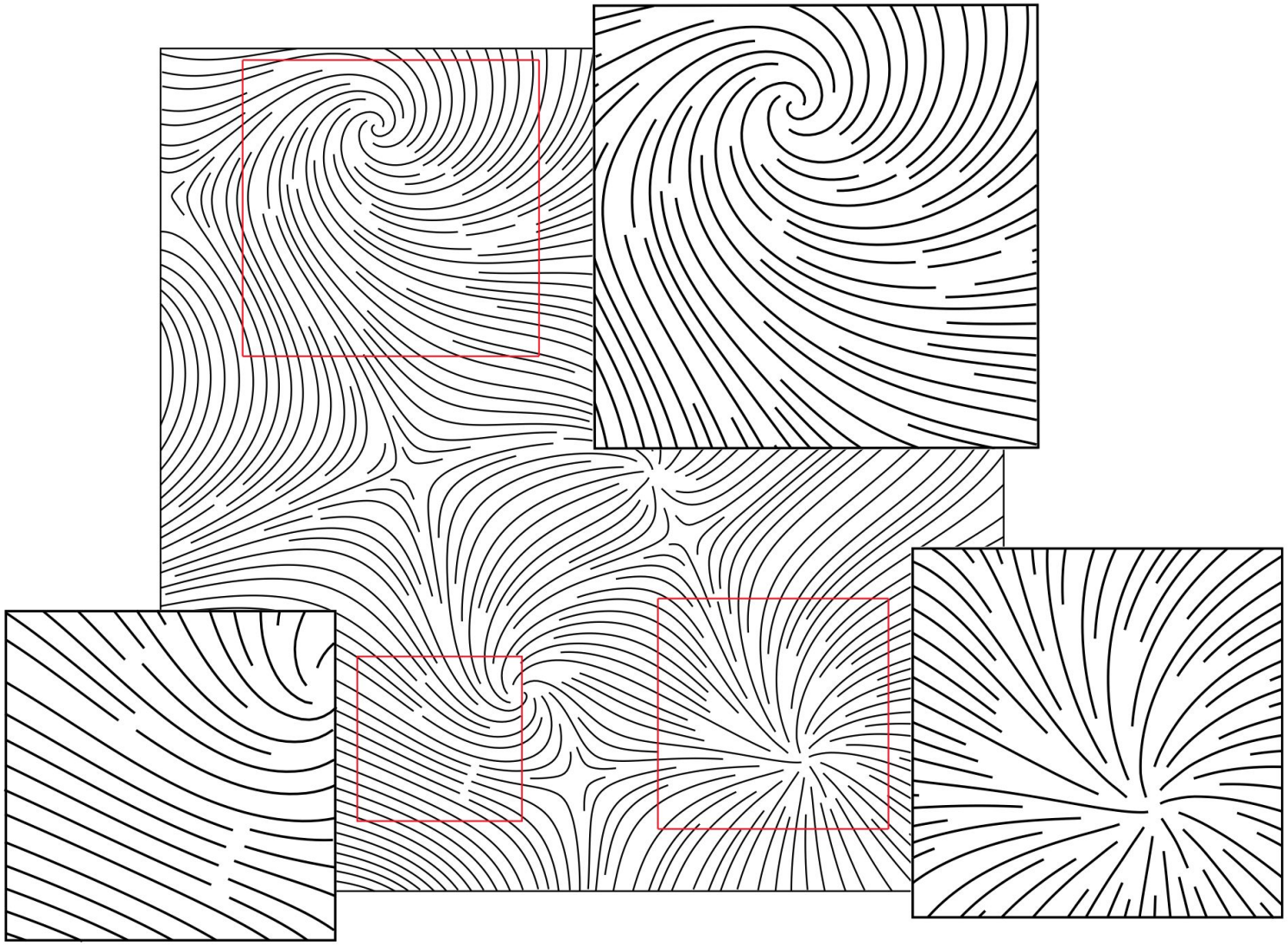


Figure 2: Local seeding strategy produces empty spaces due to the consecutive stopping of a series of streamlines (bottom right closeup). Some discontinuities also appear near singularities (top right closeup) and in laminar areas (bottom left closeup). Figure reproduced from [12].

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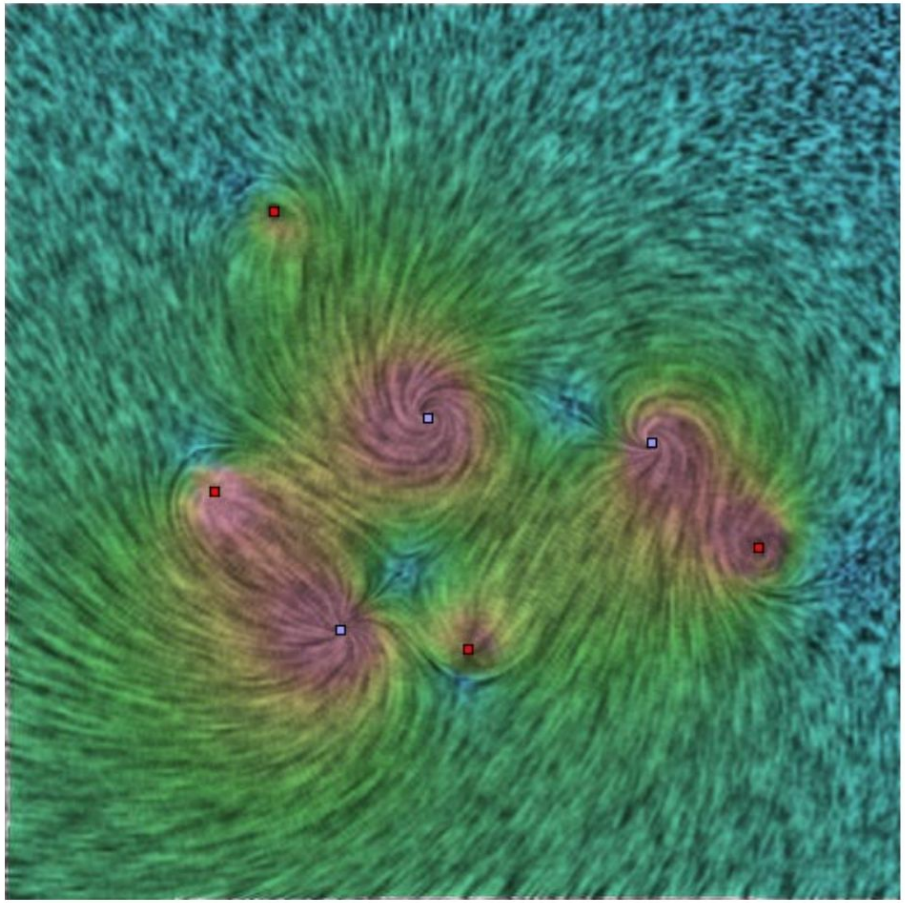
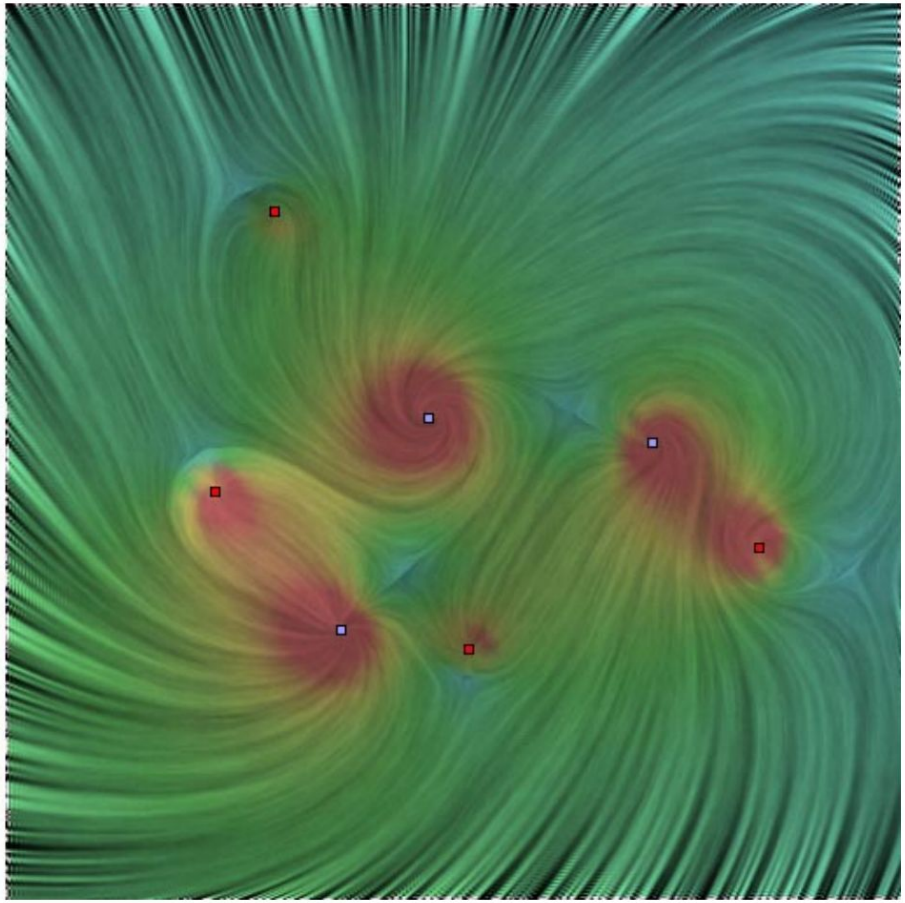
- "Image Based Flow Visualization", Jarke J. van Wij, SIGGRAPH 2002.





- 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
- Contributions:
  - Handles unsteady flow
    - w/ other techniques, 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
- 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 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)
- 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 and Martin Wattenberg http://hint.fm/wind/

Oct. 30, 2012 - Hurricane Sandy

Oct. 29, 2012 - Hurricane Sandy: landfall

Sept. 19, 2012

Sept. 7, 2012

August 29, 2012 - Hurricane Isaac

August 28, 2012 - Hurricane Isaac

June 26, 2012 - Tropical Storm Debby

May 5, 2012

March 27, 2012

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PointShop3D

- Why deal with triangles & connectivity when the triangles are smaller than a pixel?
- “Pointshop 3D: An Interactive System for Point-Based Surface Editing” Zwicker, Pauly, Knoll, Gross, SIGGRAPH 2002

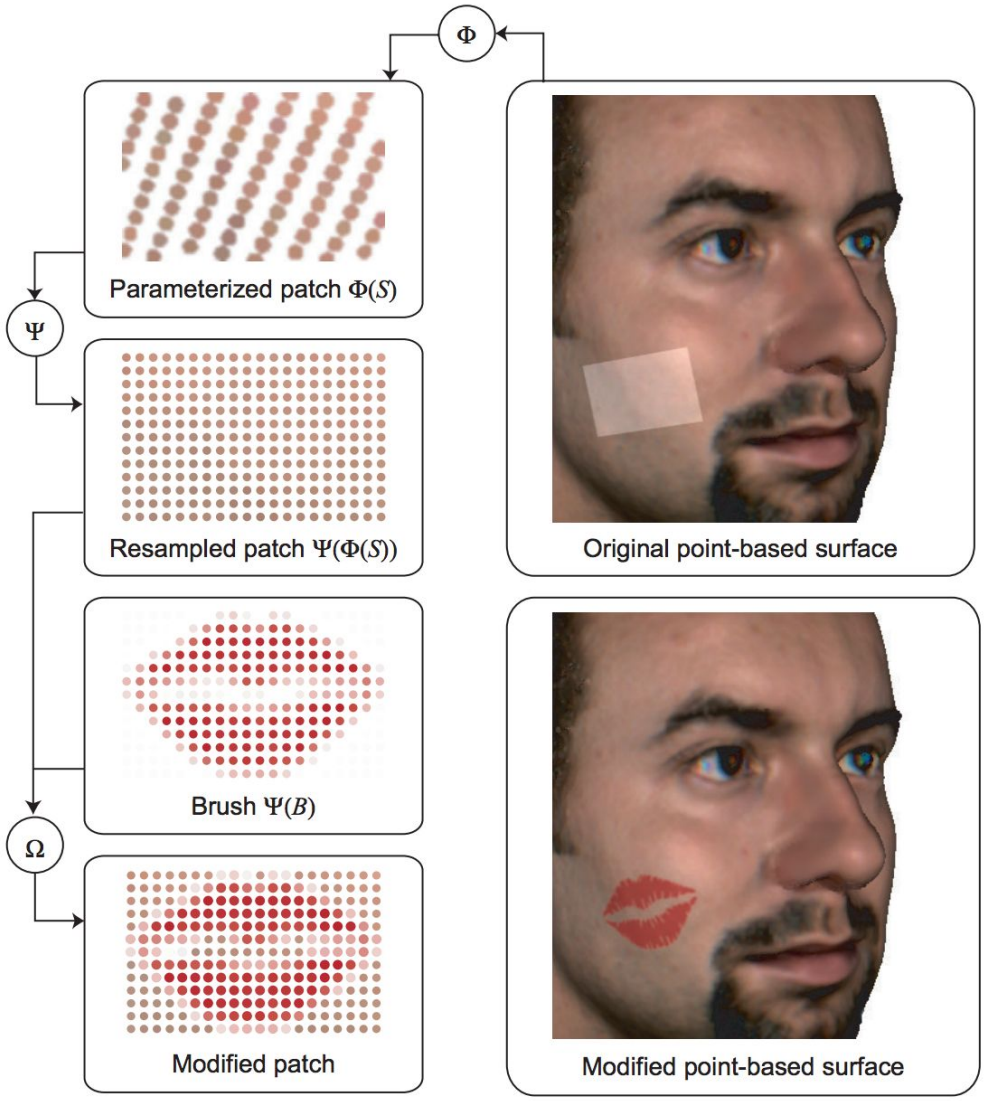


Figure 2: Overview of the operator framework for point-based surface editing.

Image segmentation from Quick Approximate Outlining

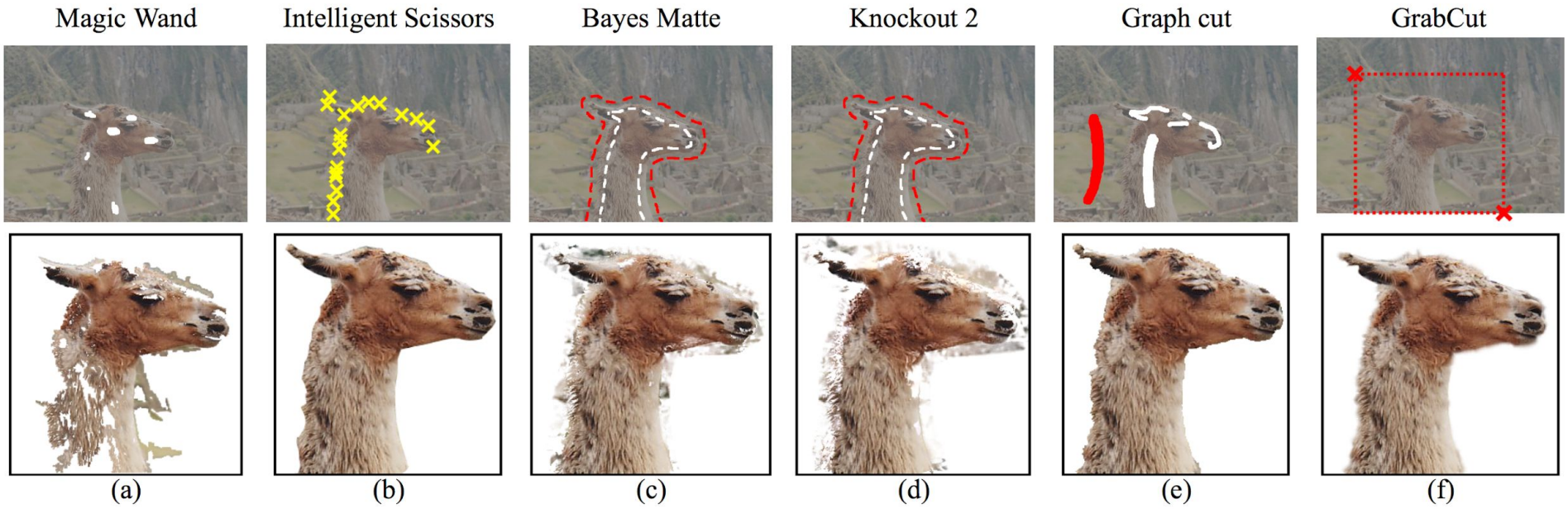
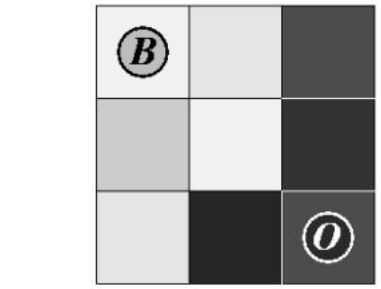


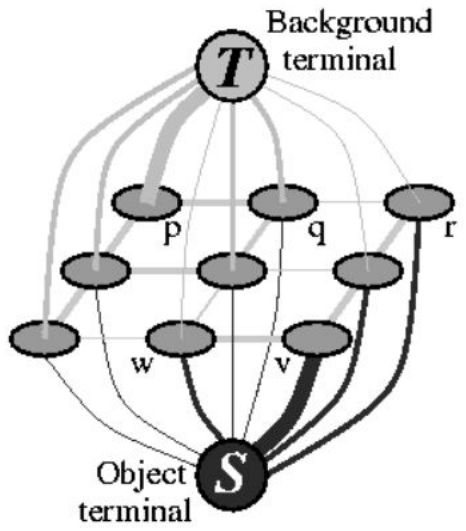
Figure 2: **Comparison of some matting and segmentation tools.** The top row shows the user interaction required to complete the segmentation or matting process: white brush/lasso (foreground), red brush/lasso (background), yellow crosses (boundary). The bottom row illustrates the resulting segmentation. GrabCut appears to outperform the other approaches both in terms of the simplicity of user input and the quality of results. Original images on the top row are displayed with reduced intensity to facilitate overlay; see fig. 1. for original. Note that our implementation of Graph Cut [Boykov and Jolly 2001] uses colour mixture models instead of grey value histograms.

"GrabCut - Interactive Foreground Extraction using Iterated Graph Cuts",
Rother, Kolmogorov, Blake, SIGGRAPH 2004

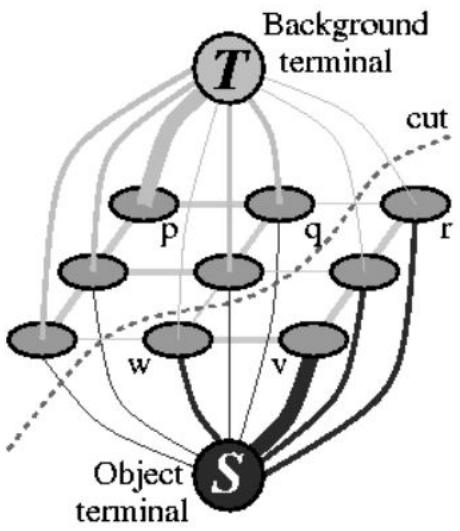


(a) Image with seeds.

(d) Segmentation results.



(b) Graph.



(c) Cut.

``Graph Cuts and Efficient N-D Image Segmentation''
Boykov & Funka-Lea, IJCV 2006

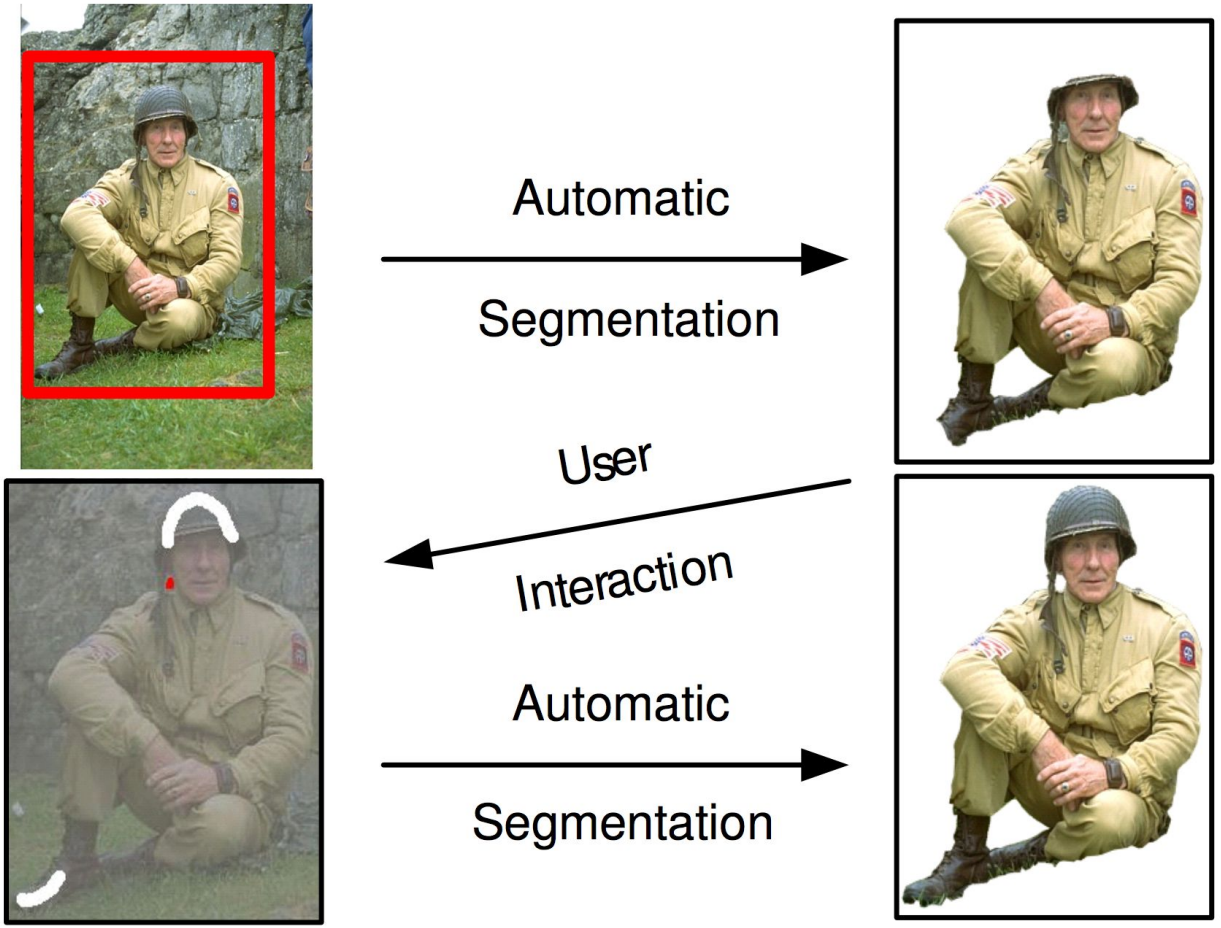
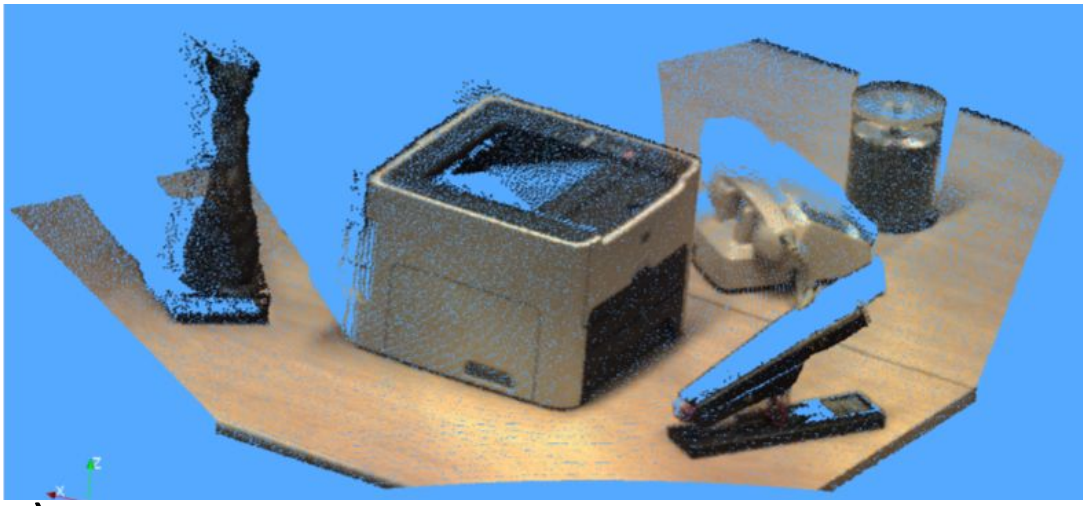


Figure 5: **User editing.** After the initial user interaction and segmentation (top row), further user edits (fig. 3) are necessary. Marking roughly with a foreground brush (white) and a background brush (red) is sufficient to obtain the desired result (bottom row).

"GrabCut -Interactive Foreground Extraction using Iterated Graph Cuts", Rother, Kolmogorov, Blake, SIGGRAPH 2004

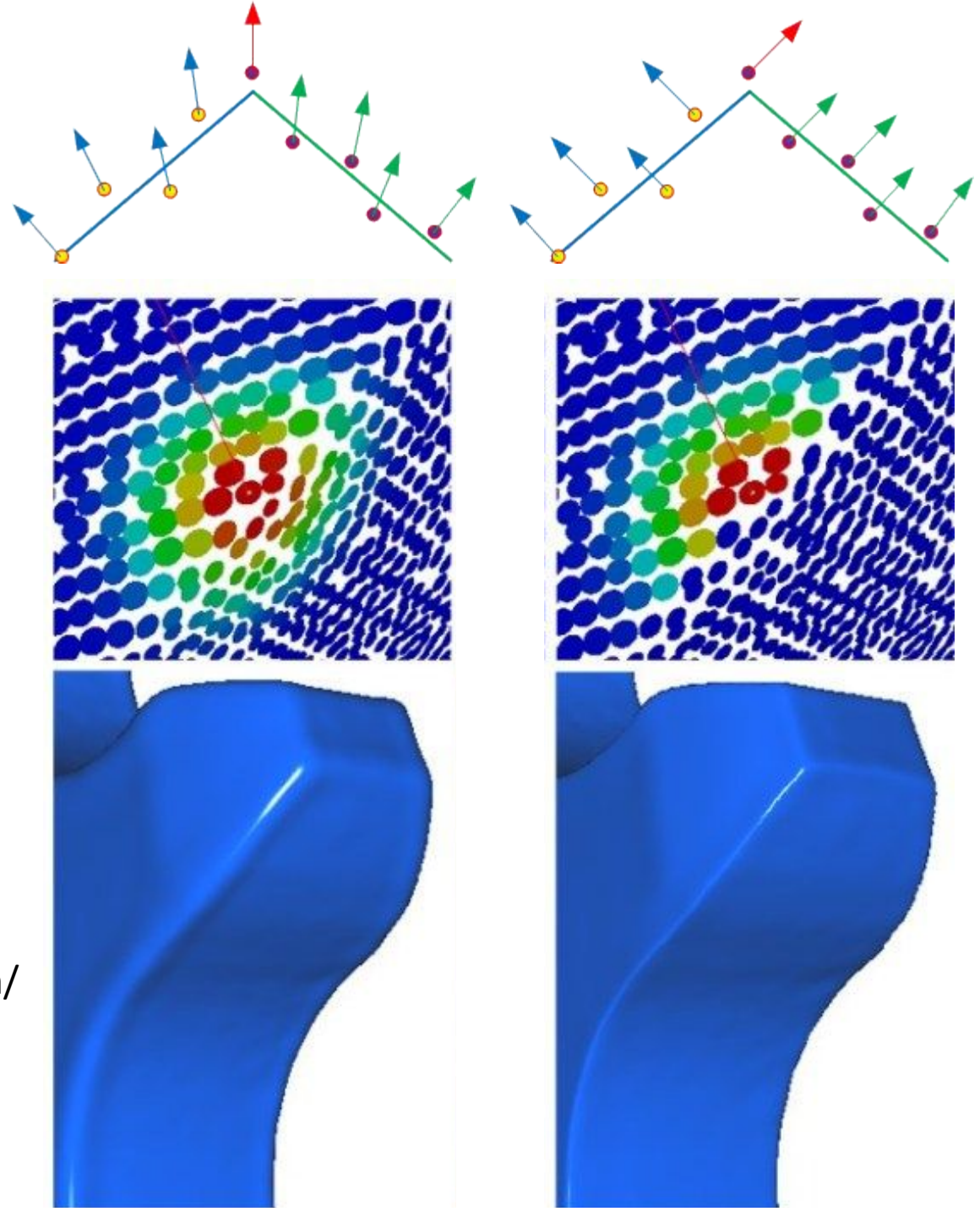
Motivation for Spatial Data Structures

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



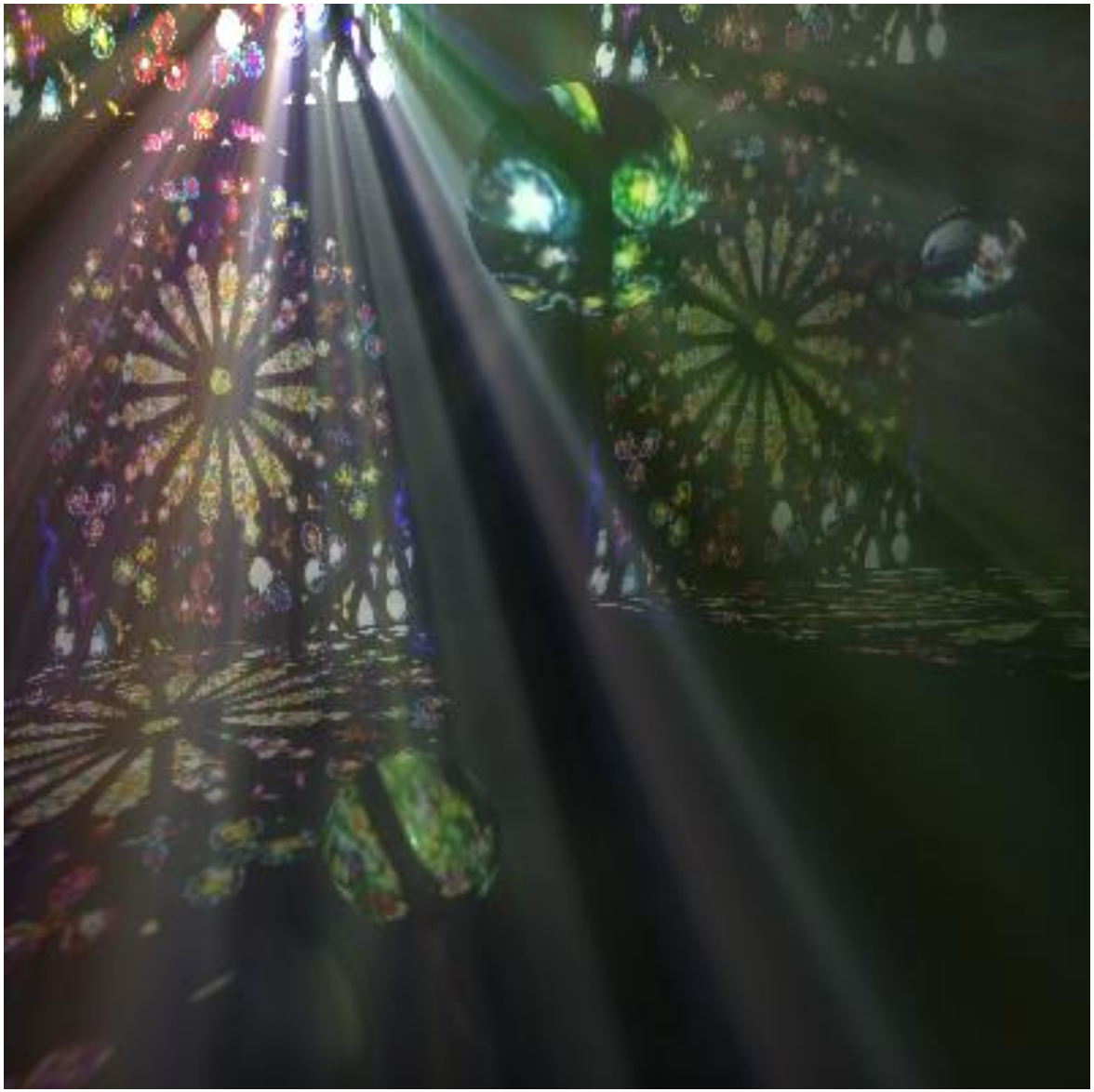
http://i.imgur.com/Xz3Z2iL.jpg

Surface Normal Estimation



http://taylorwang.wordpress.com/

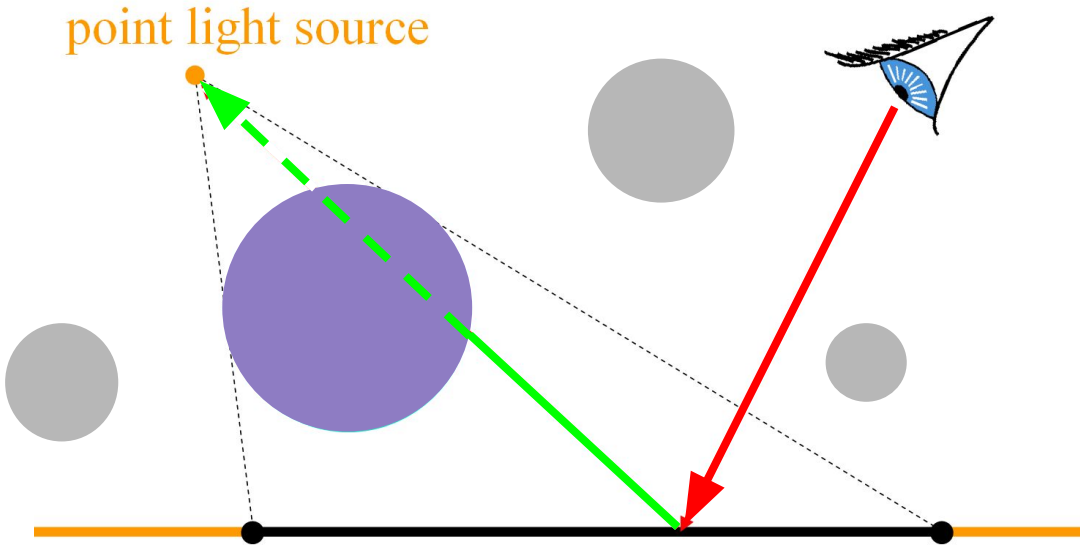
Light Rays in a Dusty Room

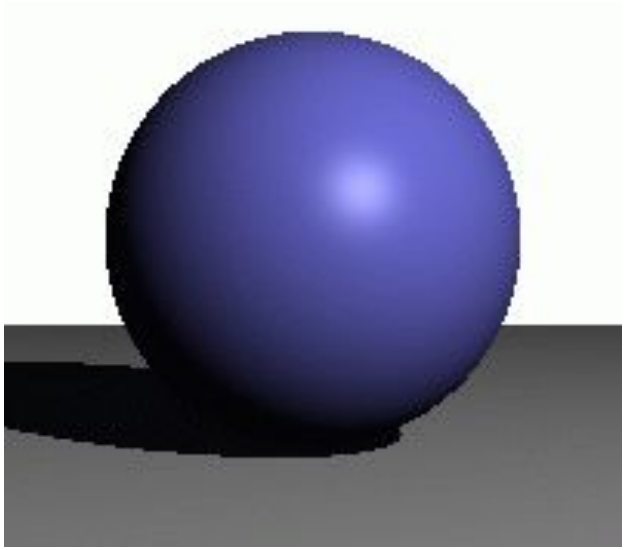


Annie Ding, MIT
6.837 Final Project
December, 2004

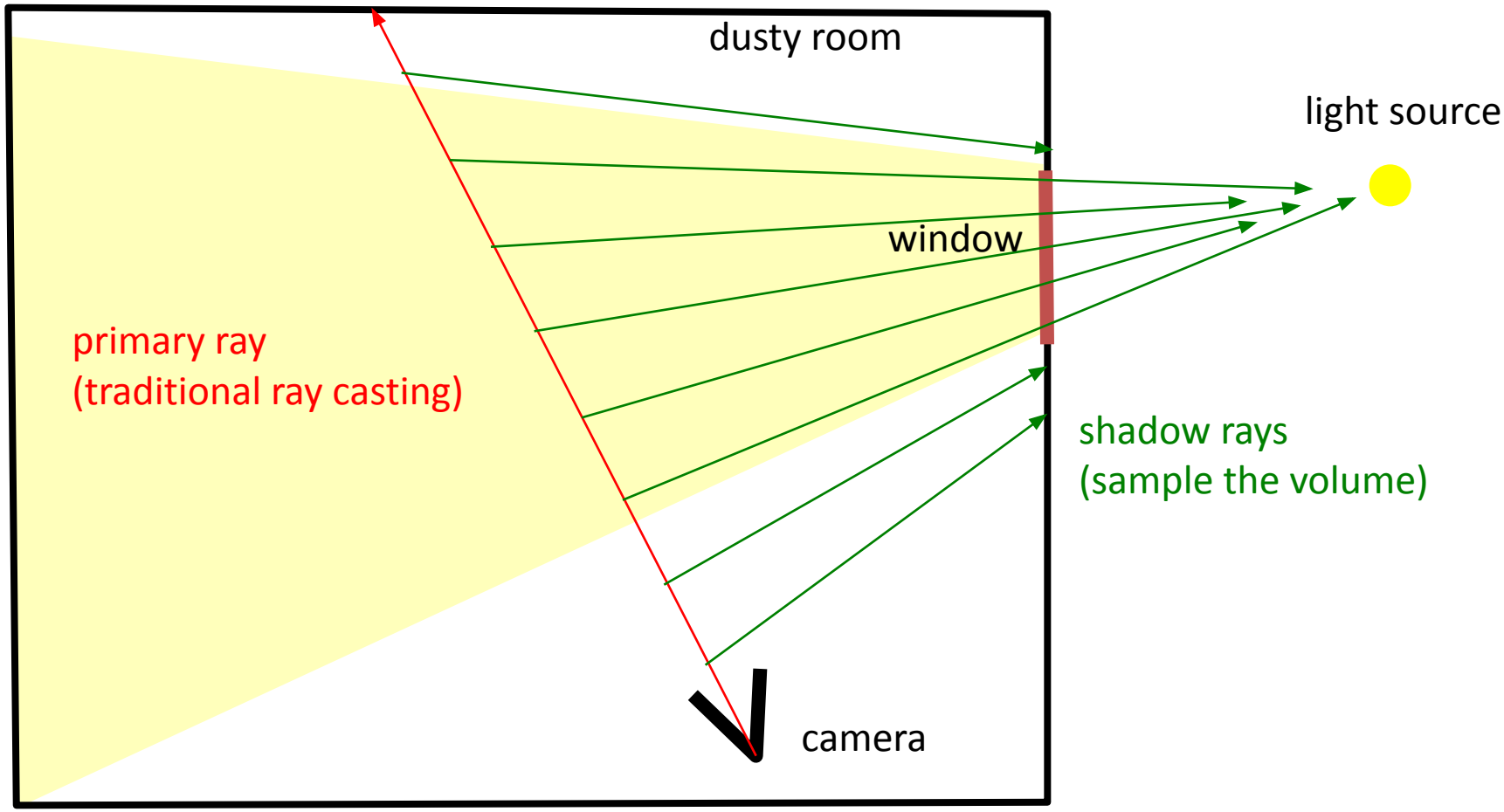
Ray Casting & Ray Tracing

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





Ray Tracing Participating Media



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Reading for Friday:

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

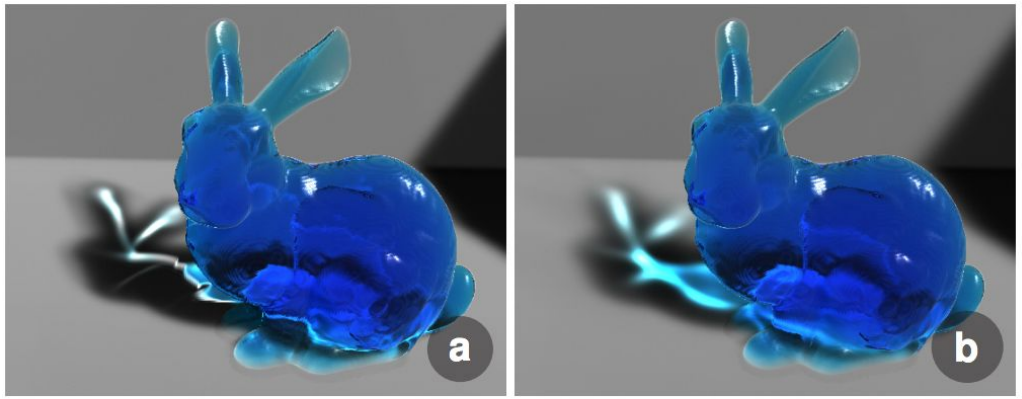

Fig. 3: Effects of light filtering. (a) No filtering. (b) Filtering of light and light direction.

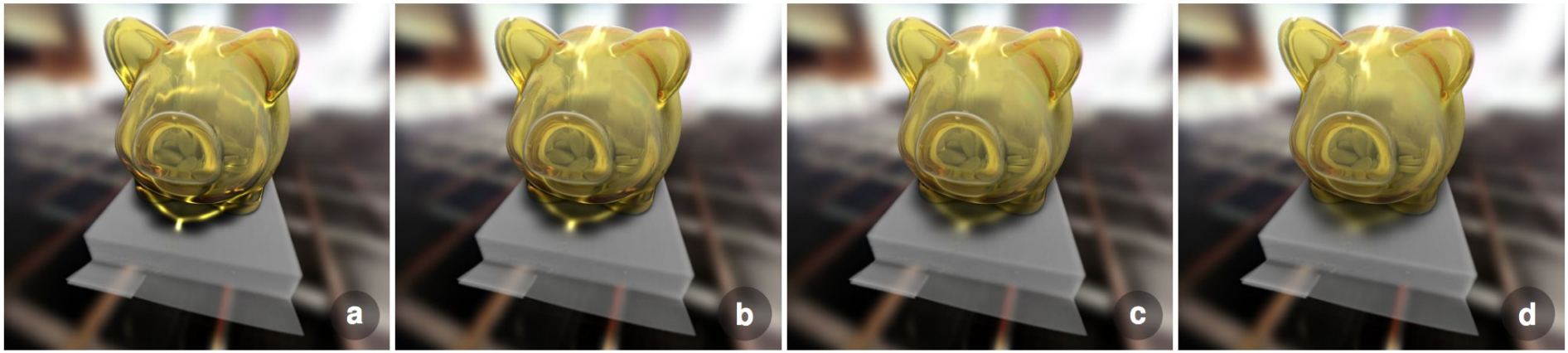

Fig. 7: CT scan of a piggy bank with refraction and combination of transmissive and reflective material properties and increasing light source softness from (a) to (d).