Visualization for Debugging
Today’s Class

- Accessing Academic Papers
- Visualization for Debugging
- Today’s Readings:
  - “Active Reading of Visualizations”, Walny, Huron, Perin, Wun, Pusch, and Carpendale, IEEE InfoVis 2017
- Readings for Next Time
IClicker: How to get an academic paper when you hit the publisher paywall?

A. Give up. Read the other paper.
B. Watch the video (hey, you weren’t going to read it anyway)
C. Use Google. Maybe some other university has this item on their reading list.
D. Go to the author’s webpage. Many/most conferences/journals allow the author to post a “pre-print” on their own site.
E. Go to the library! RPI “RensSearch” has online access to many/most technical journals. And other materials via inter-library loan. You may need VPN off-campus and/or your RCS credentials. Ask if your company has a subscription or procedure to obtain $$ materials.
Open Access to ACM Digital Library During Coronavirus Pandemic
March 30, 2020

Dear ACM Members:

As the coronavirus/COVID-19 pandemic continues, we at ACM would like to do what we can to help support the computing community. Many computing researchers and practitioners are now working remotely. In addition, teaching and learning have also moved online as more and more campuses close.

We believe that ACM can help support research, discovery and learning during this time of crisis by opening the ACM Digital Library to all. For the next three months, there will be no fees assessed for accessing or downloading work published by ACM. We hope this will help researchers, practitioners and students maintain access to our publications as well as increasing visibility and awareness of ACM’s journals, proceedings and magazines. Please be sure to inform your colleagues that the ACM DL is now open, and will continue that way through June 30, 2020.

This global health crisis is a unique challenge that has impacted many ACM members. We would like to express our concern and support for all who are affected by this outbreak.

Stay well!

Cherri Pancake
ACM President
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What is Debugging?

1. Identify the problem
2. Isolate the source of the problem
3. Correct the problem
   OR
   Determine a way to work around the problem
4. Test the correction and make sure it works

https://searchsoftwarequality.techtarget.com/definition/debugging
The First Computer Bug

https://www.nationalgeographic.org/thisday/sep9/ worlds-first-computer- bug/
“Thermal Debugging”

https://electronics.stackexchange.com/questions/430152/the-art-of-using-breadboard
Learning to Debug Software

• Debugging Level 1:
  – Remove syntax errors in compilation

• Debugging Level 2:
  – Produces an answer

• Debugging Level 3:
  – Matches the output provided by the instructor

• Debugging Level 4:
  – Hypothesize system behavior
  – Develop & run experiments
  – Collect data & analyze results
  – Validate (or repeat process)

Being a DS Mentor:
Helping students do steps 1-3...

Applies to software development, and other sciences too!
Print Debugging is Not Enough

• *Non-deterministic* bugs can be difficult to reproduce
• *Don’t know what to print*
  → print too much/too little
• Requires a *long time to re-run*,
  error is late in program execution
• *Fully capture a specific run*
  – Enable the program/system to “core dump”
    (save full memory content, all registers, etc.)
  – Then use traditional debugging tools to explore
Traditional Debugging Tools

- *Inspect variable state*: don’t try to print everything!
- *Inspect call stack*: who called this function with bad data??

- *Force program into a specific state*:
  - specific variable values
  - thread/process interleaving

- Operating System specific:
  - view OS specific system state, e.g. other threads, loaded libraries, kernel level info, etc.
Visual Debugging?
• Do the #’s match your intuition/hypotheses?
• Do you expect a positive correlation or a negative correlation?

• Can you improve even simple plots to allow the viewer to read(understand) information faster?
http://build.chromium.org/p/chromium.memory.fyi/console
Ray Tracing

• Debug angle & direction of reflection, shadow, & refraction rays

• Solution: Draw the rays traced for a single pixel, use color for different ray types
Ray Tracing

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Spatial Data Structures for Efficiency

• Primitives that overlap multiple cells?
  – Insert into multiple cells

• For each cell along a ray
  – Does the cell contain an intersection?
Traversing Spatial Data Structures

• Solution: Draw solid box for each visited cell
• Solution: Draw solid quad for each cross cell face
Mesh Connectivity

- Maintain consistent orientation of triangles
- Visualize surface self-intersections
- Solution: Color the "back" side blue
- Maintain connectivity through local simplification and subdivision operations
- Solution: Color edges with only 1 triangle neighbor red
“Watertight” Model Construction

- Red = edge with only 1 triangle neighbor
- Yellow = edge with > 2 triangle neighbors (non manifold)
- Green = triangle with zero area
- Blue = triangle that is neighbor to a zero area triangle
Mesh Simplification
Mesh Topology

- Neighborhood & local editing
- Lots of print statements:
  Triangle 206: 31 32 42
  Triangle 207: 31 42 28
  Triangle 208: 41 19 17
  Triangle 209: 42 41 43
  Triangle 210: 28 42 27
  <etc.>

- Solution: Draw by hand
- This graph drawing could be automated!
“Marching Tetrahedra”

“Interval volume tetrahedrization”
Visualization '97, Nielson & Sung
How Tetrahedra Fill Volumetric Space

• Drawing (in 2D) didn’t work
• Creating an OpenGL visualization didn’t work (even with transparency)
• Solution: build lots of paper & tape models
Volumetric Exploration

- For developer or designer/modeler
- Fast interaction to understand sublayer details

Figure 9.8: A wireframe rendering of the 49,995 tetrahedra cat mesh, shown in a), is not very informative. To better visualize the shape and material of the elements, we can b) render the tetrahedra with cracks between them and c) move a clip plane through the model interactively. To view just the structure, we can render only the air/material and material/material interfaces to create d), e), & f), the illusion of a slicing through a solid material. The illusion is broken if g) a second clip plane is added.
Figure 9.7: Two-dimensional illustrations of the different tetrahedral rendering options applied to the simple model shown in a). Two sided lighting is used to b) color the back faces of surface triangles blue, which can be viewed by c) cutting the object with a clipping plane. The individual elements can be visualized with d) crack-style rendering. The shape of the internal structures can be viewed by rendering e) two-sided internal material interfaces. The internal surfaces are f) assigned the normal of the clipping plane (black arrows), to give the illusion of a g) ghost surface where the object has been sliced. The illusion is broken if h) a second clipping plane is added.
To understand relationships and thresholds
Projection

- Validate the projector world coordinate calibration
- Solution: Project the mesh from each projector, verify that the images closely align
- Surprisingly, this became one of our more popular “demo”s & this image made the RPI 2010 Research calendar
Visibility & Smooth Projection

- Occlusions & Projector Visibility
- Fade in/fade out for transitions
- Make sure the sum of all projectors = 1
- Solution: Visualization the number of projectors each patch can see
- Solution: Visualize blending weights for each projector
4x4 Calibration Projection Matrices

• Sanity check position & direction of camera & each projector
• Understand distribution of calibration error
• Solution: Render all point samples in a common coordinate system
Fluid Dynamics

- Visualize grid cell face velocities
- Interpolate face velocities to create smoothly varying vector field
- How to visualize a 3D vector field?
Today’s Takeaway Message:

Invest in Visualization for Debugging
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Reading for Today (pick one)

“Active Reading of Visualizations”, Walny, Huron, Perin, Wun, Pusch, and Carpendale, IEEE InfoVis 2017

<table>
<thead>
<tr>
<th>VIEW PRESERVING ACTIONS</th>
<th>LOOKING ACTIONS</th>
<th>FOLLOWING ACTIONS</th>
<th>CONTACT ACTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change Point of View</td>
<td>Hover Pen/Hand</td>
<td>Point or Trace in-air (near Vis)</td>
<td>Tap Pen/Hand</td>
</tr>
<tr>
<td>Non-Specific Gesture</td>
<td>Point or Trace in-air (away from Vis)</td>
<td></td>
<td>Point or Trace (contact Vis)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Touch Sheet</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VIEW ALTERING ACTIONS</th>
<th>POSITIONING ACTIONS</th>
<th>MARKING ACTIONS</th>
<th>CREATION ACTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Move Sheet</td>
<td>Hold Sheet</td>
<td>Make marks on Vis Sheet</td>
<td>Make marks on non-VIS sheet</td>
</tr>
</tbody>
</table>

Fig. 1. Physical actions we observed during our study of active reading of node-link visualizations. Physical actions are ordered from left to right by increasing physical engagement.
• Parallels to research in active reading of text
• Pen & paper annotations easier (more fluid) than digital (have to learn option menus)
• Pilot study to explore qualitative use
  + second study for precision
• Action types:
  – View preserving (looking/following/contact)
  – View altering (positioning/marking/creation)
  – Goals: recognizing, tracking, reorganizing, decoding, and analyzing
• Vary graph size -- people use different techniques with larger graphs
• Recommendations for interactive visualization design (supporting active reading) & further studies
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DimpVis: DimP Information Visualization
(DimP = Prior paper “Video Browsing by Direct Manipulation”)

Fig. 4. Navigation in time for bar charts is achieved by dragging a selected bar vertically along its hint path. The hint path slides horizontally to stay connected with the bar and finger.

Is this intuitive? Is this practical?
Dynamic bar charts… cool!
No natural way to overlay the trajectory Time axis overlaps (left->right) with whatever (non time-based) data the horizontal axis represents
Fig. 6. Pie charts are adjusted in time by dragging an edge of a segment in angular directions along its hint path. The hint path slides in and out along the radius to remain connected with the finger position and edge of the segment.
Fig. 7. Heat maps are adjusted in time by dragging vertically in the space of the colour scale. The hint path slides horizontally to stay connected with the cell and finger.

But is this intuitive way to interact?
No natural direction to spatially overlay the trajectory
• “Interaction Ambiguity”
  – What if data is not clearly headed in a direction?
  – What if data has constant value for two or more timesteps?
  – What if data returns in the direction it came from?
  – What if there are multiple times that “the bar graph is at value 500”?

• Avoid/disambiguate:
  – Temporal continuity enforced at cusps
  – Fake loops can be traversed to change time, even if the object you are directly manipulating does not change.
    – Nonintuitive?
  – Does this work if the path has lots of overlaps/loops?

Fig. 3. Temporal ambiguity occurs in a scatter plot when a point does not move between time steps. Temporal navigation capabilities are provided in ambiguous using loops in which one transit around the loop corresponds to one time step.
• Related work
  – Visualize trends/trajectories of multiple individual data points
• Keeps your focus on the data you are interested in (not distracted by spatially separate slider).
• Touch is preferable to mouse (which also separates user from data).
  – somatic: affecting the body; corporeal or physical; the vertebrate nervous system that regulates voluntary movement
  – Very game-like, fun to use
  – Like playing connect the dots (but what if I want to go my own way?)
  – Futuristic & forward thinking
  – But mouse precision is so much better than “fat finger”
• Hard to understand interaction from static figures (despite lots of diagrams and overlays)
  – Video was more clear
    Did you read the paper too or just watch the video?
Small Multiples

http://www.latimes.com/science/la-me-g-california-drought-map-htmlstory.html
Evaluation

• Quantitative evaluation compared to traditional time slider and small multiples – mixed results, but better in some cases
• Measure performance (time & error rate) to complete tasks in reading & observing trend
  – Spatial task “When is the bar at height 3?” vs.
  – Temporal task “In 1995, what is the height of the bar?”
  – Comparison “When is A greater than B?”
  – Distribution “When do both A & B decrease?”
  – Outliers “When does A move in opposite direction to other points?”
• Test cases for study
  – Real data, but adjusted to ensure just 1 “correct” answer
  – 3 techniques (DimpVis, slider bar, small multiples)
    x 2 visualizations (scatter plot, bar chart)
• Technique Comments/Concerns/Ideas
  – Dragging along a path isn’t that you have true control over where the object should go, you are constrained to follow its path
  – DimP same as time slider, only more confusing since it the path bends in strange ambiguous ways – seems like a gimmick
  – Showing the paths of 1 or more data points forward & back in time seems helpful
  – Instead of the path (directly manipulating) of a single point, can we show (control time via) the average path of multiple points?
  – Instead of replacing a linear slider (so many other ways to do this) what about using this for a true 2D “slider”?
• Additional “features”
  – Traditional time slider
    • why did they have to add this? DimP manipulation is nonintuitive/hard to control?
  – Flexible rubber band (threshold for direct manipulation)
  – Snap to discrete timepoint
  – Fast forward (jump to time point with tap)
• Tasks removed from study because
  – Not enough time
  – Performing the task was “frustratingly difficult” during pilot study
• Set of clear hypotheses
  – Use of statistical tests (ANOVA), judges for data set size whether the measured differences are significant or could probabilistically just be noise (not significant)
  – Their hypotheses partially supported or rejected by measurements
  – Subjectively DimpVis was preferred! But Is this reproducible with another set of users?
Fig. 8. Scatter plot task completion times.

Fig. 9. Scatter plot subjective ratings.
• “Enhanced engagement with data”
• Some misuse of tool (intuition/prior experience w/ other interfaces)
  – Attempted 2 finger interaction
  – Attempted to drag in opposite direction vertically
• Open Questions
  – Scalability
• Great job removing outside factors from what was being tested
• Clearly listed hypotheses (# of hypotheses seemed low)
• Refreshing that they didn’t just propose a visualization, they tested it thoroughly!
• “temporal navigation” felt like I was reading a paper on time travel 😊
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Readings for Friday (pick one)

"An Image-based Approach to Extreme Scale In Situ Visualization and Analysis", Ahrens, Patchett, Jourdain, Rogers, O'Leary, & Petersen, Supercomputing 2014
Fig. 10. (a) An overview of traffic flows over the Paris area. Outgoing traffic flows have been marked with the green arrows, while incoming traffic flows have been marked with a red arrow. (b) The traffic flows have been bundled, selected, and the dynamics of these traffic flows are displayed using the movable windows.