Paper: Polaris
Paper: D3
Paper: Vega-Lite

Tamara Munzner
Department of Computer Science
University of British Columbia

CPSC 547, Information Visualization
Week 11: 13 November 2025

www.cs.ubc.ca/~tmm/courses/547-25

Plan for today

- peer review one direction
- break
- peer review other direction
- mini-lecture on systems papers

Paper: D3 System

Paper: D3

- paper types
  - –design studies
  - –technique/algorithm
  - –evaluation
  - –model/taxonomy
  - –**system**

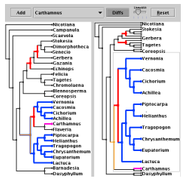
[D3: Data-Driven Documents. Bostock, Ogievetsky, Heer. IEEE Trans. Visualization & Comp. Graphics (Proc. InfoVis), 2011.]

Toolkits

- imperative: how
  - –low-level rendering: Processing, OpenGL
  - –parametrized visual objects: prefuse
    - also flare: prefuse for Flash
- declarative: what
  - –Protoviz, D3, ggplot2
  - –separation of specification from execution
- considerations
  - –expressiveness
    - can I build it?
  - –efficiency
    - how long will it take?
  - –accessibility
    - do I know how?

WebGL/OpenGL

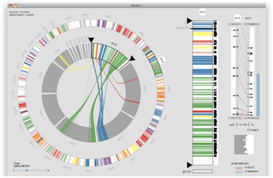
- graphics library
  - –pros
    - power and flexibility, complete control for graphics
    - hardware acceleration
    - many language bindings: js, C, C++, Java (w/ JOGL)
  - –cons
    - big learning curve if you don't know already
    - no vis support, must roll your own everything
  - –example app: TreeJuxtaposer (OpenGL)



[Fig 5. Munzner et al. TreeJuxtaposer: Scalable Tree Comparison using Focus+Context with Guaranteed Visibility. Proc SIGGRAPH 2003, pp 453-462.]

Processing / p5.js

- layer on top of Java/OpenGL, Javascript/WebGL
- visualization esp. for artists/designers
- pros
  - –great sandbox for rapid prototyping
  - –huge user community, great documentation
- cons
  - –poor widget library support
- example app: MizBee



[Fig 1. Meyer et al. MizBee: A Multiscale Synteny Browser. Proc. InfoVis 2009.]

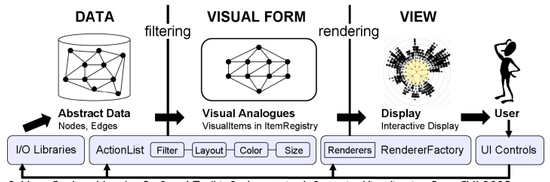
prefuse

- infovis toolkit, in Java
- fine-grained building blocks for tailored visualizations
- pros
  - –heavily used (previously)
  - –very powerful abstractions
  - –quickly implement most techniques covered so far
- cons
  - –no longer active
  - –nontrivial learning curve
- example app: DOITrees Revisited

[DOITrees Revisited: Scalable, Space-Constrained Visualization of Hierarchical Data. Heer and Card. Proc. Advanced Visual Interfaces (AVI), pp. 421–424, 2004.]

prefuse

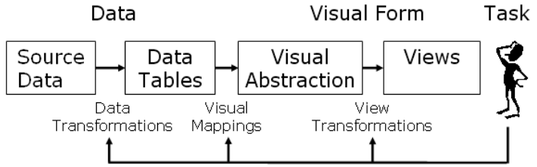
- separation: abstract data, visual form, view
  - –data: tables, networks
  - –visual form: layout, color, size, ...
  - –view: multiple renderers



[Fig 2. Heer, Card, and Landay. Prefuse: A Toolkit for Interactive Information Visualization. Proc. CHI 2005, 421-430]

InfoVis Reference Model

- conceptual model underneath design of prefuse and many other toolkits
- heavily influenced much of infovis (including nested model)
  - –aka infovis pipeline, data state model



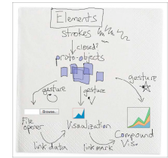
[Redrawn Fig 1.23. Card, Mackinlay, and Shneiderman. Readings in Information Visualization: Using Vision To Think, Chapter 1. Morgan Kaufmann, 1999.]

Declarative toolkits

- imperative tools/libraries
  - –say exactly **how** to do it
  - –familiar programming model
    - OpenGL, prefuse, ...
- declarative: other possibility
  - –just say **what** to do
  - –Protovis, D3

Protovis

- declarative infovis toolkit, in Javascript
  - –also later Java version
- marks with inherited properties
- pros
  - –runs in browser
  - –matches mark/channel mental model
  - –also much more: interaction, geospatial, trees,...
- cons
  - –not all kinds of operations supported
- example app: NapkinVis (2009 course project)



[Fig 1, 3. Chao. NapkinVis. http://www.cs.ubc.ca/~tmm/courses/533-09/projects.html#will]

Protovis Validation

- wide set of old/new app examples
  - –expressiveness, effectiveness, scalability
  - –accessibility
- analysis with cognitive dimensions of notation
  - –closeness of mapping, hidden dependencies
  - –role-expressiveness visibility, consistency
  - –viscosity, diffuseness, abstraction
  - –hard mental operations

[Cognitive dimensions of notations. Green (1989). In A. Sutcliffe and L. Macaulay (Eds.) People and Computers V. Cambridge, UK: Cambridge University Press, pp 443-460.]

D3

- declarative infovis toolkit, in Javascript
- Protovis meets Document Object Model
- pros
  - –seamless interoperability with Web
  - –explicit transforms of scene with dependency info
  - –massive user community, many thirdparty apps/libraries on top of it, lots of docs
- cons
  - –even more different from traditional programming model
- example apps: many

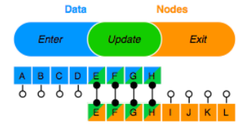
D3

- objectives
  - –compatibility
  - –debugging
  - –performance
- related work typology
  - –document transformers
  - –graphics libraries
  - –infovis systems
    - general note: all related work sections are a mini-taxonomy/typology!

[D3: Data-Driven Documents. Bostock, Ogievetsky, Heer. IEEE Trans. Visualization & Comp. Graphics (Proc. InfoVis), 2011.]

D3 capabilities

- query-driven selection
  - –selection: filtered set of elements queries from the current doc
    - also partitioning/grouping!
  - –operators act on selections to modify content
    - instantaneous or via animated transitions with attribute/style interpolators
    - event handlers for interaction
- data binding to scenegraph elements
  - –data joins bind input data to elements
  - –enter, update, exit subselections
  - –sticky: available for subsequent re-selection
  - –sort, filter

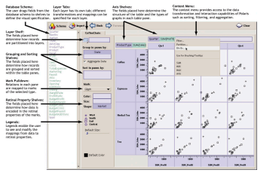


[D3: Data-Driven Documents. Bostock, Ogievetsky, Heer. IEEE Trans. Visualization & Comp. Graphics (Proc. InfoVis), 2011.]

D3 Features

- document transformation as atomic operation
  - scene changes vs representation of scenes themselves
- immediate property evaluation semantics
  - avoid confusing consequences of delayed evaluation
- validation
  - performance benchmarks
    - page loads, frame rate
  - accessibility
  - (adoption)
    - everybody has voted with their feet by now!

Paper: Polaris/Tableau System



Polaris

A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases

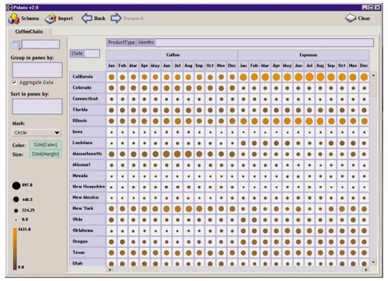
Chris Stolte, Diane Tang, Pat Hanrahan

http://www.graphics.stanford.edu/projects/polaris/

Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases. *Stolte, Tang and Hanrahan, IEEE TVCG 8(1):52-65 2002*

Polaris: Stolte, Tang, and Hanrahan

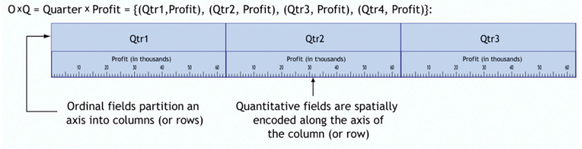
- infovis spreadsheet
  - table cells have graphical elements, not just numbers
  - wide range of channels and marks
- example
  - marks: circles
  - color channel: saturation
  - size channel: area
  - partition: state x product:month
    - ord x ord



[Fig 3a. Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases. Stolte, Tang and Hanrahan, IEEE TVCG 8(1):52-65 2002.]

Table Algebra :: Interactive Interface

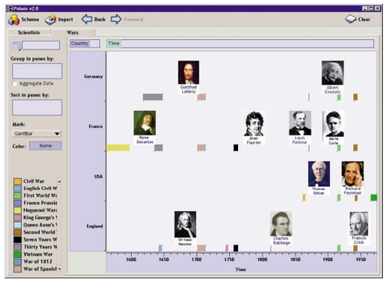
- drag and drop actions map to formal language underneath
  - partitioning using shelves
  - different results for ord vs quant



[Fig 2. Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases. Stolte, Tang and Hanrahan, IEEE TVCG 8(1):52-65 2002.]

Polaris

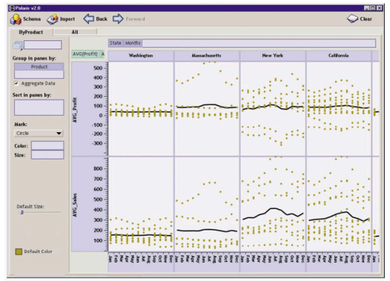
- example
  - marks: Gantt chart bars
  - color channels: nominal / categorical
  - spatial position channels: country x year
    - ord x quant



[Fig 3b. Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases. Stolte, Tang and Hanrahan, IEEE TVCG 8(1):52-65 2002.]

Polaris

- example
  - views: scatterplots
  - marks: points
  - spatial position channels: profit x month
    - quant x (2 ord)



[Fig 3d Polaris: A System for Query, Analysis and Visualization of Multi-dimensional Relational Databases. Stolte, Tang and Hanrahan, IEEE TVCG 8(1):52-65 2002.]

Terminology I: Now and Upcoming

- Marks and Channels
  - retinal variables/properties: *visual channels*
  - mark: *mark*
- Data Abstraction
  - column or field: *attribute*
    - nominal: *categorical*
    - ordinal: *ordered*
    - quantitative: *quantitative*
  - row or record: *item*
  - dimension / independent / ordinal: *key attribute*
    - all ordinal fields treated as dimensions in Polaris
  - measure / dependent : *value attribute*
    - all quantitative fields treated as measures in Polaris

Terminology II: Upcoming

- Data Abstraction
  - deriving data
- Map Color and Other Channels
  - hue: *hue*
  - value: *saturation*
  - brightness: *luminance*
- Manipulate View
  - sorting
- Facet Into Multiple Views
  - pane: *view*
  - partitioning
  - brushing: *linked highlighting*
- Reduce Items and Attributes
  - aggregation, filtering

Polaris: Pre and post

- influences
  - Bertin's Semiology of Graphics book (1967 / 1998)
  - Wilkinson's Grammar of Graphics book (1999 / 2005)
  - Mackinlay's APT paper/system (1986)
  - Cleveland's Visualizing Data book (1993)
- Stolte and Hanrahan commercialized as Stanford spinoff Tableau Software
  - major success story in vis, $2B IPO in 2013
  - Mackinlay joined in 2004, Wilkinson joined in 2014
- Tableau use in this course
  - very useful for analysis projects
  - possible sandbox for experimentation when starting programming projects
  - you can request free student license, good for one year
    - http://www.tableau.com/academic/students