**Idiom: streamgraph**
- express values
- quantitative attributes
- no keys, only values
- data
- two quant attribs
- mark: points
- channels
- hue + vertical position
- tasks
- find trends, outliers, distribution, correlation, clusters
- scalability

**Idiom: bar chart**
- one key, one value
- data
- one quant attrib, one quant attrib
- mark: lines
- channels
- length to express quant value
- length: spatial region (one per mark)
- order by quant attrib
- aligned by label (alphabetically), by length attrib (data-driven)
- task
- compare, lookup values
- scalability
- dozens to hundreds of levels for key attrib

**Idiom: heatmap**
- two keys, one value
- data
- two quant attribs (gene, experimental condition)
- one quant attrib (expression levels)
- mark: area
- aggregate and align in 2D matrix
- indexed by 2 categorical attributes
- channels
- length and color hue
- per row (ordered x-axis)
- task
- part-to-whole relationship
- scalability
- >= 100 rows, 100s of cols, >=50 quant attrib levels

**Idiom: scatterplot matrix, parallel coordinates**
- scatterplot (SPLOM)
- rectilinear, parallel, radial
- all possible pairs of axes
- scalability
- dozens to hundreds of items
- parallel coordinates
- parallel axes, jagged line representing item
- rectilinear, item as point
- axis ordering is major challenge
- scalability
- dozens of attribs
- hundreds of items

**Task: Correlation**
- scatterplot matrix
- positive correlation
- diagonal low-to-high
- negative correlation
- diagonal low-to-low
- uncorrelated
- parallel coordinates
- positive correlation
- parallel line segments
- negative correlation
- all segments cross at halfway point
- uncorrelated
- scattered crossings
**Protovis Validation**
- wide set of old/new app examples
  - expressiveness, effectiveness, scalability
- analysis with cognitive dimensions of notation
  - cleanness of mapping, hidden dependencies
  - role-expressiveness visibility, consistency
  - viscosity; diffuseness, abstraction
  - hard mental operations


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**Paper: D3**
- paper types
  - design studies
  - technique/algorithm
  - evaluation
  - model/taxonomy
  - system
- declarative: what
  - Protovis, D3, ggd2
  - separation of specification from execution
- considerations
  - expressiveness
  - can’t build it
  - efficiency
  - how long will it take?
  - accessibility
  - do I like it now?

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**InfoVis Reference Model**
- conceptual model underlies design of prefaces and many other toolkits
- heavily influenced much of infovis (including nested model)
- aka infovis pipeline, data state model

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**Declarative toolkits**
- imperative toolkits
  - say exactly how to do it
  - familiar programming model
  - OpenGL, preface, ...
- declarative: other possibility
  - just say what to do
  - Protovis, D3

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**Preprocessing**
- 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
  - no longer arcane
- non-learning curve
- example app: DOITrees Revisited

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

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**Orientation limitations**
- rectilinear: scalability w/ flexes
  - 3+ axes hard
  - rare in science
  - 4+ impossible
- parallel: unfamiliarity, training time
- radial: perceptual limits
  - angles lower precision than lengths
  - asymmetry between angle and length
- can be exploited

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**Further reading**

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**PostScript Validation**
- rectilinear good for linear vs nonlinear trends
- radial good for cycle patterns

---

**Idioms: normalized stacked bar chart**
- task
  - part-to-whole judgements
  - stacked bar chart, normalized so full vert height
  - single stacked bar equivalent to pie
  - high information density requires narrow margins
- pie chart
  - information density requires large circles

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**Idioms: pie chart, polar area chart**
- area marks with angle channel
- accuracy: angles much less accurate than line length
- polar area chart
- area marks with length channel
- more direct analog to bar charts
- data
  - using key: emb. quant value symb
  - part-to-whole judgements

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**Idioms: radial bar chart, star plot**
- radial bar chart
  - radial axes meet at central ring, line mark
- star plot
  - radial axes, meet at central point, line mark
  - rectilinear axes, skewed vertically
  - accuracy
    - less accurate than skewed with rectilinear

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**Protovis**
- declarative infovis toolkit, in JavaScript
- uses layer.js version
- marks with inherited properties
- pros
  - runs in browser
  - matches mark/channel mental model
  - also much more: intersection, geospatial, trees...
- cons
  - not all kinds of operations supported
  - Napvis (2009 course project)

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**Toolskits**
- imperative: how
  - low-level rendering: Processing, OpenGL
  - parameterized visual objects: preface
  - data flow for Flash
- declarative: what
  - Protovis, D3, ggd2
  - separation of specification from execution
  - considerations
    - expressiveness
    - can’t build it
    - efficiency
    - how long will it take?
    - accessibility
    - do I like it now?

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

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**Idioms: glyph maps**
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D3
• declarative infovis toolkit, in Javascript
• Protovis meets Document Object Model
• pros
– seamless interoperability with Web
– explicit transforms of scenes with dependency info
– massive user community, many third-party 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

D3 related work typology
– document transformers
– graphics libraries
– infovis systems
* general note: all related work sections are a mini-taxonomy!

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 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
* everybody has voted with their feet by now!

Next Time
• to read
– VAD Ch. 8: Arrange Spatial Data
– Radial Sets: Interactive Visual Analysis of Large Overlapping Sets
  Bilal Alsallakh, Wolfgang Aigner, Silvia Miksch, and Helwig Hauser.
* paper type: technique