Separability vs. Integrality

2 groups each: integral area
4 groups total: integral area

Height
Red
Green
Fully separable
Some interference
Some/significant interference
Major interference

2 groups each: integral area
3 groups total: integral area
4 groups total: integral area

Spatial position ranks high for both

Categorical color: limited number of discriminable bins

Human perception built on relative comparisons
• great if color contiguous
• surprisingly bad for absolute comparisons

Noncontiguous small regions of color
• fewer less than you were

Categorical color: limited number of discriminable bins

• http://www.colorbrewer.org

• saturation and area example: size affects salience!

Categorical color: limited number of discriminable bins

• http://www.colorbrewer.org

• saturation and area example: size affects salience!
Ordered color: Rainbow is poor default

- problems
  - perceptually unordered
  - perceptually nonlinear
- benefits
  - five-grained structure visible
  - rememble
- alternatives
  - large-scale structure fewer hues
  - fine-structure multiple hues with monotonically increasing luminance (eg viridis, Kryphon)

Viridis
- colorful, perceptually uniform, colorblind-safe, monotonically increasing luminance
- limited contrast
- scalable
- perceptually ordered

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Express Values

### Tables

- Attributes (columns)
- Items (rows)
- Cell containing value

### Multidimensional Table

- Value in cell

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**Alignment**

- **Encode**
  - Arrange
  - Order
  - Align
- **Arrangement**
  - Parallel
  - Radial
- **Orientation**
  - Horizontal
  - Vertical

---

**Idiom: scatterplot**

- **Express Values**
  - quantitative attributes
  - no keys, only values
  - data
    - 2 quantitative attributes
    - bar plots
    - histogram
    - stacked bar
  - channels
  - axis
  - titles
  - markers
  - legends
  - grid
  - colors
  - transparency
  - size
  - shape
  - color

---

**Idiom: bar chart**

- one key, one value
- data
  - values
  - bar, area, line, point
  - legend
  - title
  - axis
  - grid
  - bars
  - markers
  - bars
  - colors
  - transparency
  - size
  - shape
  - color

---

**Some keys**

- **express values**
  - separate, order, align regions
  - separate, order, align
  - independent attribute
  - dependent attribute
  - value
- **region**
  - categorical attributes
  - use ordered attribute to order and align regions

---

**Some keys: Categorical regions**

- **Separated**
  - ordered
  - unaligned
- **Order**
  - separate
- **Align**
  - separate

---

**Some keys: Numerical values**

- **Separate**
  - order
  - align
  - independent attribute
  - dependent attribute
  - value
- **Region**
  - categorical attributes
  - use ordered attribute to order and align regions

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**Separated, Aligned and Ordered**

- **Separated but not ordered or aligned**
- **Limitation**
  - hard to know rank: what's the 4th most? the 7th?
Choosing bars vs line charts
- depends on type of key attrib
  - bar charts if categorical
  - line charts if ordered
- do not use line charts for categorical key attribs
- violates expressiveness principle
- implication of trend too strong
  - does not override semantics!
- "The more male a person, the taller he is!"

Arrange networks and trees
- node-link best for small networks
- weighted edge between nodes
- high information density: requires narrow rectangle
- node-link view in Figure 7.5b.
- matrix views can also show weighted networks, where each link has an as-
  be distinguishable between the largest and the smallest cell size.

VolumeMatrix

List Recursive Subdivision

Parallel

Population maps
- beware!
- absolute vs relative again
- population density vs per capita
- investigate with Ben Jones Tableau Public demo
- http://public.tableau.com/profile/ben.jones storyline=11171947689
- yes, unless you look at per capita (relative) numbers

Population maps thickness

Population maps thickness

Bayesian surprise maps
- use models of expectations to highlight surprising values
- confounds (population) and variance (sparsity)

Bayesian surprise maps

Idioms:

Idioms: pie chart, polar area chart
- pie chart
  - area marks with single channel
  - accuracy: angles less accurate than line length
  - arch height also less accurate than line length
- polar area chart
  - area marks with length channel
  - more direct analog to bar charts
- data
  - 1 using key attrib, 1 quant value attrib
  - task
  - part-to-whole judgements

Idioms: choropleth map
- use given spatial data
  - when central task is understanding spatial relationships
- data
  - geographic geometry
  - table with 1 quant attribute per region
  - encoding
  - use given geometry for area mark boundaries
  - sequential segmented colormap (more later)
  - (geographic heatmap)

Idioms: force-directed placement
- visual encoding
  - link connection marks, node point marks
- considerations
  - spatial position: no meaning directly encoded
  - line to line extension intepretation
  - proximity semantics?
  - sometimes meaningful
  - sometimes arbitrary artifact of layout algorithm
  - increase with length
- tasks
  - explore topology, locate paths, clusters
- scalability
  - node-edge density $< 4N$

Idioms: adjacency matrix view
- data: network
  - transform into some data/encoding to heatmap
  - derived data: from network
  - 1 quant attrib
  - weighted edge between nodes
  - 2 quant attrib: node list x 2
- visual encoding
  - cell shows presence/absence of edge
- scalability
  - IK nodes, 3M edges

Idioms: glyphmaps
- rectilinear good for linear vs nonlinear trends
- radial good for cyclic patterns

Idioms: line chart / dot plot
- one key, one value
- data
  - 2 quant attrib
  - mark points
- line connection marks between them
- channels
  - aligned lengths to express quant value
  - separated and ordered by key attrib into horizontal regions
- task
  - find trend
  - visual markers emphasize ordering of items along key axes by explicitly showing relationship between one item and the next
- scalability
  - # of key levels, # of value levels

Idioms: heatmap
- two keys, one value
- data
  - 2 quant attrib (gene, experimental condition)
  - 1 quant attrib (expression level)
- markers:
  - areas
  - separated and edge in 2D matrix
  - indexed by 2 categorical attributes
- channels
  - color by quant attrib
  - (gradient diverging colormap)
- task
  - find clusters, outliers
  - scalability
  - # of rows, # of cols of quant levels, # of quant attrib levels

Axis Orientation

Rectilinear

Parallel

Radial

Idioms: adjacency comparison
- adjacency matrix strengths
  - predictability, scalability supports summarizing
  - some topology tasks transivle
- node-link diagram strengths
  - topology understanding path tracing
  - inherent, no training needed
- empirical study
  - node-link best for small networks
  - matrix best for large networks
- fast & slow invariants: topology structure!

Idioms: network diagrams
- node-link diagrams
  - visual encoding
  - visual encoding
  - edge/arc
  - task
  - find clusters, outliers
  - scalability
  - # of key levels, # of value levels

Node-ID Links Diagrams

Adjacency Matrix

Enclosure

Inclusion
How to handle complexity: 1 previous strategy + 3 more

- derive new data to show within view
- change view over time
- facet across multiple views
- reduce items/attributes within single view