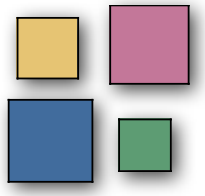


Interactive Graphics for Statistics

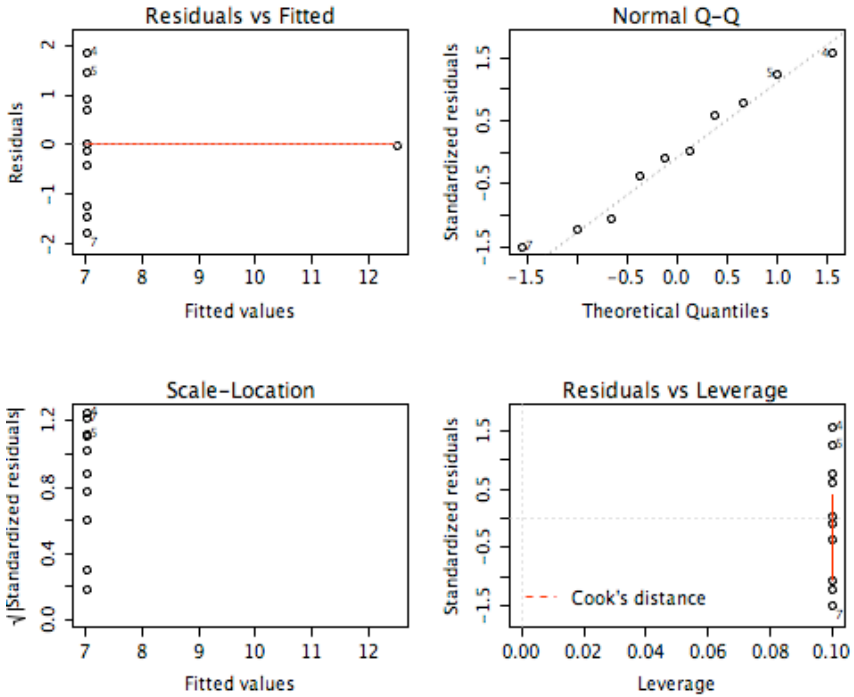
Principles & Examples

Martin Theus

martin.theus@math.uni-augsburg.de

Graphics in Statistics: Diagnostics vs. Analysis

- Continuous Data …



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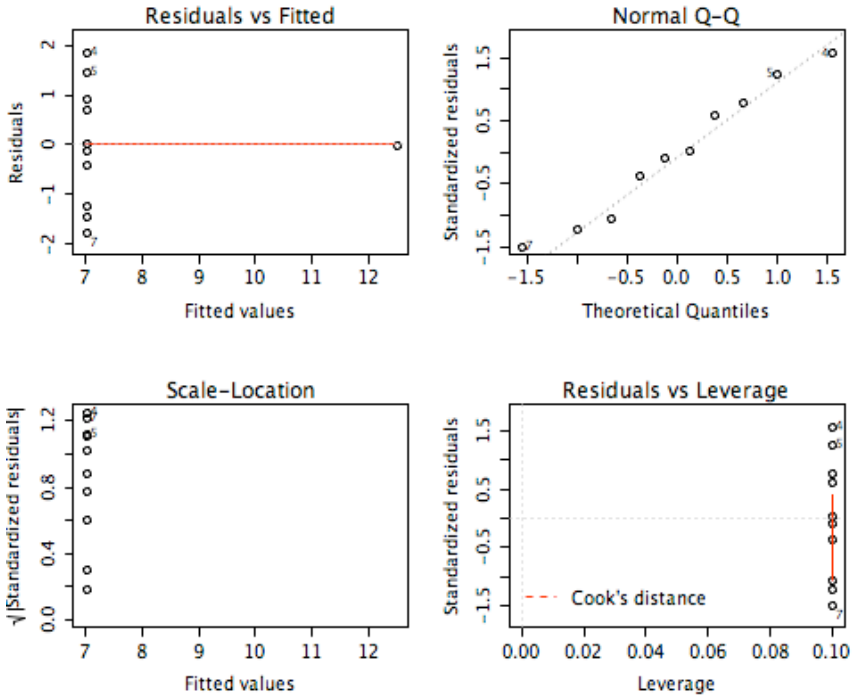
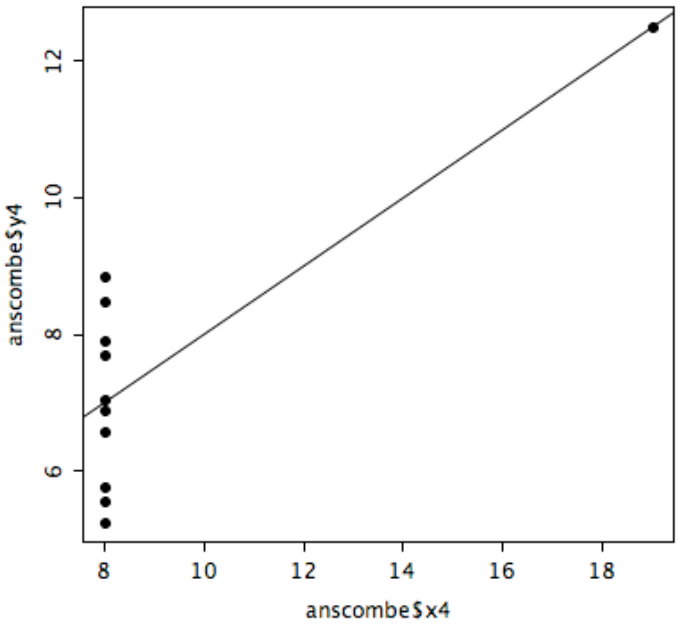
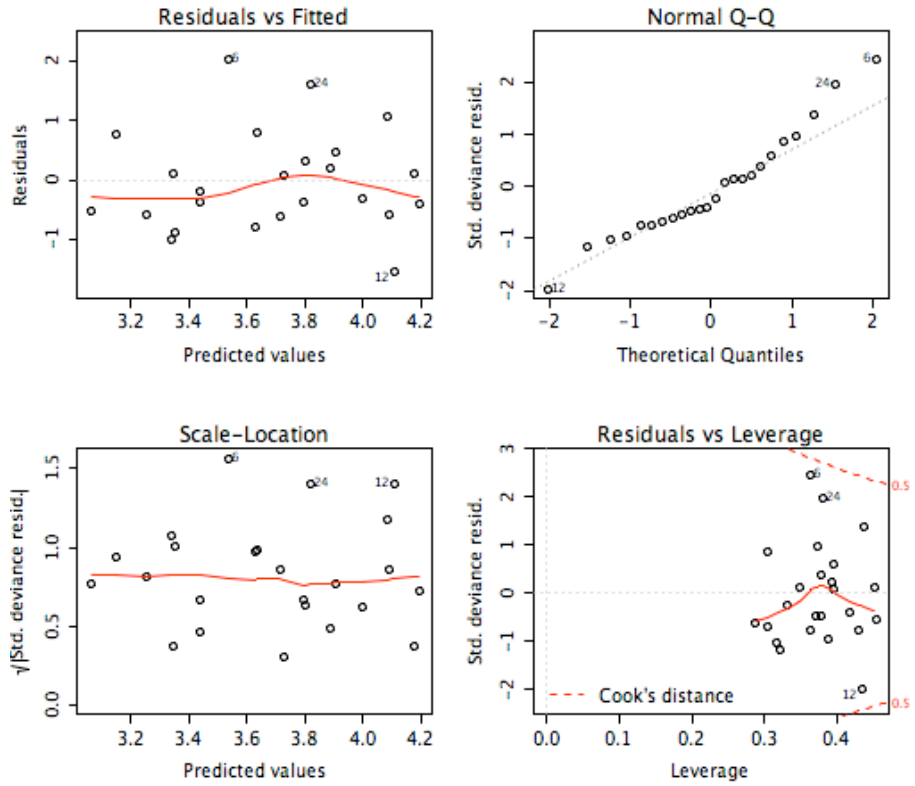




Graphics in Statistics: Diagnostics vs. Analysis

- Categorical Data …



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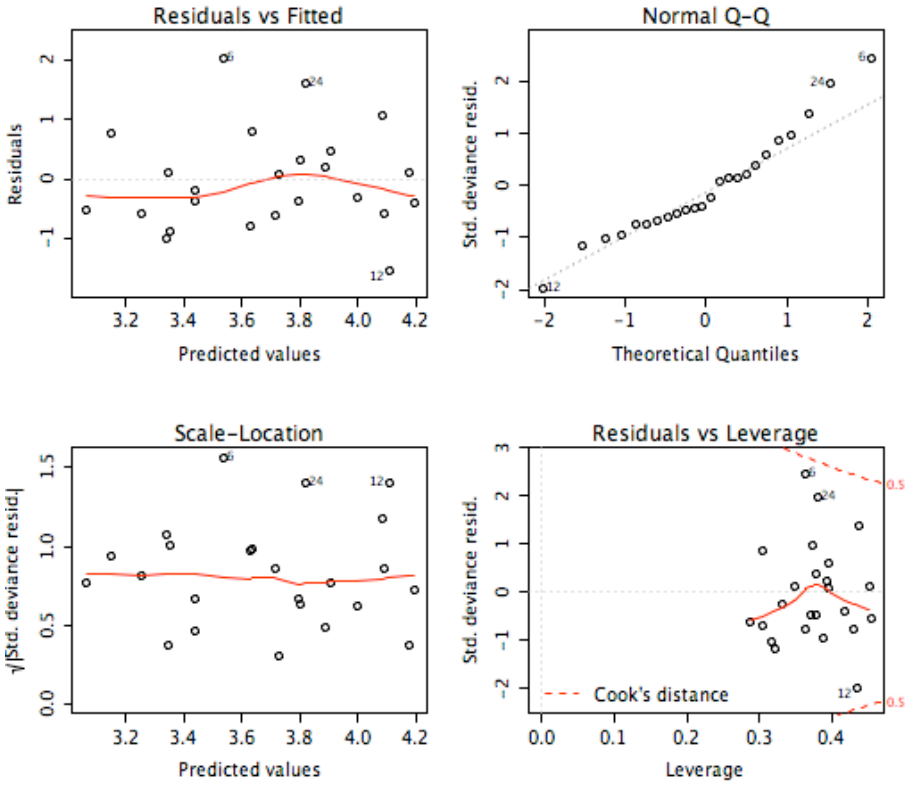

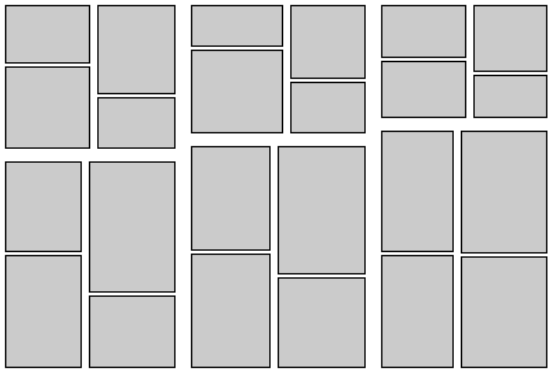

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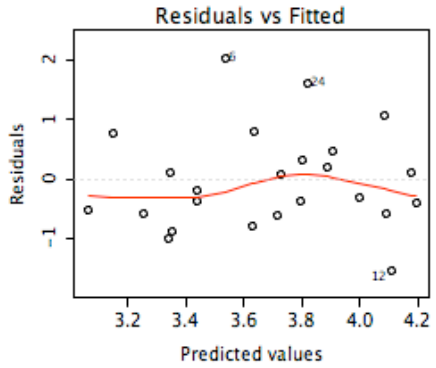
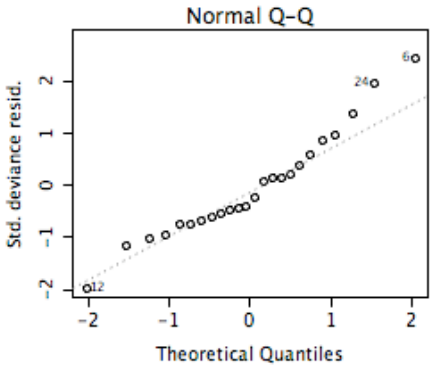
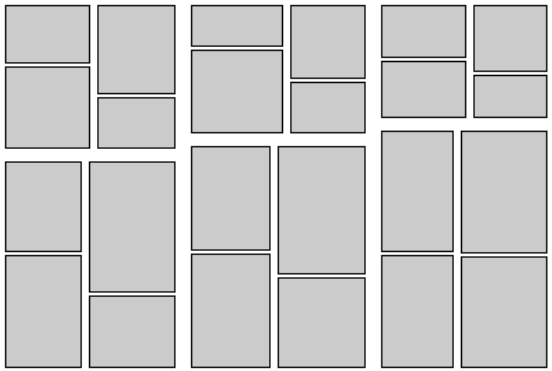
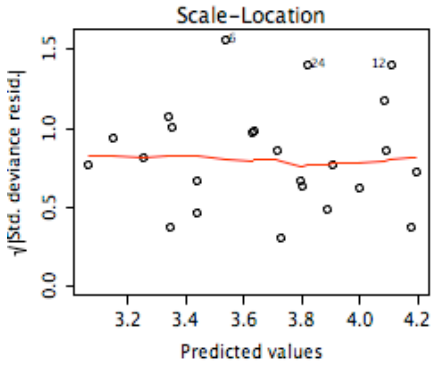
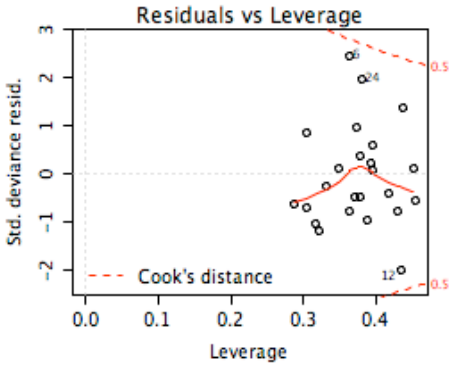
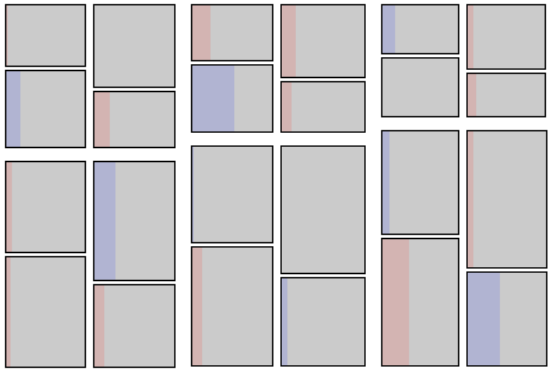


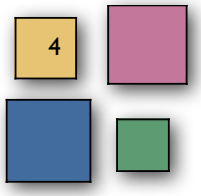












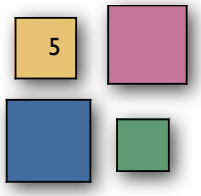
Graphics for Data Analysis ...

- is not based on formal theory
- but has proven to be very effective

- is not taught in standard curricula
- but used by most statisticians once they left college

- is supporting an interactive and iterative exploration of data
- thus needs interactive software tools

- is not well supported by most statistics software
- but there is software that helps



Interactive Graphical Tools for DA: History

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Tukey et al.

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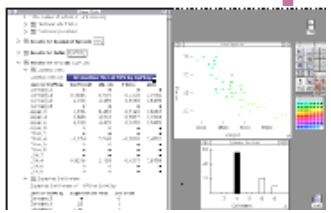

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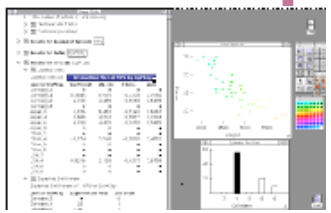

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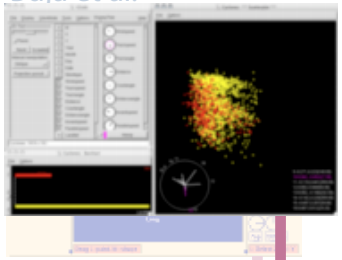

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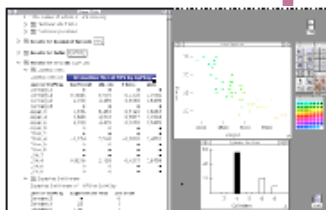

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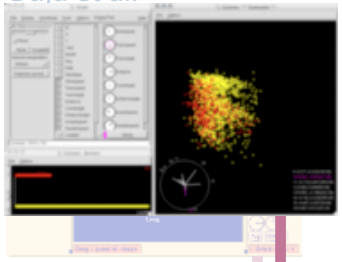

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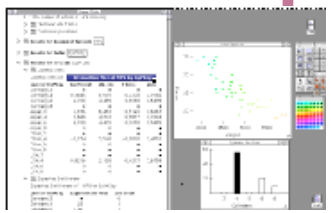

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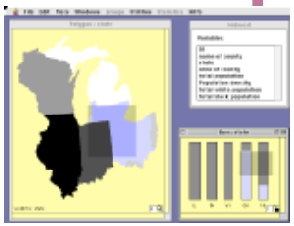

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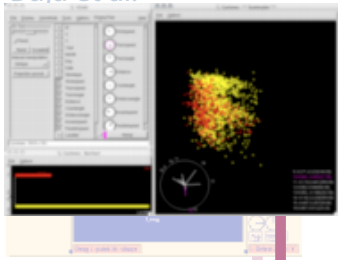

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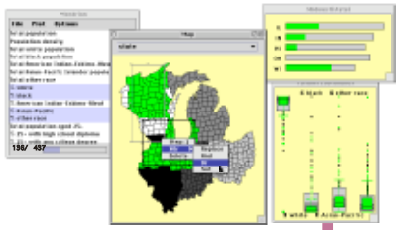

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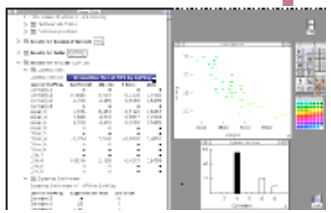

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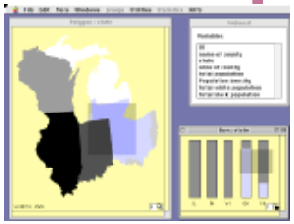

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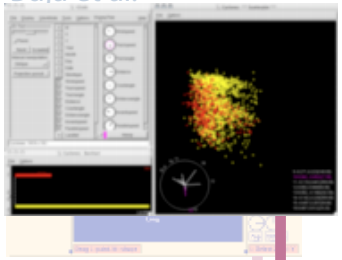

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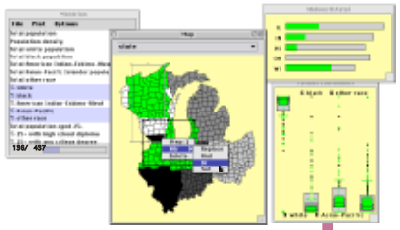

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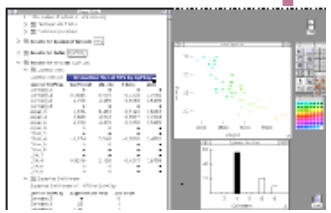

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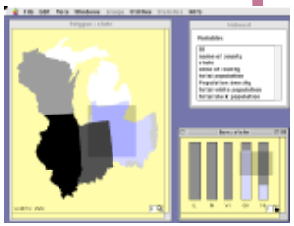

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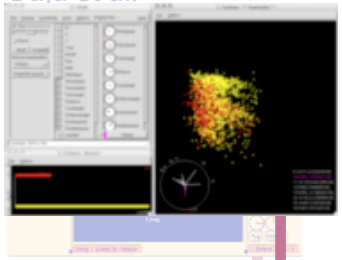

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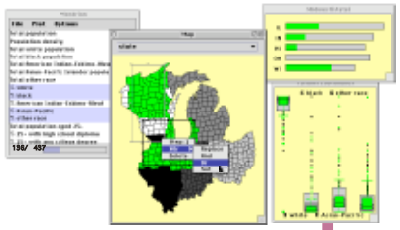

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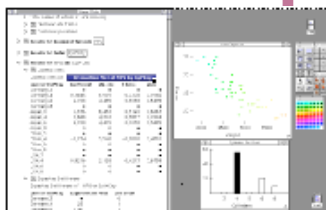

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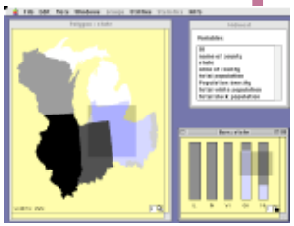

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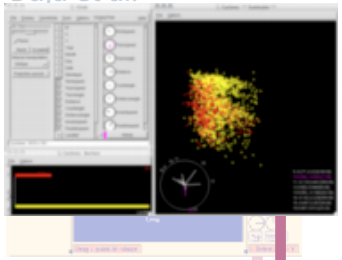

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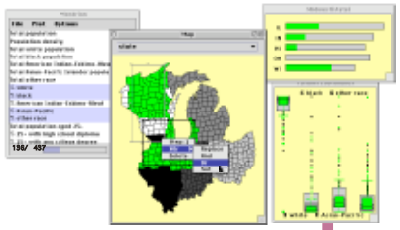

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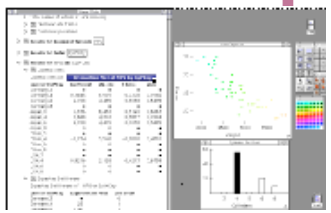

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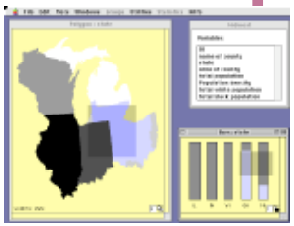

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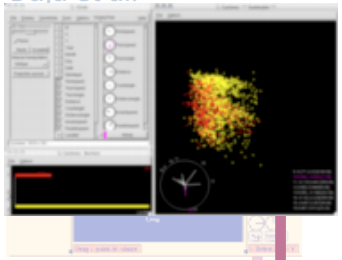

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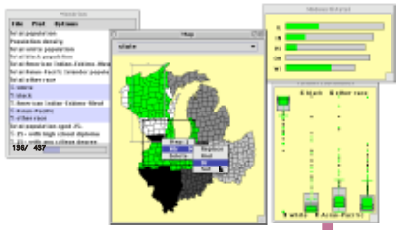

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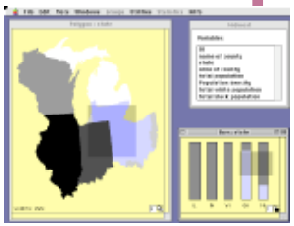

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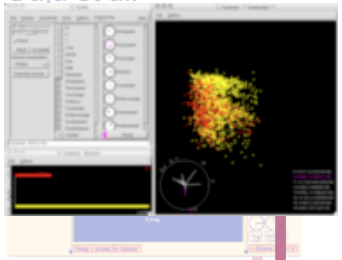

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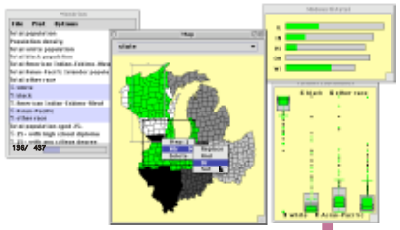

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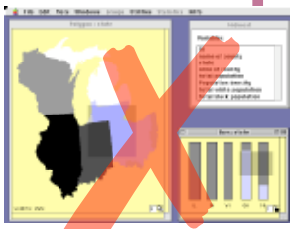

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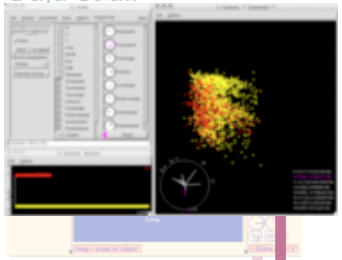

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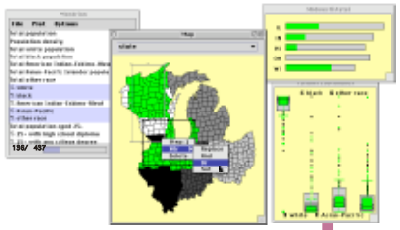

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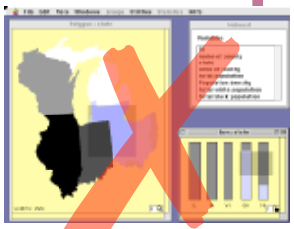

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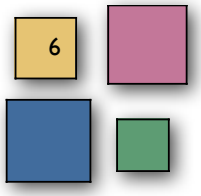
people forget far faster than they learn ⇒ give them time!



On Hammers and Nails ...

- No one single tool is universal enough to cover every problem we might want to handle in data analysis ⇒ use the best suited!?

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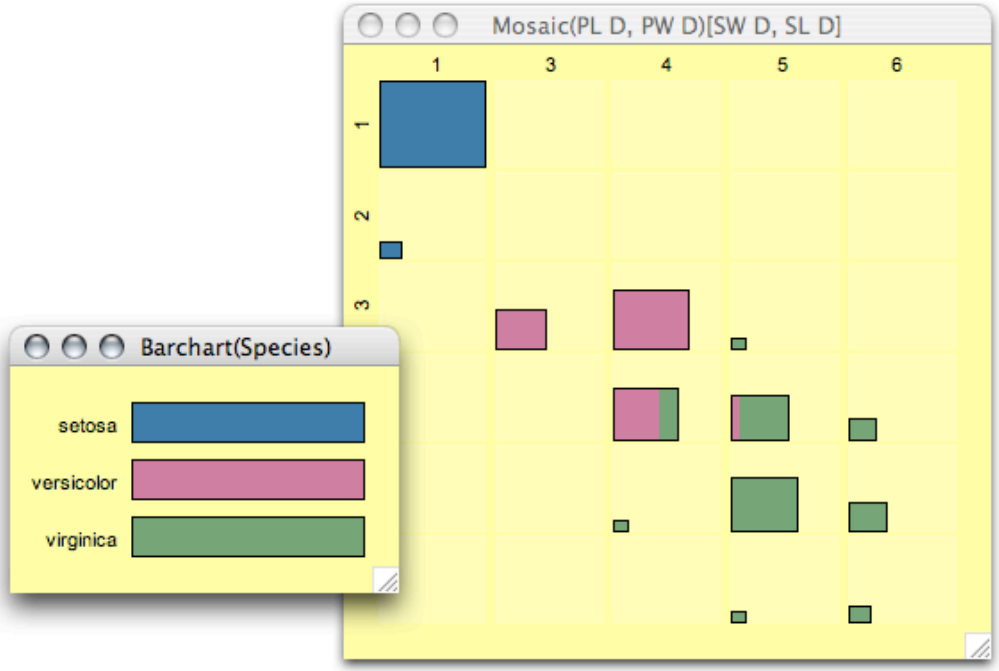

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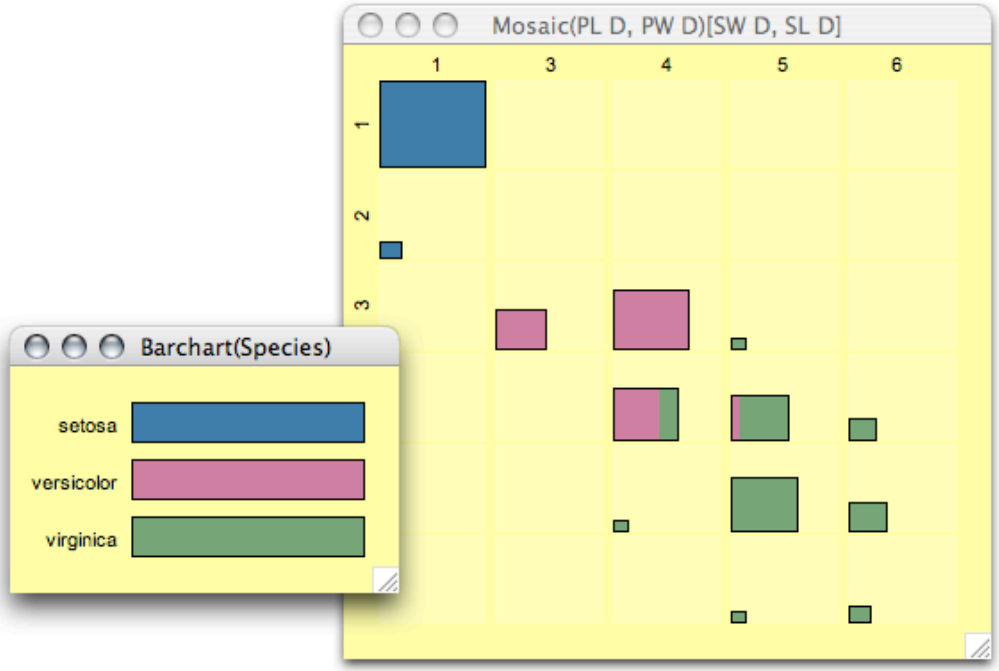
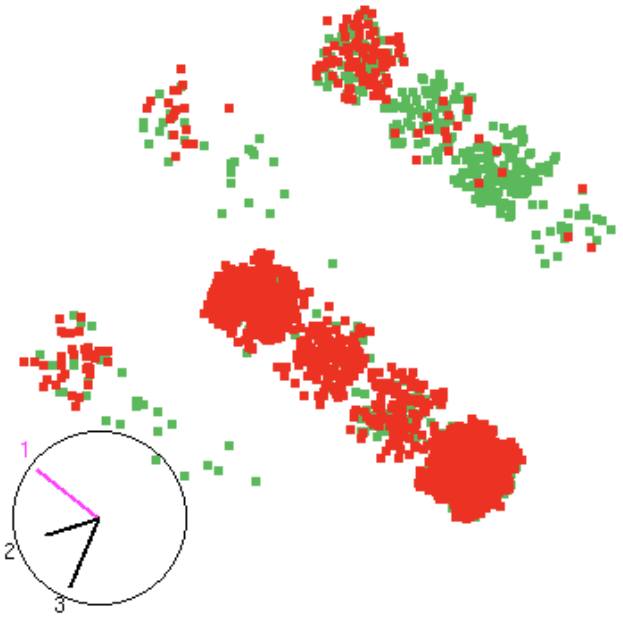
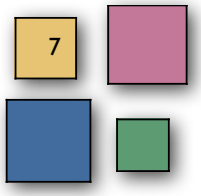
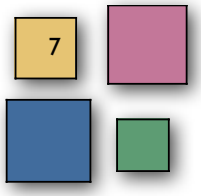


Titanic data in a scatterplot





What is Interactive Statistical Graphics about?

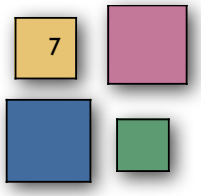


What is Interactive Statistical Graphics about?

- **Direct manipulation is at the core**

  (classical computational statistics was 90% algorithm and 10% interface – Interactive Statistical Graphics is 10% algorithm and 90% interface!)

  - Selection of subgroups, i.e., conditioning
  - Modification of plot parameters



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  - data can be **selected**
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  - support for **highlighting**
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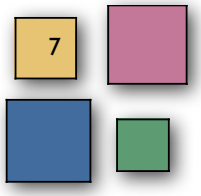

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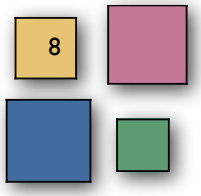
- **Interactive Graphics $\neq$ Dynamic Graphics**

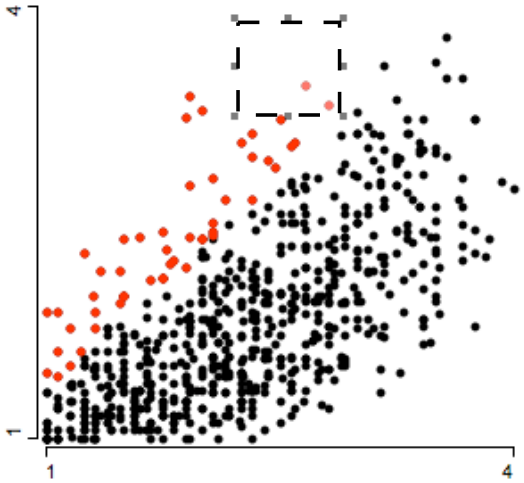
  dynamic variation of plot parameters (animation) was the first interaction to be implemented 30 years ago, but is now out-dated.



Where did Linking go?

- Linking is used to (optionally) propagate attributes of the data

Example:



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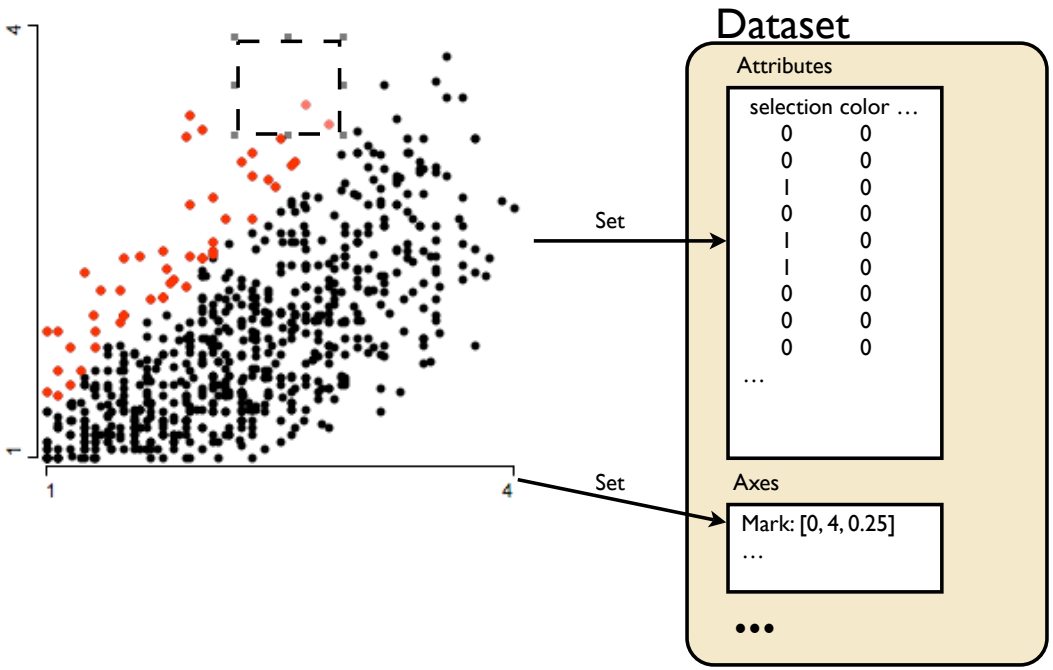

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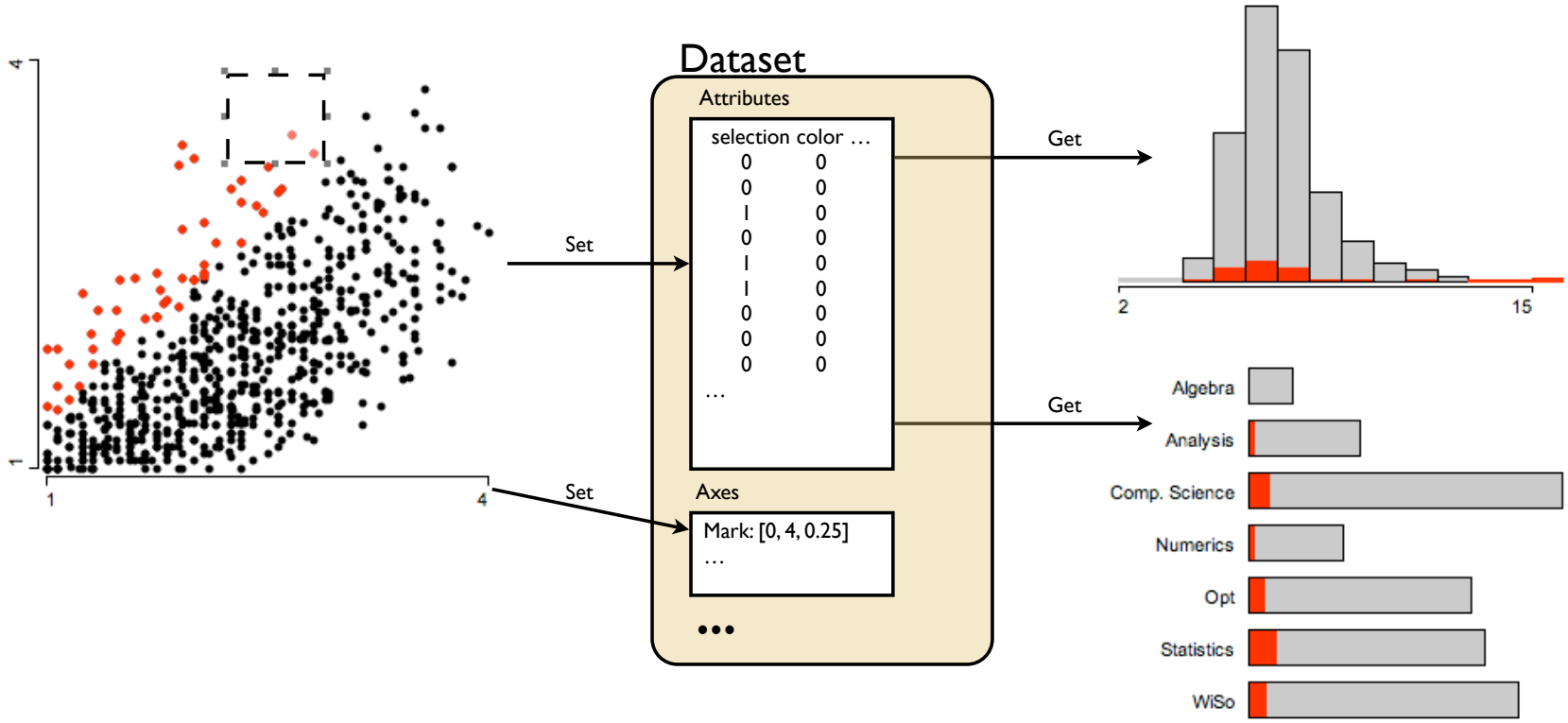

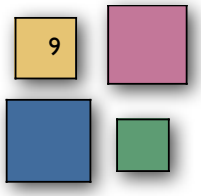

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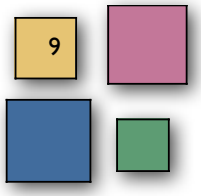

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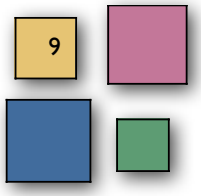

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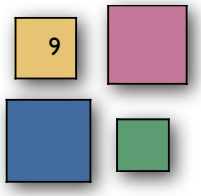
  - (transient) highlighting
  - (persistent) color brushing
  - symbols
  - visibility



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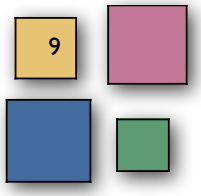

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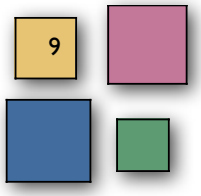

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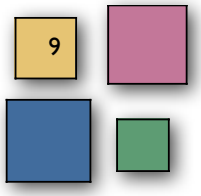

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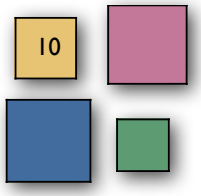
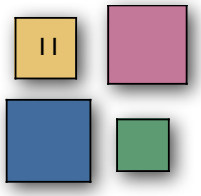
- Linking of attributes of the data (or any other “incarnation” of the data) is **optionally**.
- Setting and/or getting of attributes may have **constraints** (group selections, cross-relation selections, …)



More on Selections …

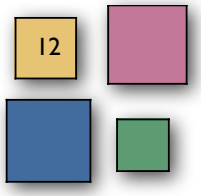
- Different tools can be used (point, rectangle, slice, lasso, brush, …) – most of them select parallel or orthogonal to variable axes.
- Successive selection steps must be combinable with boolean operators (single step selections can only select trivial sets).
- Multiple brushes can be used to define a sequence of selections.
- Painting (persistent brush selection) is actually covered by a selection sequence when all brushes are in “OR” mode.
- Prefer parametric selection over arbitrary selections.
  (How to communicate a lasso selection, or a selection in some high-dimensional rotated space?)



More on Highlighting ...

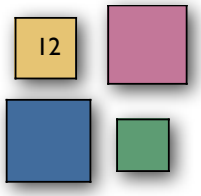
- Implementation of highlighting for glyph-based plots is trivial.
- Highlighting for rectangle based plots is still straight forward.
- The highlighting in a plot not necessarily is of the same type as the plot itself, but it must be faithful to the plots definition.
- Highlighting is a transient attribute of the data and usually compares to the complete sample,

  Color brushing defines a persistent group membership, and thus the groups should compare between each other.
- Not all plots can be used to implement (sensible) highlighting …



More on Queries ...

- Graphics are good at communicating qualitative information but fail to give exact quantities ⇒ need queries to get exact values.
- Interactive graphics often display very little scale information (cf. Tufte's "data-ink-ratio").
- The level of detail of a query should have optional granularities, e.g. scatterplot:



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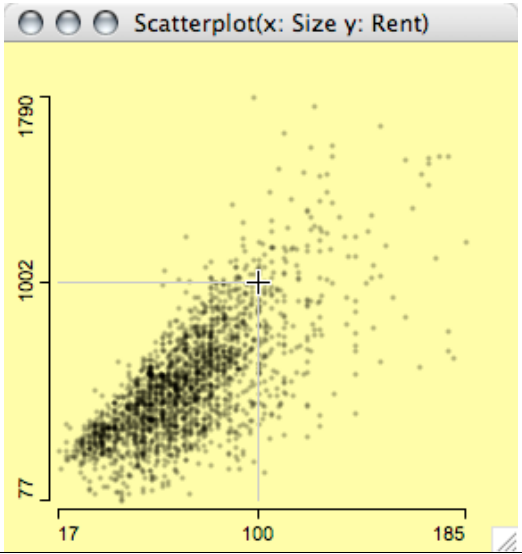

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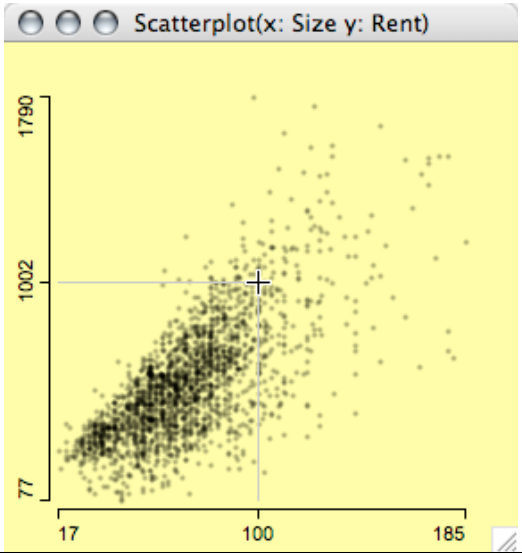
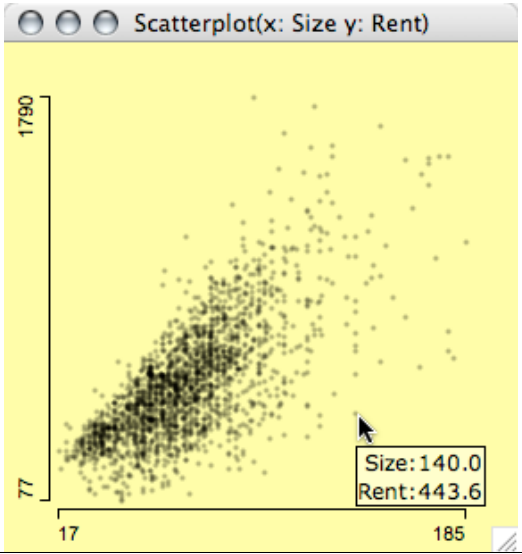


standard



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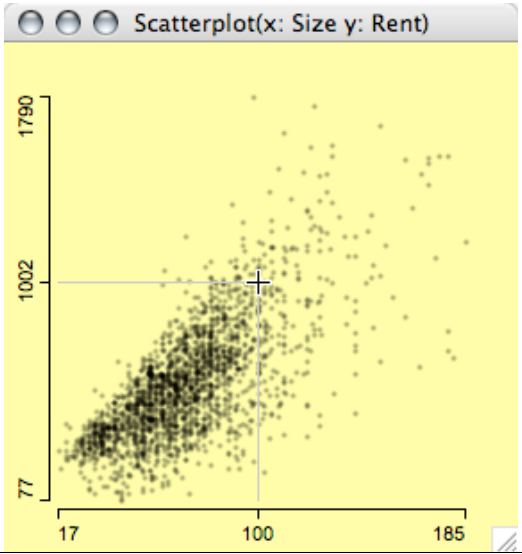

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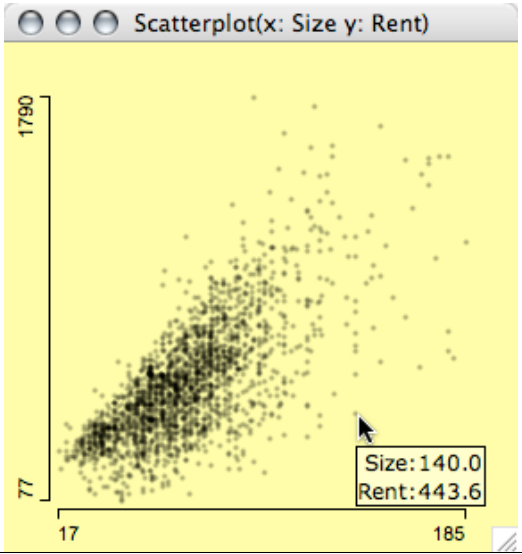
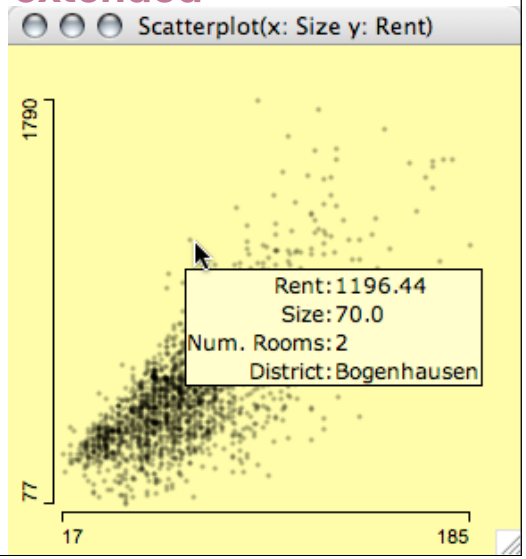
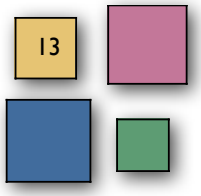


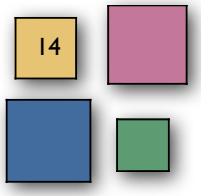
extended





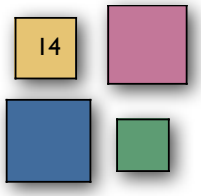
Interacting with Plots

- Typical manipulations comprise of:
  - Selections ✔
  - Change of scale
    - axes
    - zoom (includes logical zooming)
    - (order)
  - Change of order (both manually and automatically)
    - categories in a barchart
    - variables in parallel coordinates
    - variables in a mosaic plot
  - Change of plot parameters, e.g.
    - anchor point, bin width in histogram
    - point size in scatterplots
    - …
- Important: Identify general concepts!



On the Interface

- The usability of an interactive, computer based system can be strongly improved by strict conventions.
- All interactions (selection, queries, ordering, zoom, …) **MUST** be implemented consistently across all plots and summaries.



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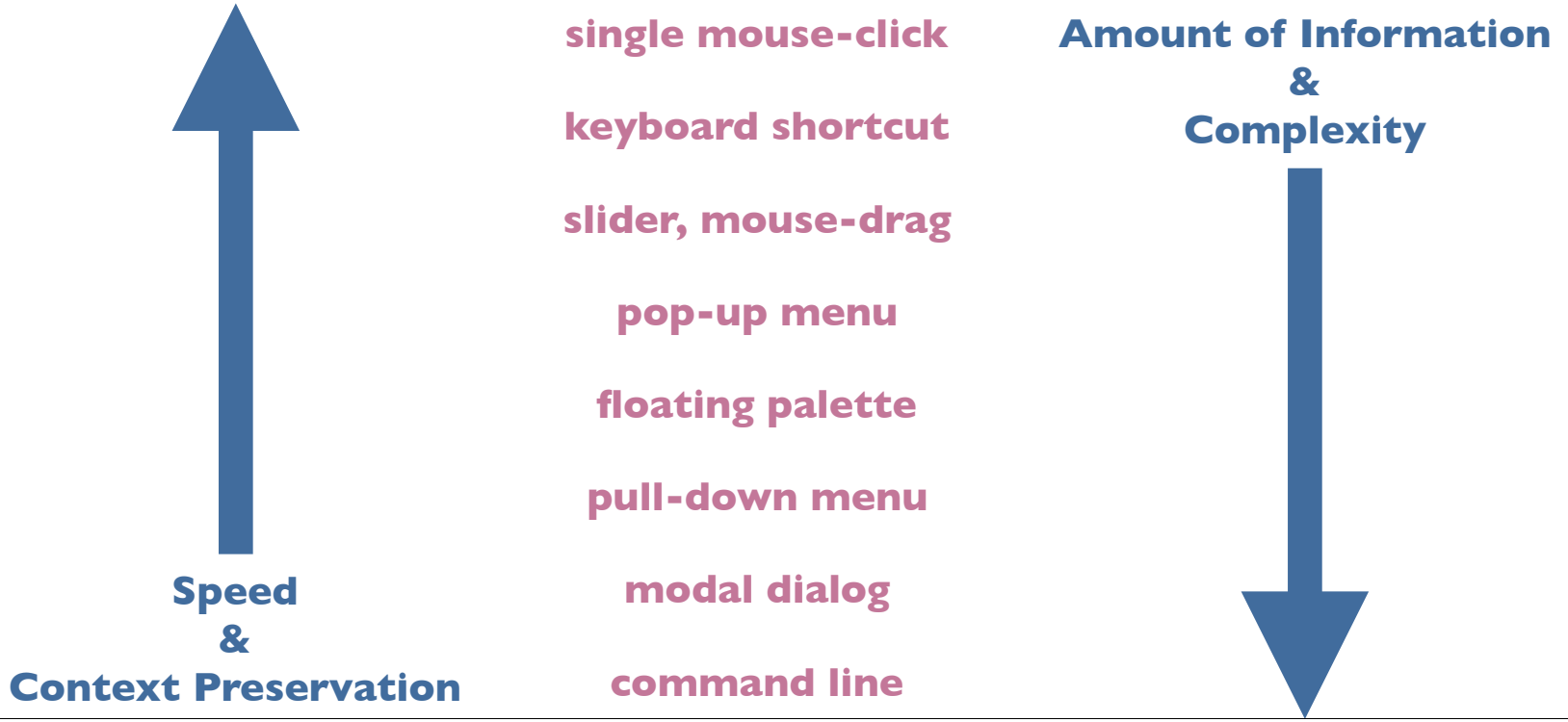
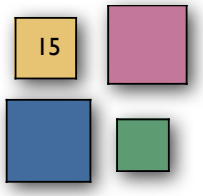
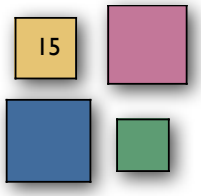




Less can be more ...

- Software should offer a clearly defined (orthogonal) set of functions, which can be combined to get a wider range of functionality.

- Examples:
  - Painting Mode is a brush in OR mode and covered by selection sequences ✓
  - Categorizing a continuous variable via a histogram



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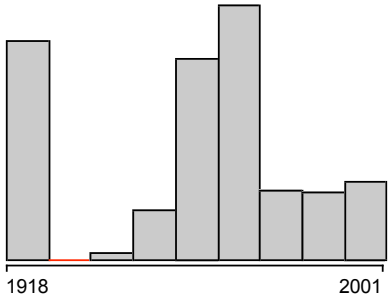

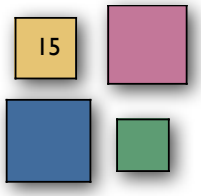

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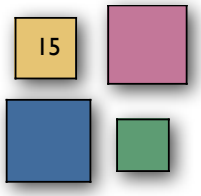

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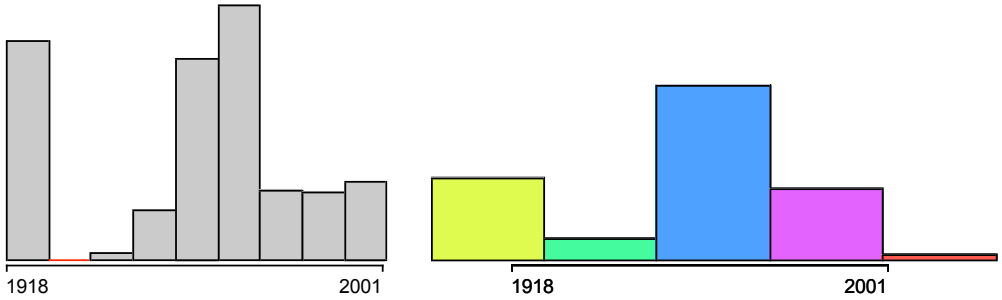

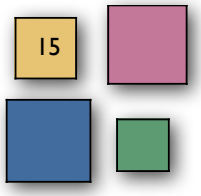

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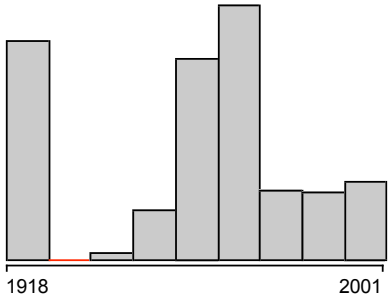

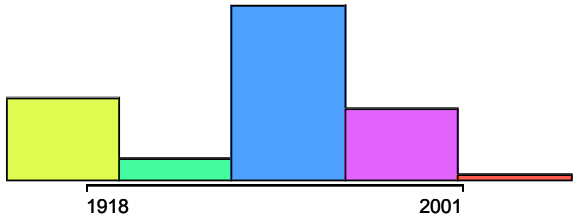

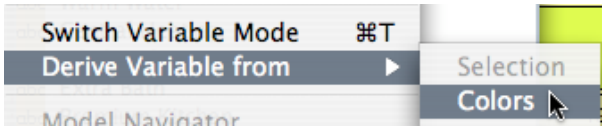

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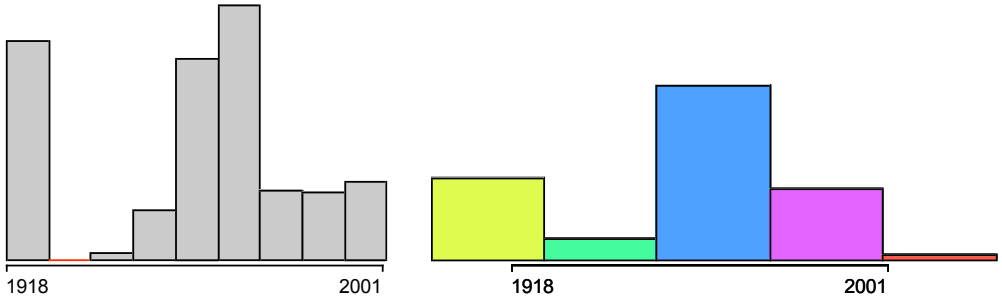

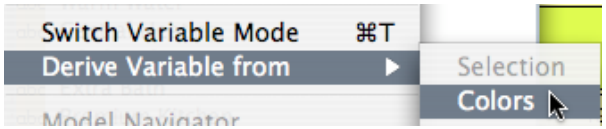

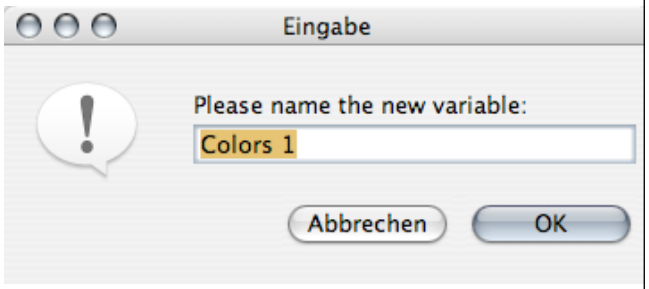

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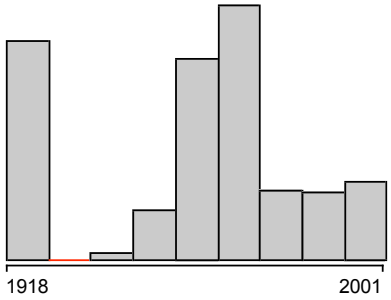
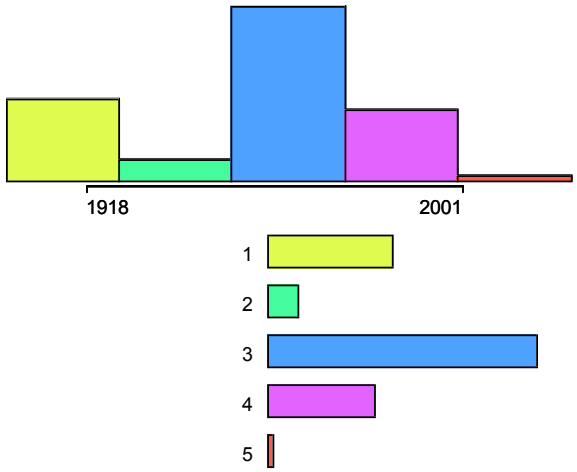
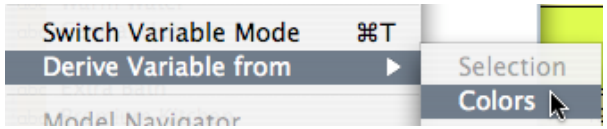
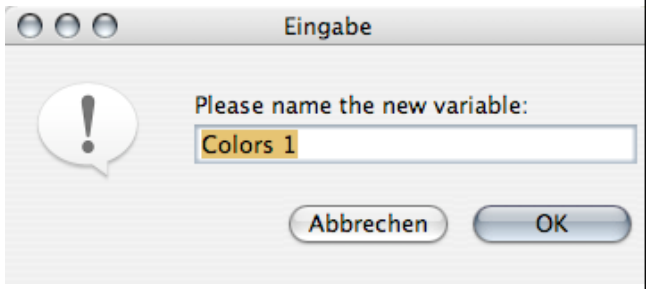


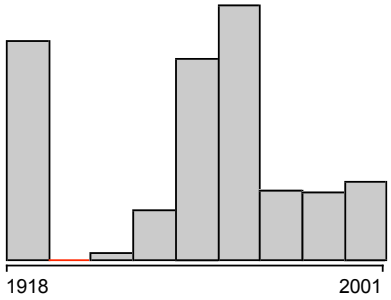


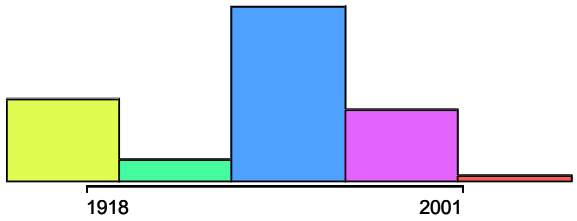


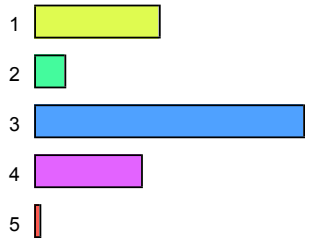


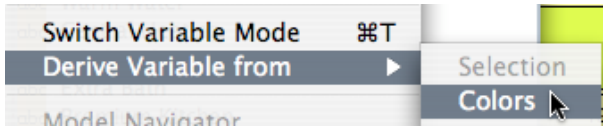
Less can be more ...

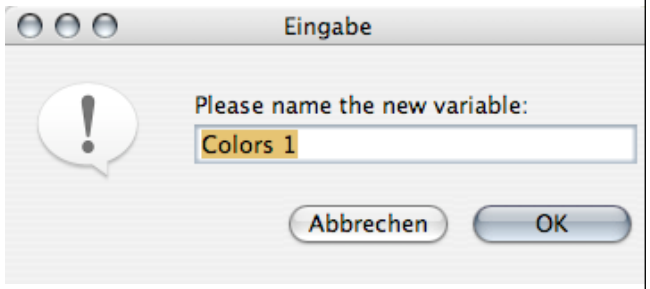
- Software should offer a clearly defined (orthogonal) set of functions, which can be combined to get a wider range of functionality.
- Examples:
  - Painting Mode is a brush in OR mode and covered by selection sequences ✓
  - Categorizing a continuous variable via a histogram



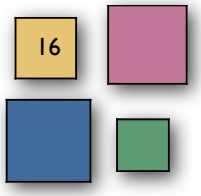








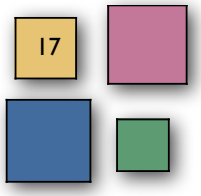
- Functions are less obvious for a novice user!



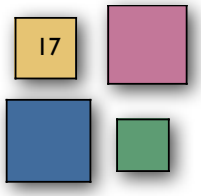
Rendering Quality is an Issue!

- Most graphics systems (S, R, SAS, …) were designed at times where “pen on paper” was the rendering model.
- Drawing on a computer screen will introduce rounding problem; the size of small objects is usually far off from what it should be.
- Anti-aliased graphics and sub-pixel rendering are not only a “matter of taste”.
- Overplotting is not an inherent problem of computer graphics, but if software does not handle it decently, the interpretation of (glyph based) graphics can lead to wrong conclusions.

  (extremely misleading with color brushing!)

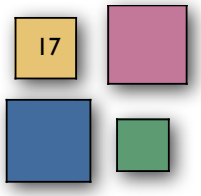


Conclusion



Conclusion

- Graphics for data analysis is still rare, as
  - the focus of statistical education is often not on data analysis.
  - it is not taught at universities (except for some misfits).
  - there is not much continuity in tools yet.
  - it still lacks possible formalization.



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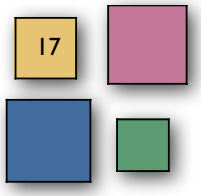

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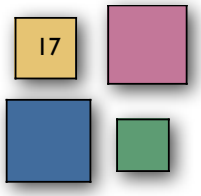

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- Unfortunately statistical computing degraded to implementing yet another package for R ⇒ not much hope for new software.
- Apart from a formal description in a mathematical sense, the way of teaching concepts and tools via case studies seems to be quite promising …

"Commercial Break"