Implementation of Interactive Statistical Graphics Software

Platform Independence

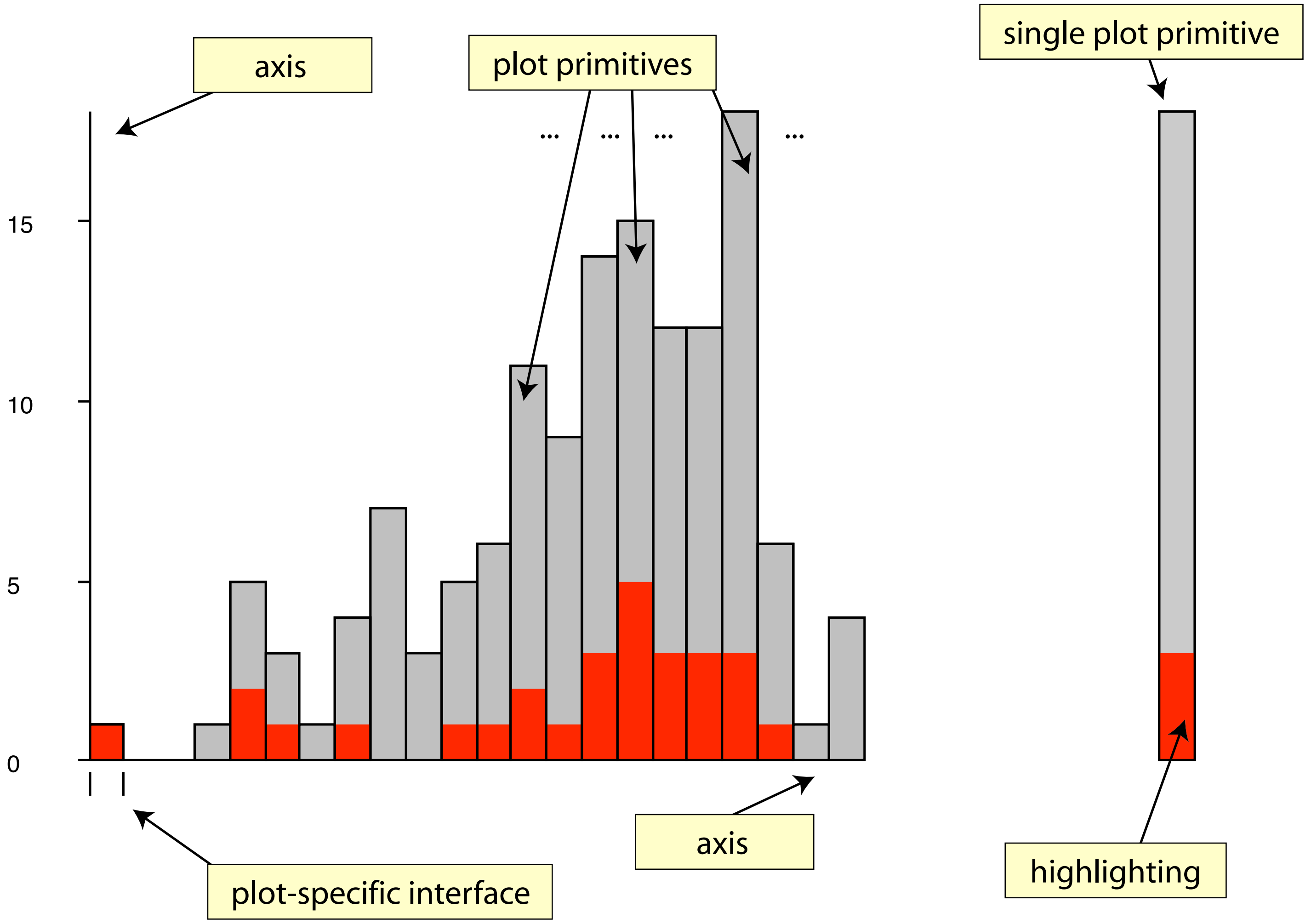
- We got tired of “Your software is great, but we don’t use Macs!”
- Academic software environments are heterogeneous
  ⇒ so are the software projects.
- Potential users of academic software are 95% Windows
  ⇒ can not be ignored!
- Cross platform development (i.e. maintaining multiple code bases at least in parts) is far too expensive!
- R put up a standard in being available for “any” platform
  ⇒ that’s what people more and more expect
- Still only one choice ⇒ JAVA

JAVA

- Really available on almost all platforms
  (Even Sun-independent implementations on LINUX)
- “write once – run everywhere” still dominates “write once – debug everywhere”
- Knows how to deal with graphics
  - AWT
  - JFC
  - 2D
  - PS printing
- Package/Library system
- Developing (e.g. 1.5 implements native hardware acceleration)

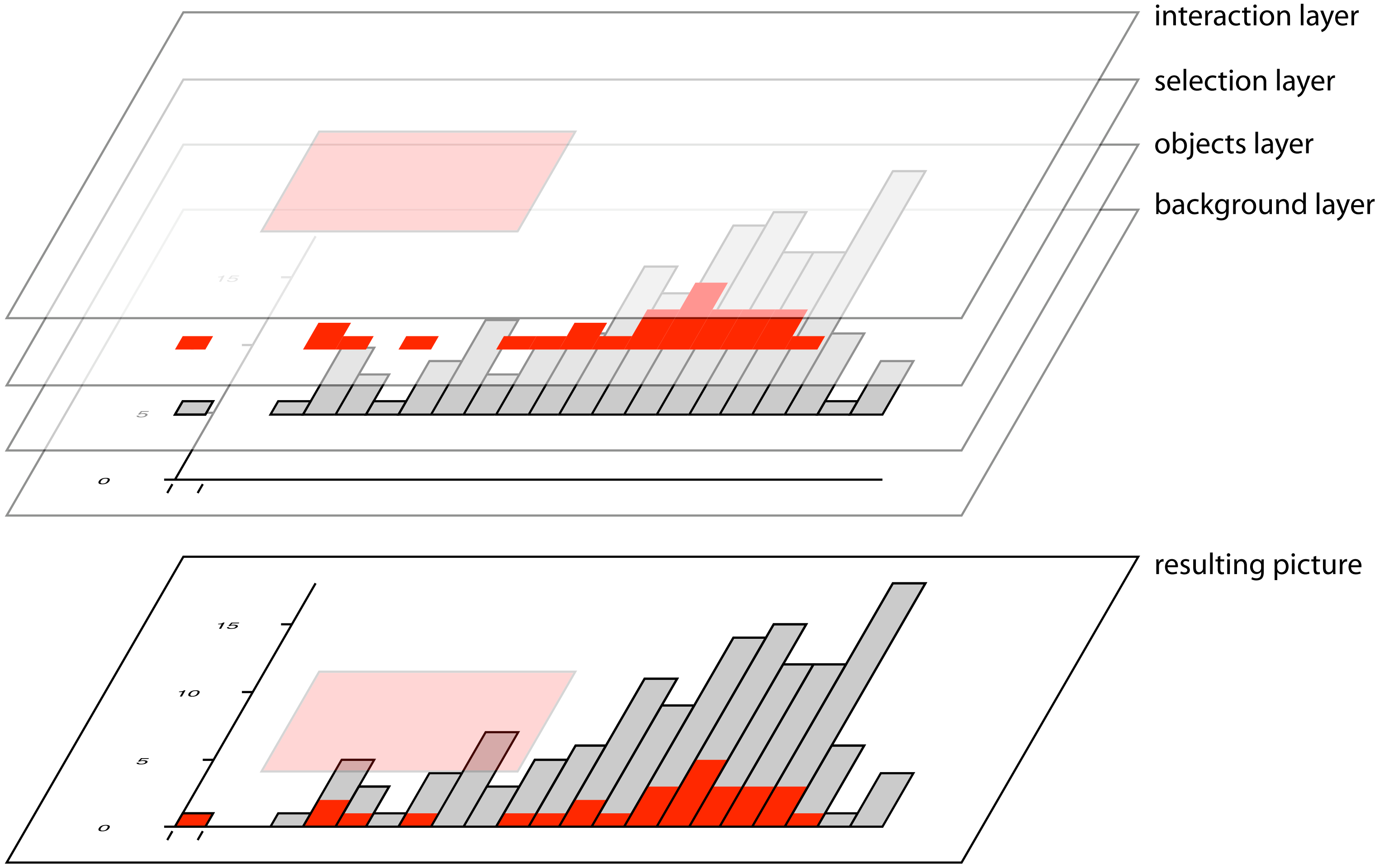
Decomposition of Graphs

- In an object-oriented programming environment/language, an effective definition of the graphical objects is key.
- Typical Objects
  - plot primitives
    - points
    - lines
    - boxes
  - axes
  - plot specifics
- Example: Histogram
  - primitives: boxes
  - axes
    - x: range
    - y: count or probability
  - plot specifics
    - origin and width control



Layers

- 4 layers can be defined to group the different plot components
  - Interaction layer
  - Selection layer
  - Object layer
  - Background layer



- The layers are defined according to their update frequencies from least frequent update to most frequent update, i.e.

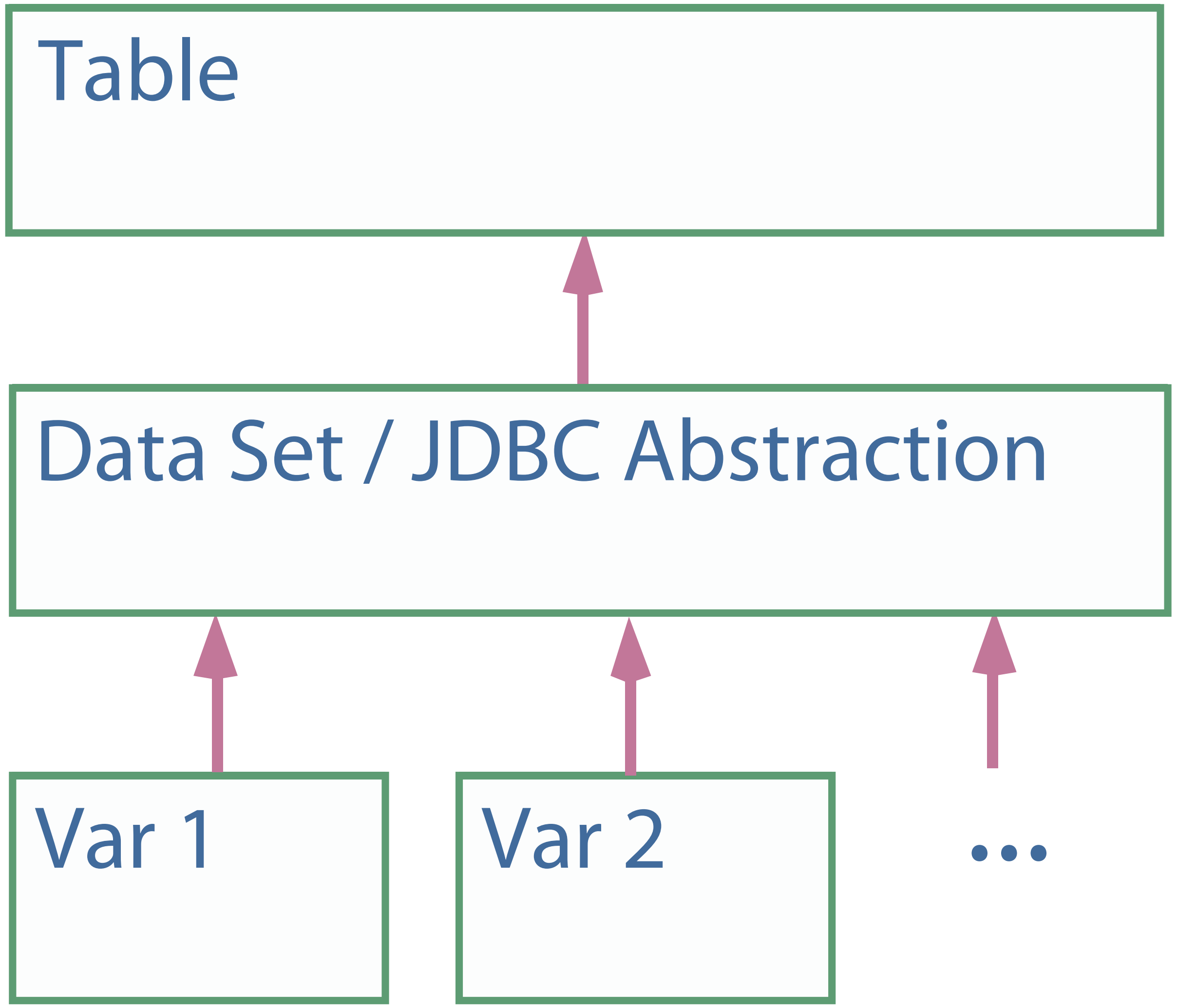
  interaction ➢ selection/highlighting ➢ objects ➢ axes (background)

- Very important to speed up drawing times!

Object Hierarchy: Data

- Data are abstracted in data set objects.
- If the data source is a flat file, the actual data resides in double arrays (one per variable)
- For data in databases, only the connection information is stored
- For convenience a Table object exists ‘above’ the data set class

All plot for categorical data access the data only through the Table class!



ASCII Files

- (At least for statisticians) most data sits in flat files

- Mondrian accepts tab separated ASCII files with headers
  - Export as ‘.tsv’ in Excel
  - in R use: write.table(mydata, "myfile", quote = F, sep = "\t ", row.names = F)

- ASCII files can include an optional set of polygons for map plotting

  For each area, there must be a description via a closed polygon of x- and y-coordinates, and a matching link in the data matrix.

  (A “standard” for map files would be nice …)

- Missing values are **not** supported.

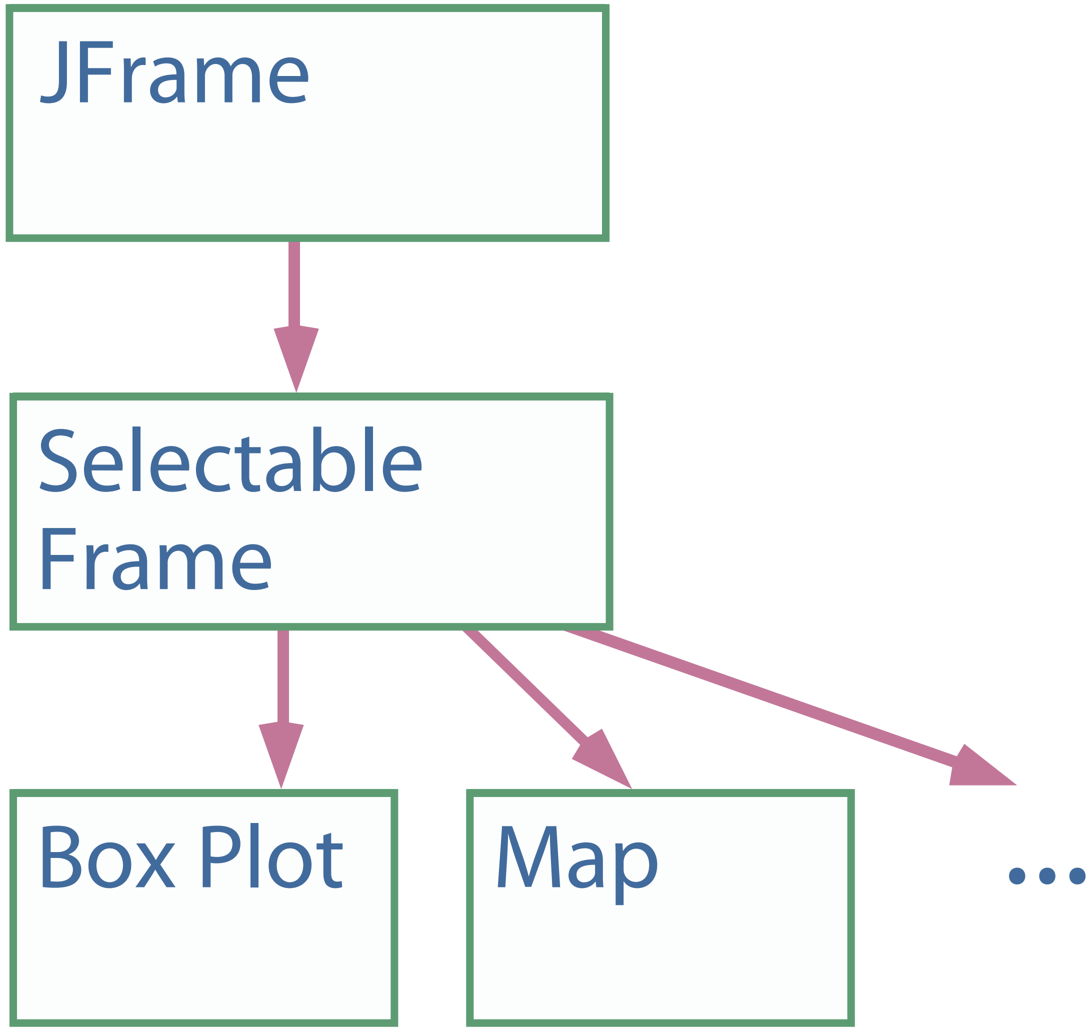
Database Connections

- Connecting directly to databases has many advantages
  - + no data handling within Mondrian
  - + works **very** efficient on categorical and summarized data
  - + scales up to “any” size of data set
  - + natural management of missing values (NULLs)
  - + selection and linking translates directly in SQL clauses
  - + data is always up-to-date
  - + far wider range of data problems
- Disadvantages are
  - – access of single records can be comparatively expensive
  - – update strategies for DB changes must be included
- Mondrian uses elementary JDBC functionality

… still at an experimental stage – proof of concept

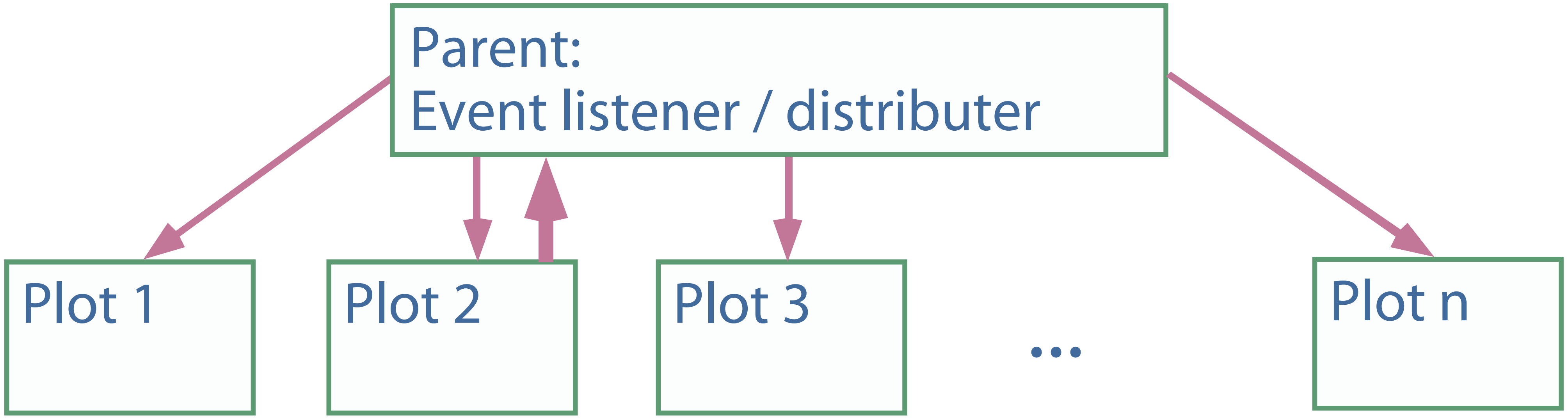
Object Hierarchy: Graphs

- Mondrian graphs use JFC and Java2D
- Base class is the SelectableFrame which handles all
  - selections
  - zooming
  - event handling
- All plots are derived from the SelectableFrame
- Object hierarchy was deliberately choose to be very flat, to speed up computation



Event Handling

- Mondrian implements two custom events
  - dataChanged
  - selectionChanged
- **dataChanged** is fired, whenever a plot changed data, e.g. reorder of categories or transformations
- **selectionChanged** is fired whenever the selection changed
- Both event types are distributed by a parent event listener!



Interface Conventions

- There is a tight and consistent mapping of interactions
  - **Selections**
    click and drag ➢ create a selection rectangle / brush
    click on selection rectangle handle ➢ resize this selection
    popup-trigger on selection rectangles ➢ alter this selection
  - **Interrogation**
    popup-trigger on objects ➢ interrogation
    shift click in selection rectangle ➢ interrogation
  - **Alterations**
    meta-click and drag ➢ zoom in/out
    (middle click on Windows)
    popup-trigger on background ➢ get plot options

    alt-click and drag ➢ reorder objects
    page-up /-down ➢ cycle through views
    arrows up/down and left/right ➢ increase/decrease plot parameters

Communication with R

- Big problem in statistical software development:

  Methods are re-implemented over and over again whenever systems, packages and/or programing languages change

- Examples of custom development
  - Adding a linear regression to a scatterplot ✔
  - Adding a lowess smoother to a scatterplot ✘

- Better solution: Re-use of existing and tested components

- Right now R is the cheapest and best available source of statistical routines, written in R-code, C and Fortran

- Problem: R has **no** decent interface other than the REPL-loop

Talking to R via Rserve

- Rserve (developed by Simon Urbanek) runs R as a background process and communicates via socket connections with R
- Many potential clients can talk to Rserve – for Mondrian we need the JAVA-client.
- Example: Adding a density function to a histogram

```
try {
  Rconnection c = new Rconnection();
  double[] xVal = data.getRawNumbers(tablep.initialVars[0]);
  c.assign("x", xVal);

  RList l = c.eval("density(x, bw="+bWidth+", from="+xMin+", to="+xMax+")").asList();
  double[] dx = (double[]) l.at("x").getContent();
  double[] dy = (double[]) l.at("y").getContent();

  if( displayMode.equals("Histogram") && !CDPlot )
    for( int f=0; f<dx.length-1; f++ ) {
      bg.drawLine( (int)userToWorldX( dx[f] ),   (int)userToWorldY( dy[f] ),
                   (int)userToWorldX( dx[f+1] ), (int)userToWorldY( dy[f+1] ));
    }
    …
  c.close();
} catch(RSrvException rse) {System.out.println("Rserve exception: "+rse.getMessage())
```

How to use Mondrian “from Outside”

- Mondrian was never designed to offer single classes to other applications
(almost all classes would need to be “exported” in order to use a single plot)
- Nonetheless, Mondrian can be invoked from other applications
- If Mondrian runs within the same VM as the caller application, functions like
  - Get selected points
  - Set selection
  - Data changed

can be used.

What is still missing?

- Clean up, clean up, clean up, clean up, clean up, …
- Better data reader, especially for handling NAs
- Completion of the DB interface for all data access functions
- Saving of preferences
- Methods to communicate with other JAVA apps
- More enhanced graphics …
- …

The "Skeletons in the Closet"

- Mouse-Event and Mouse-Modifier model is clumsy …
  (… and sometimes source of errors)
- General event model is based on JAVA 1.1, should be updated
- Should make use of **Java2D** throughout the application
- General hot selection concept does not really fit into Mondrian
- Handling of missing values would be a pain
- …

Wrap Up & Outlook

- Implementation of interactive software is relatively expensive …
- … but, once you know how to do it right, it is far from being rocket science.
- **Important**
  “Don’t think of implementing a tool, but of implementing properties and strategies!”
  (Comp. scientists often think in terms of a tool not of the problem)
- After ~5 years of development of Mondrian, many concepts could be clarified – finding the “right” interface is always a challenge
- iPlots for R will bring ISG to the “masses”, once it is completed.