Introduction to Data Science: Interactive Visualization

Héctor Corrada Bravo

University of Maryland, College Park, USA

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Why Interactivity?

Reduce data dimension: allow user to explore large datasets by quickly switching between dimensions

Overview first, zoom and filter, details on demand: Provide big picture, let the user explore details as they desire

Linked views for high dimensions: There is a limit to the number of aesthetic mappings in a single graphic, make multiple graphics but link data objects between them

Examples

Politics: http://www.nytimes.com/interactive/2012/11/02/us/politics/paths-to-the-white-house.html?_r=0

Movies: http://www.nytimes.com/interactive/2013/02/20/movies/among-the-oscar-contenders-a-host-of-connections.html

Sports: https://projects.fivethirtyeight.com/2018-march-madness-predictions/

Web-based interactive visualization

Take advantage of HTML document description and the Document Object Model interface to *bind* data to page elements.

- Shiny: bind data to controls
- Data-driven Documents (d3.js): bind data to svg elements directly

HTML and DOM

Web pages are structured using Hypertext Markup Language

Basic idea is to only specify *content* and *structure* but not specify directly *how* to render pages.

```
<!DOCTYPE html>
<html>
  <head>
    <title>Page Title</title>
  </head>
  <body>
    <h1>Page Title</h1>
    <p>This is a really interesting paragrap
  </body>
</html>
```

HTML and DOM

Web pages are structured using Hypertext Markup Language

Structure is provided by page *elements.* An important element we'll see later is the arbitrary grouping/containment element `div`.

```
<!DOCTYPE html>

<html>

  <head>

    <title>Page Title</title>

  </head>

  <body>

    <h1>Page Title</h1>

    <p>This is a really interesting paragrap

  </body>

</html>
```

HTML and DOM

Web pages are structured using Hypertext Markup Language

The hierarchical structure of elements in a document are defined by the *Document Object Model* (DOM).

```
<!DOCTYPE html>

<html>

  <head>

    <title>Page Title</title>

  </head>

  <body>

    <h1>Page Title</h1>

    <p>This is a really interesting paragrap

  </body>

</html>
```

CSS

Cascading Style Sheets are used to style elements in the DOM.

```
body {
  background-color: white;
  color: black;
}
```

CSS

In general:

```
selectorA,

selectorB,

selectorC {

  property1: value;

  property2: value;

  property3: value;

}
```

SVG

Scalable Vector Graphics (SVG) is special element used to create graphics with text.

```
<svg width="50" height="50">
  <circle cx="25" cy="25" r="22" fill="blue" stroke="gray" stroke-width="2"/>
</svg>
```

SVG

Elements have *geometric* attributes and *style* attributes.

```
<circle cx="250" cy="25" r="25"/>
```

`cx`: x-coordinate of circle center

`cy`: y-coordinate of circle center

`r`: radius of circle

SVG

Elements have *geometric* attributes and *style* attributes.

```
<rect x="0" y="0" width="500" height="50"/>
```

`x`: x-coordinate of left-top corner

`y`: y-coordinate of left-top corner

`width`, `height`: width and height of rectangle

SVG

style attributes

```
<circle cx="25" cy="25" r="22" fill="yellow" stroke="orange" stroke-width="5"/>
```

can be styled by class as well

```
svg .pumpkin {
  fill: yellow;
  stroke: orange;
  stroke-width: 5;
}
```

```
<circle cx="25" cy="25" r="22" class="pumpkin">
```

Shiny and D3

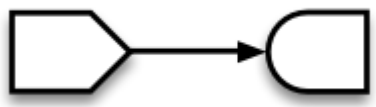
Shiny: construct DOM and bind data (variables for example) to elements (a slide control for example) http://shiny.rstudio.com

D3: bind data to SVG element attributes (position, size, color, transparency, etc.) http://d3js.org

Reactivity

Interactivity and binding in Shiny achieved using *reactive programming*.

Where objects *react* to changes in other objects.

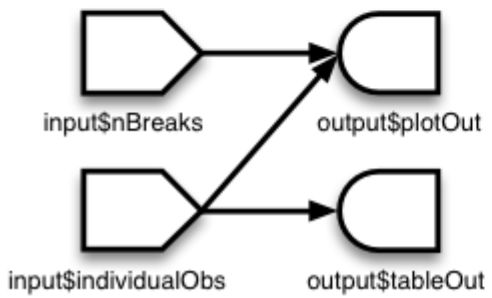


Reactivity

Example:

```
shinyServer(function(input, output) {
  output$plotOut <- renderPlot({
    hist(faithful$eruptions, breaks = as.numeric(input$nBreaks))
    if (input$individualObs)
      rug(faithful$eruptions)
  })

  output$tableOut <- renderTable({
    if (input$individualObs)
      faithful
    else
      NULL
  })
})
```



Reactivity

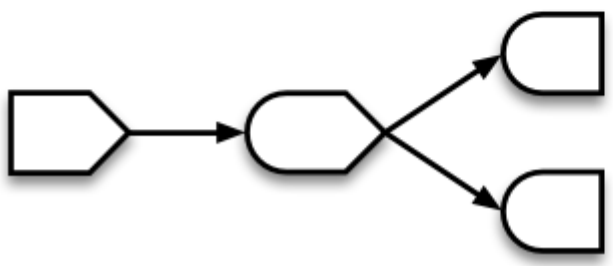
With intermediate objects:

```
fib <- function(n) ifelse(n<3, 1, fib(n-1)+fib(n-2))

shinyServer(function(input, output) {
  currentFib         <- reactive({ fib(as.numeric(input$n)) })

  output$nthValue    <- renderText({ currentFib() })
  output$nthValueInv <- renderText({ 1 / currentFib() })
})
```

Here is the new graph structure:



Reactivity

A standard paradigm for interactive (event-driven) application development

A nice review paper: http://dl.acm.org/citation.cfm?id=2501666

Binding data to graphical elements

With Shiny we can bind data objects to document elements.
More examples: http://shiny.rstudio.com/gallery/

We can also bind data directly to *graphical* elements since using SVG these are also document elements (D3).

D3 Tutorial

Slides

D3 Alternatives

- If you want to use a toolkit of standard charts based on d3: NVD3
- An alternative declarative library: Vega
- A no-hassle interactive vis library for multiple languages:
  - plotly R
  - plotly python
  - plotly JS

D3 and R

- We saw previously that D3 can access external data through `json`
- That's how we can pass data from R to the Javascript browser

D3 and R

- rCharts: Most mature. Provides binding between R and a small set of javascript viz libraries.
- ggvis: Uses grammar of graphics like ggplot2, bindings to Vega to define JS charts.
- htmlwidgets a formalization of how to bind R to JS libraries.
- Roll your own

D3 and jupyter

In jupyter you can use HTML and javascript directly, and use D3 and other JS libraries through that.

For more info: https://blog.thedataincubator.com/2015/08/embedding-d3-in-an-ipython-notebook/

Interactive visualization

Essential tool for exploration

Helps manage high-dimensionality of data (don't go 3D, link charts!!)