

Visualization Basics

Joseph Adler, Drew Conway, Jake Hofman, Hilary Mason

February 1, 2011

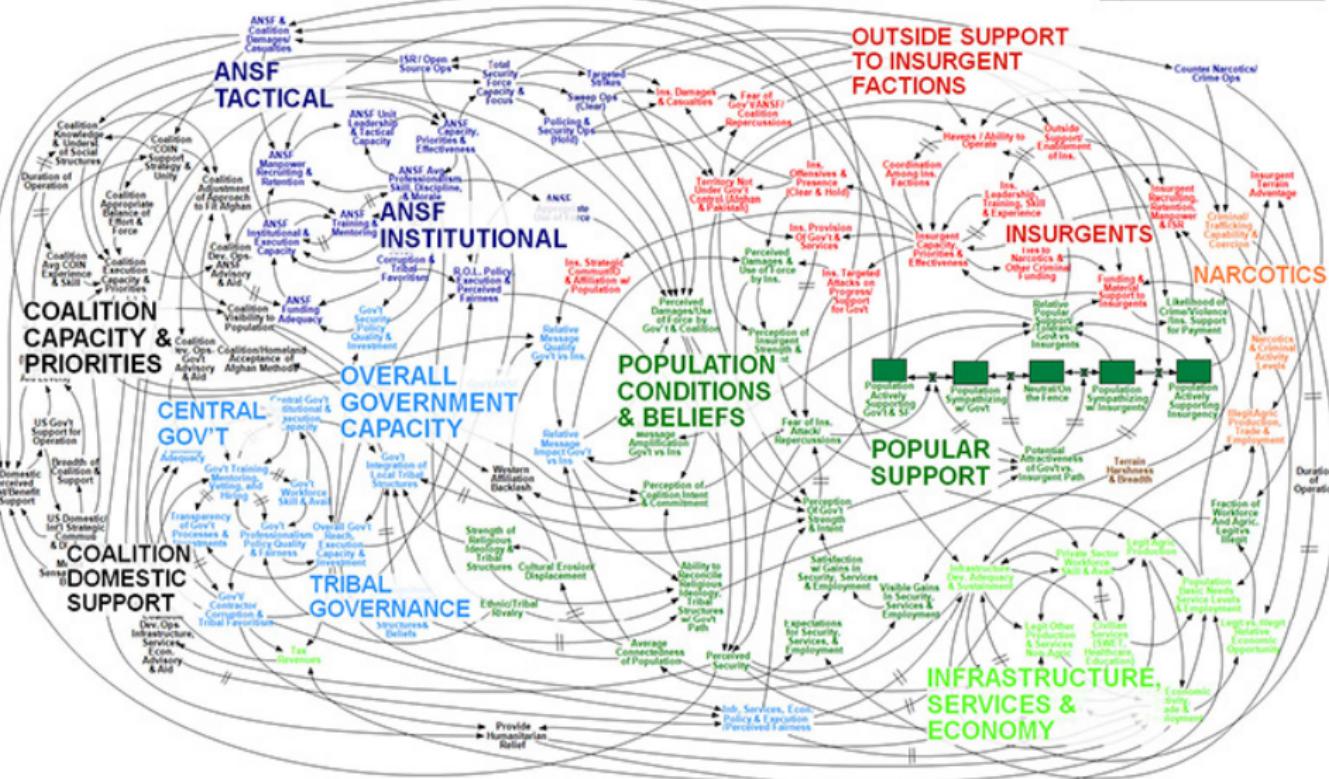


Creative Commons Attribution-Share Alike 3.0

Afghanistan Stability / COIN Dynamics

 = Significant Delay

- Population/Popular Support
- Infrastructure, Economy, & Services
- Government
- Afghanistan Security Forces
- Insurgents
- Crime and Narcotics
- Coalition Forces & Actions
- Physical Environment

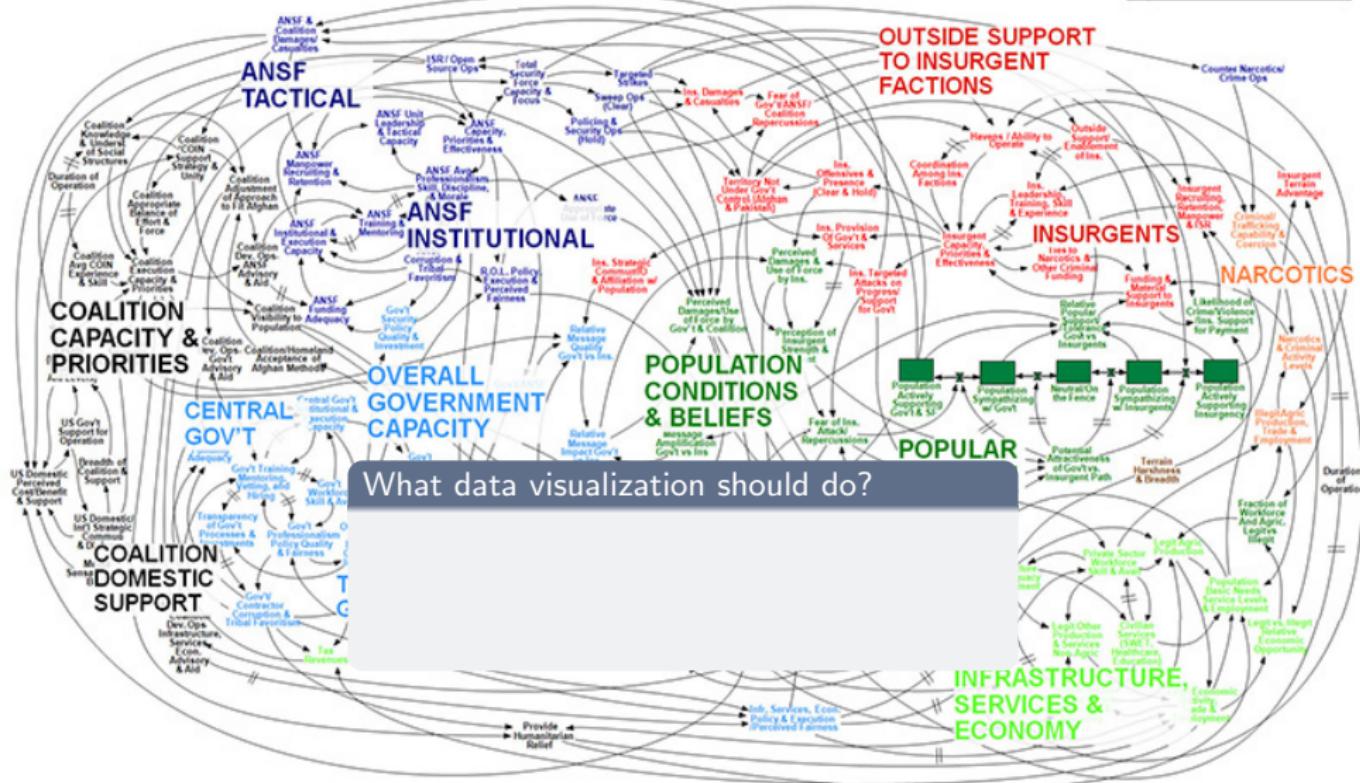


WORKING DRAFT - V3

Afghanistan Stability / COIN Dynamics

 = Significant Delay

- Population/Popular Support
- Infrastructure, Economy, & Services
- Government
- Afghanistan Security Forces
- Insurgents
- Crime and Narcotics
- Coalition Forces & Actions
- Physical Environment

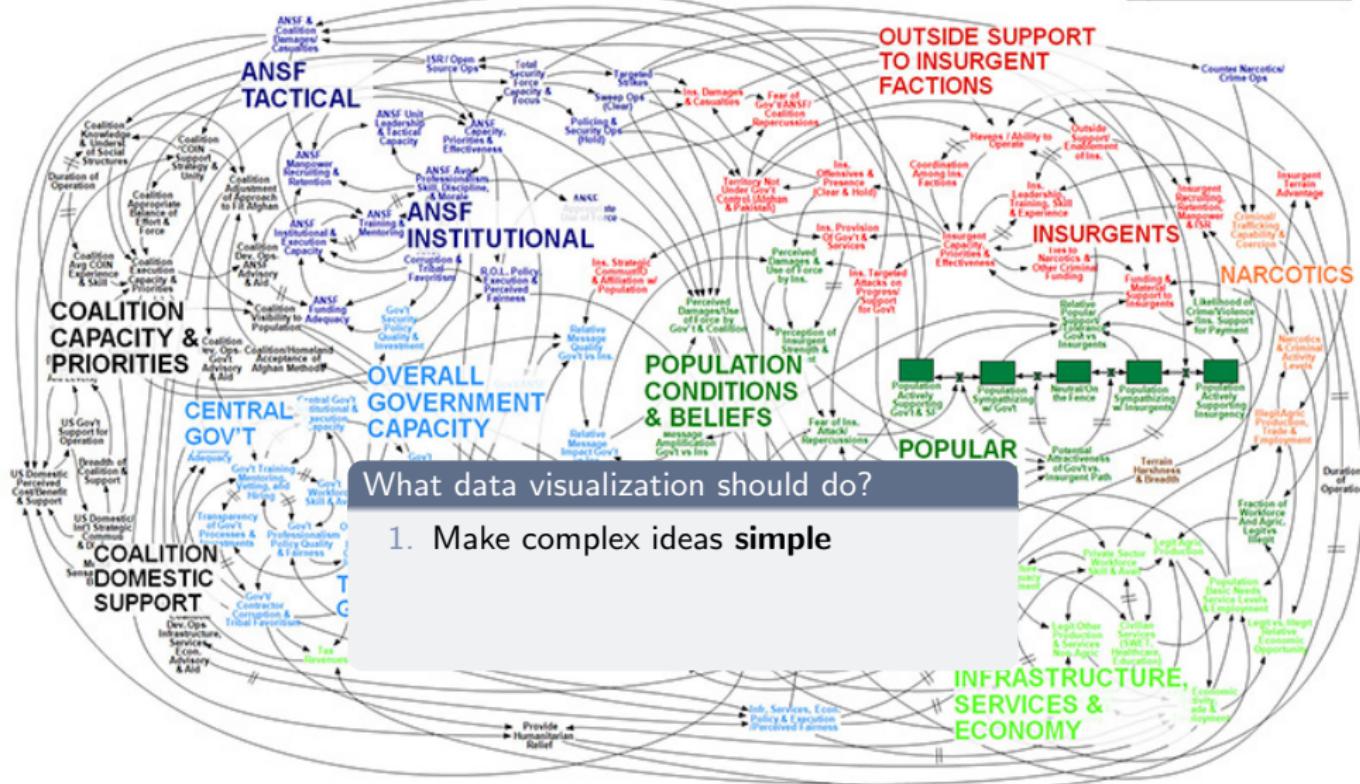


WORKING DRAFT - V3

Afghanistan Stability / COIN Dynamics

 = Significant Delay

- Population/Popular Support
- Infrastructure, Economy, & Services
- Government
- Afghanistan Security Forces
- Insurgents
- Crime and Narcotics
- Coalition Forces & Actions
- Physical Environment

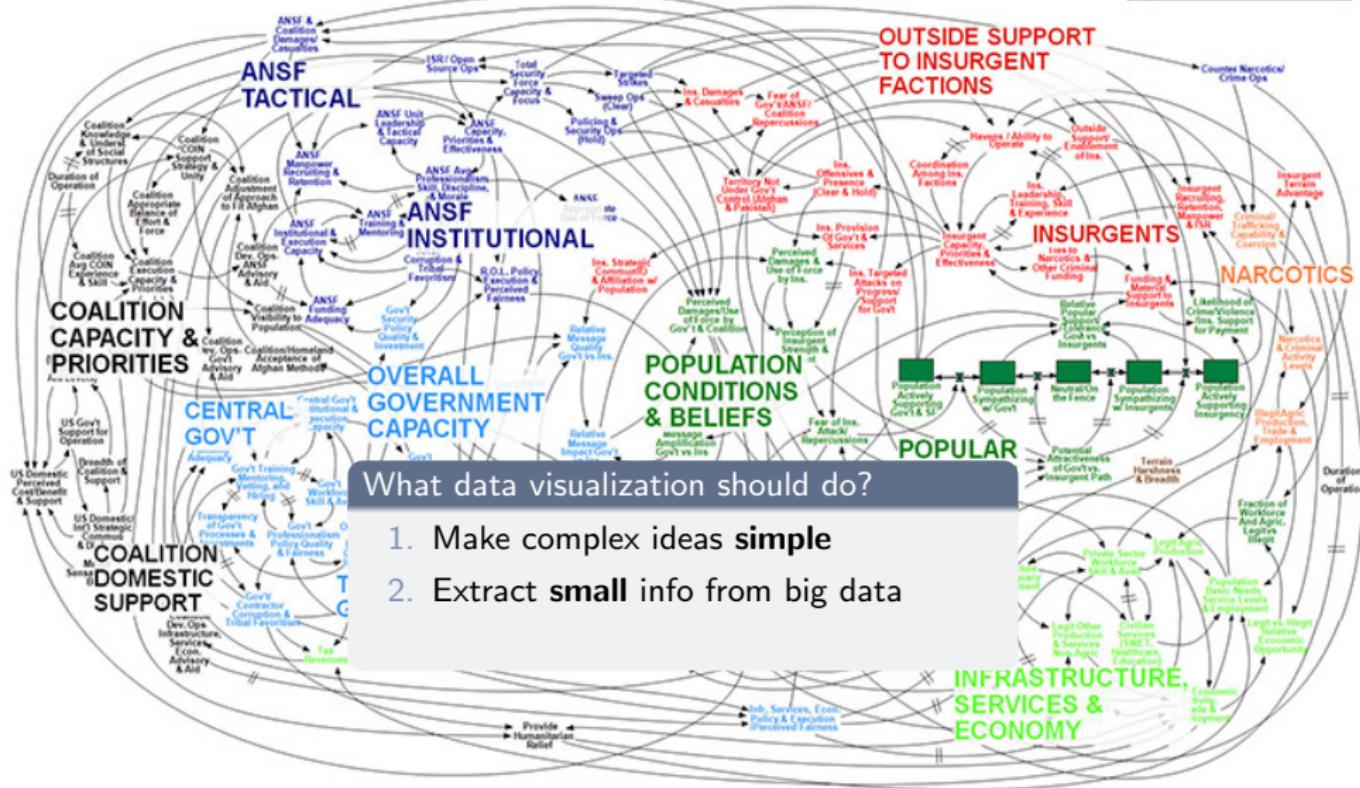


WORKING DRAFT - V3

Afghanistan Stability / COIN Dynamics

 = Significant Delay

- Population/Popular Support
- Infrastructure, Economy, & Services
- Government
- Afghanistan Security Forces
- Insurgents
- Crime and Narcotics
- Coalition Forces & Actions
- Physical Environment

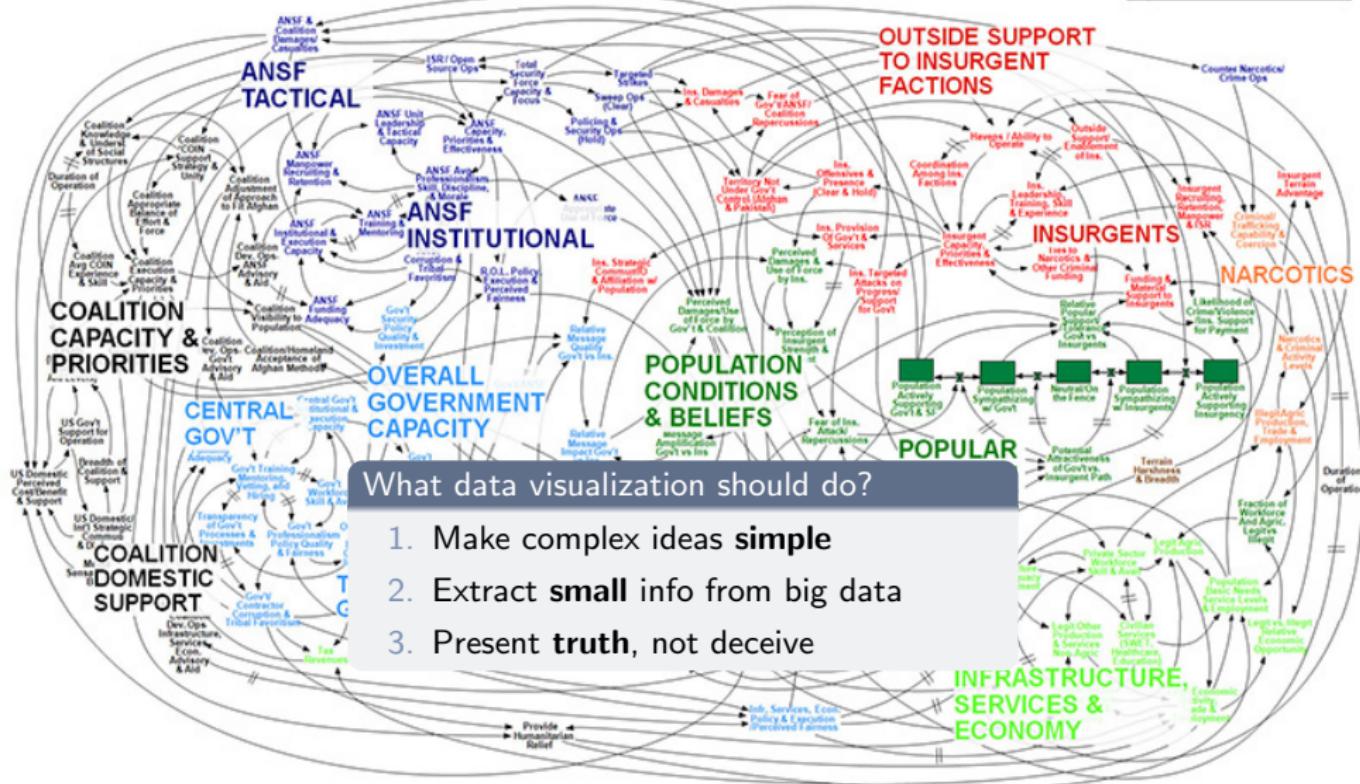


WORKING DRAFT - V3

Afghanistan Stability / COIN Dynamics

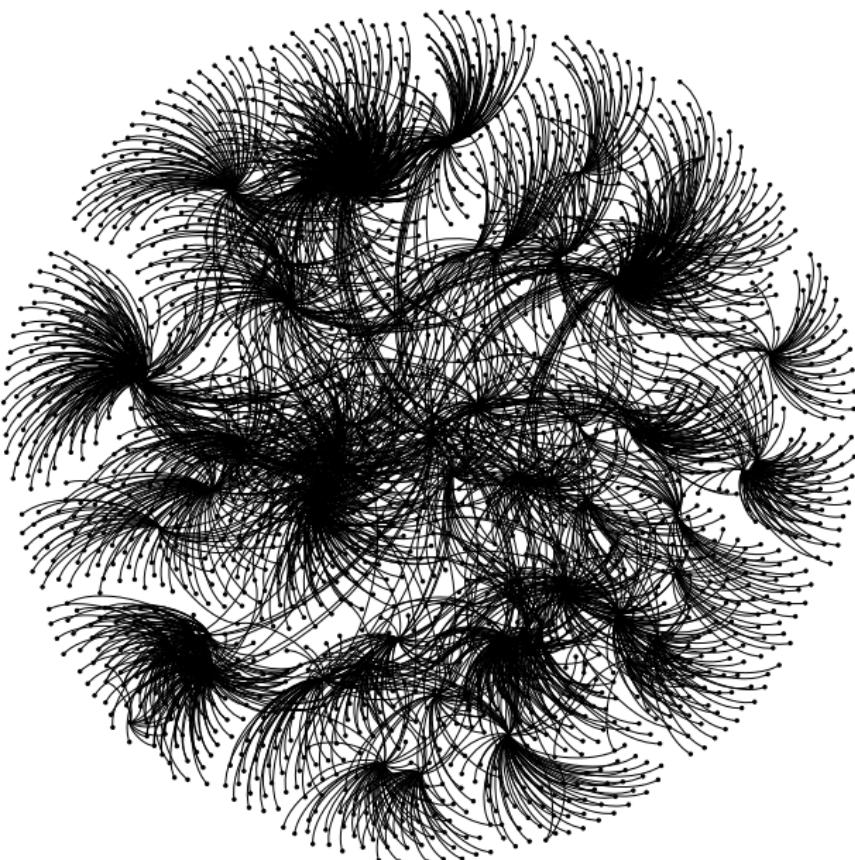
 = Significant Delay

- Population/Popular Support
- Infrastructure, Economy, & Services
- Government
- Afghanistan Security Forces
- Insurgents
- Crime and Narcotics
- Coalition Forces & Actions
- Physical Environment

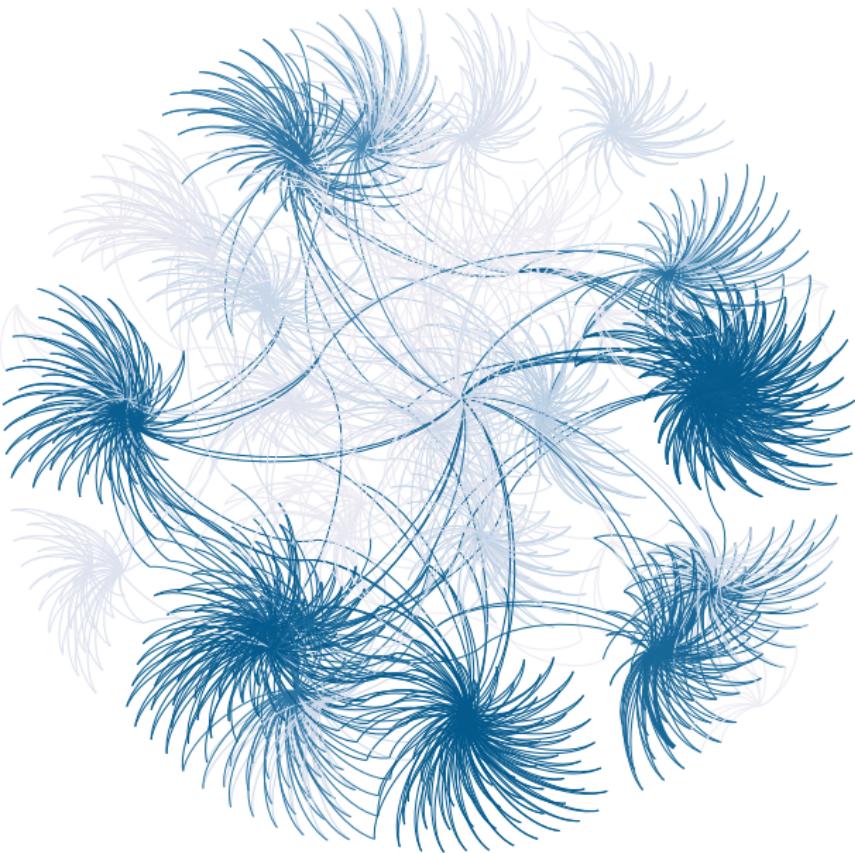


WORKING DRAFT - V3

Make complex ideas **simple**



Make complex ideas **simple**

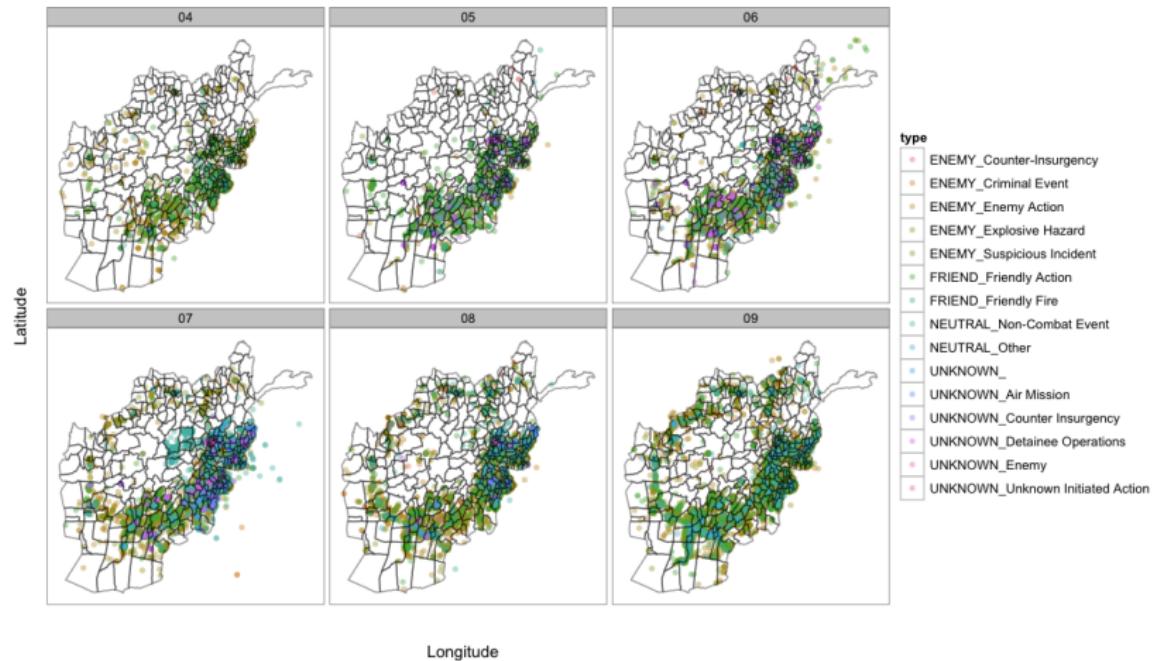


Good example of complexity reduction

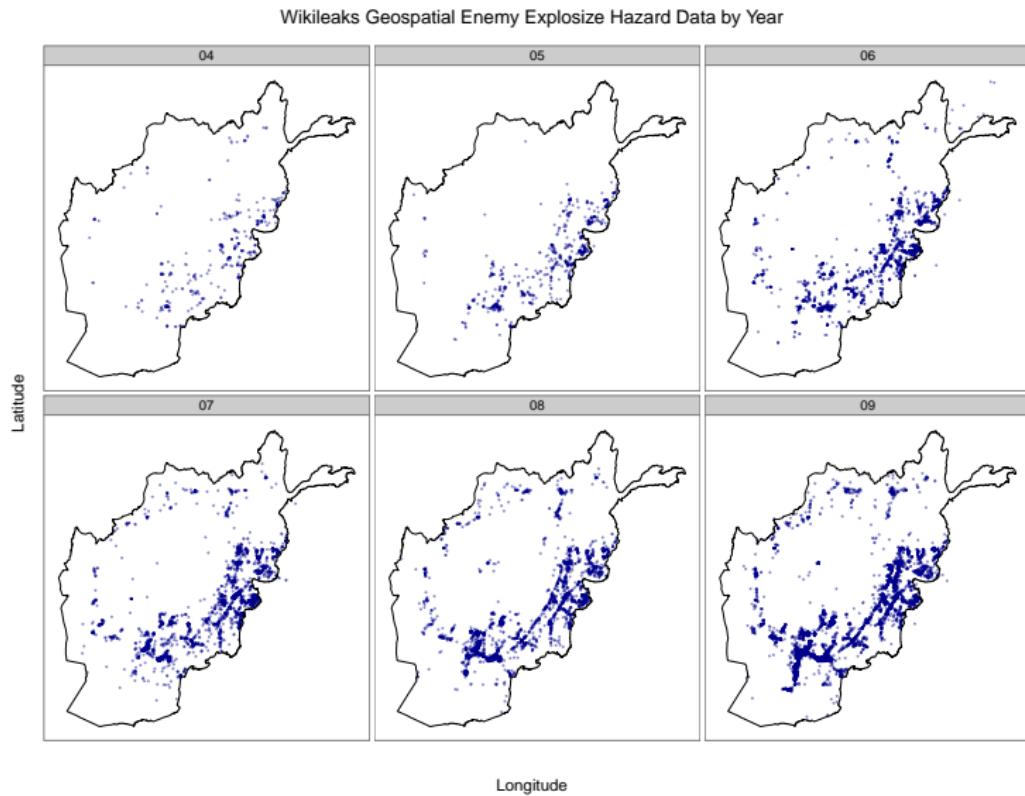


Extract **small** info from big data

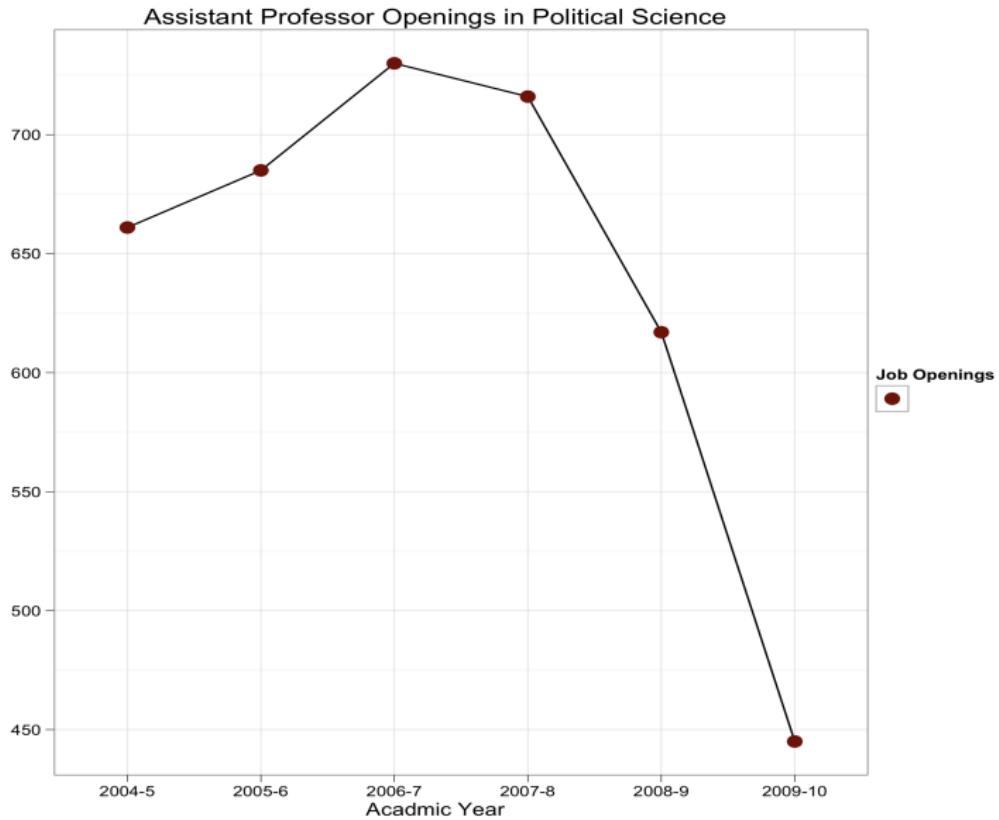
Wikileaks Geospatial Attack Data by Year and Type (Afghanistan District Boundaries)



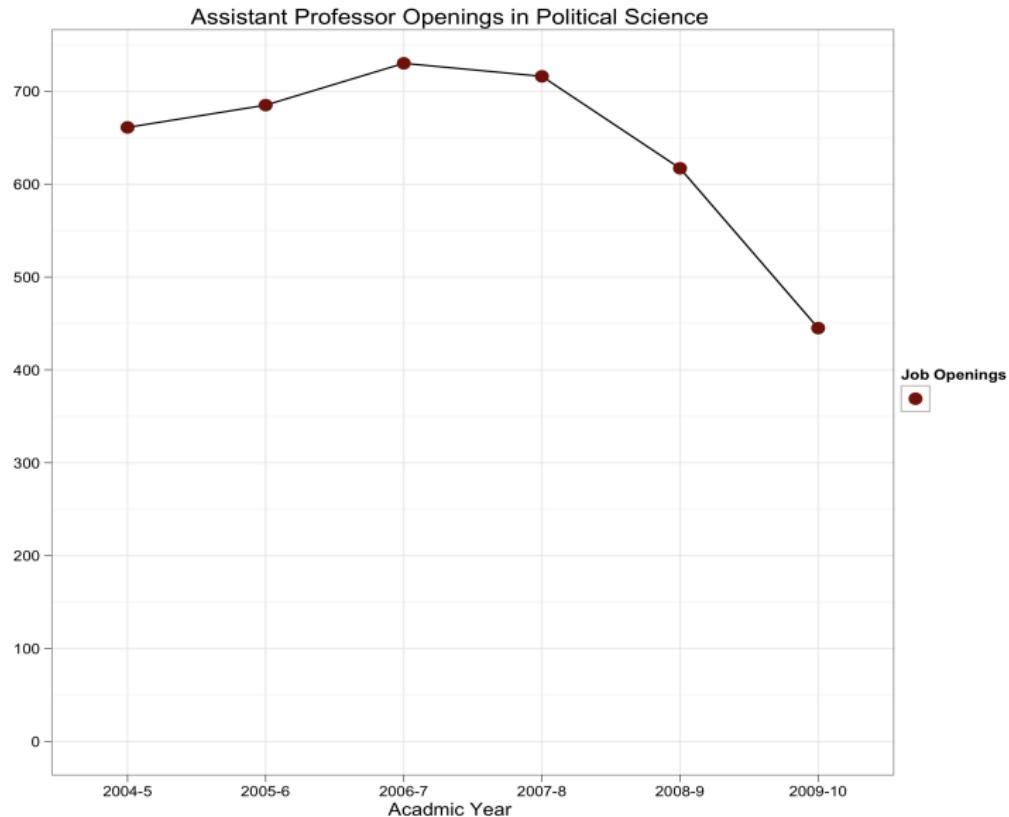
Extract **small** info from big data



Present **truth**, do not deceive



Present **truth**, do not deceive



Commercial data visualization tools

Data visualization is very popular...



Commercial data visualization tools

Data visualization is very popular...



data visualization software

Search

About 2,410,000 results (0.18 seconds)

[Advanced search](#)

Strata ♥'s visualization!

```
$ wget -O strata.htm http://strataconf.com/strata2011/public/schedule/full  
$ tr -cs 'A-Za-z' '\n' < strata.html | grep -c "visual"
```

24

Commercial data visualization tools

Data visualization is very popular...



data visualization software

About 2,410,000 results (0.18 seconds)

Search

[Advanced search](#)

Strata ❤'s visualization!

```
$ wget -O strata.htm http://strataconf.com/strata2011/public/schedule/full  
$ tr -cs 'A-Za-z' '\n' < strata.html | grep -c "visual"  
24
```



GoodData

Google



ReadWriteWeb

The New York Times Company

the guardian

Open-source visualization tools

For this tutorial we will not be using any commercial tools

- ▶ Instead utilizing **only open-source tools**

Open-source visualization tools

For this tutorial we will not be using any commercial tools

- ▶ Instead utilizing **only open-source tools**

There are many tools at our disposal

- ▶ Here we will use **two premier scientific computing environments**



Python's scientific computing holy trinity



Python's scientific computing holy trinity



Python's primary library
for **mathematical** and
statistical computing.
Containing sub-libs for

- ▶ Numeric optimization
- ▶ Clustering
- ▶ Linear algebra
- ▶ ..and many others

Python's scientific computing holy trinity



Python's primary library
for **mathematical and**
statistical computing.
Containing sub-libs for

- ▶ Numeric optimization
- ▶ Clustering
- ▶ Linear algebra
- ▶ ..and many others

The primary data type in
SciPy is an array

- ▶ Data manipulation is
similar to that of
MATLAB

Python's scientific computing holy trinity



Python's primary library for **mathematical and statistical** computing.
Containing sub-libs for

- ▶ Numeric optimization
- ▶ Clustering
- ▶ Linear algebra
- ▶ ..and many others

The primary data type in SciPy is an array

- ▶ Data manipulation is similar to that of MATLAB

NumPy is an extension of the SciPy data type to include **multidimensional arrays and matrices**

- ▶ Provides many functions for working on arrays and matrices
- ▶ Very useful for representing relational data

Python's scientific computing holy trinity



Python's primary library for **mathematical and statistical** computing.
Containing sub-libs for

- ▶ Numeric optimization
- ▶ Clustering
- ▶ Linear algebra
- ▶ ..and many others

The primary data type in SciPy is an array

- ▶ Data manipulation is similar to that of MATLAB

NumPy is an extension of the SciPy data type to include **multidimensional arrays and matrices**

- ▶ Provides many functions for working on arrays and matrices
- ▶ Very useful for representing relational data

Both SciPy and NumPy rely on the C library LAPACK for very fast implementation

Python's scientific computing holy trinity



Python's primary library for **mathematical and statistical** computing.
Containing sub-libs for

- ▶ Numeric optimization
- ▶ Clustering
- ▶ Linear algebra
- ▶ ..and many others

The primary data type in SciPy is an array

- ▶ Data manipulation is similar to that of MATLAB



NumPy is an extension of the SciPy data type to include **multidimensional arrays and matrices**

- ▶ Provides many functions for working on arrays and matrices
- ▶ Very useful for representing relational data

Both SciPy and NumPy rely on the C library LAPACK for very fast implementation



matplotlib is **primary plotting library in Python**

- ▶ Supports 2- and 3-D plotting
- ▶ API allows embedding in apps

Python's scientific computing holy trinity



Python's primary library for **mathematical and statistical** computing.
Containing sub-libs for

- ▶ Numeric optimization
- ▶ Clustering
- ▶ Linear algebra
- ▶ ..and many others

The primary data type in SciPy is an array

- ▶ Data manipulation is similar to that of MATLAB

NumPy is an extension of the SciPy data type to include **multidimensional arrays and matrices**

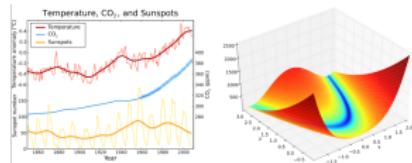
- ▶ Provides many functions for working on arrays and matrices
- ▶ Very useful for representing relational data

Both SciPy and NumPy rely on the C library LAPACK for very fast implementation



matplotlib is **primary plotting library in Python**

- ▶ Supports 2- and 3-D plotting
- ▶ API allows embedding in apps



Python's scientific computing holy trinity



Python's primary library for **mathematical and statistical** computing.
Containing sub-libs for

- ▶ Numeric optimization
- ▶ Clustering
- ▶ Linear algebra
- ▶ ..and many others

The primary data type in SciPy is an array

- ▶ Data manipulation is similar to that of MATLAB

NumPy is an extension of the SciPy data type to include **multidimensional arrays and matrices**

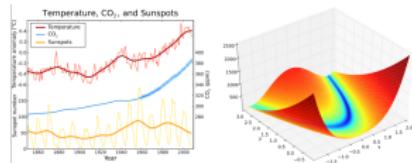
- ▶ Provides many functions for working on arrays and matrices
- ▶ Very useful for representing relational data

Both SciPy and NumPy rely on the C library LAPACK for very fast implementation



matplotlib is **primary plotting library in Python**

- ▶ Supports 2- and 3-D plotting
- ▶ API allows embedding in apps



All graphics are highly customizable and professional publication ready

Python's scientific computing holy trinity



Python's primary library for **mathematical and statistical** computing. Containing sub-libs for

- ▶ Numeric optimization
- ▶ Clustering
- ▶ Linear algebra
- ▶ ..and many others

The primary data type in SciPy is an array

- ▶ Data manipulation is similar to that of MATLAB

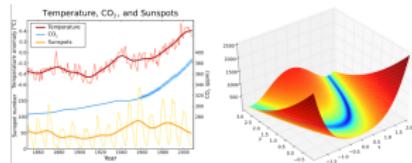
NumPy is an extension of the SciPy data type to include **multidimensional arrays and matrices**

- ▶ Provides many functions for working on arrays and matrices
- ▶ Very useful for representing relational data

Both SciPy and NumPy rely on the C library LAPACK for very fast implementation

matplotlib is **primary plotting library in Python**

- ▶ Supports 2- and 3-D plotting
- ▶ API allows embedding in apps



All graphics are highly customizable and professional publication ready

The R Language

lattice

ggplot2

Data visualization in R

The R Language

"freely available language and environment for statistical computing and graphics..."

lattice

ggplot2

The R Language

"freely available language and environment for statistical computing and graphics..."

CRAN

- ▶ Massive library of specialized packages
- ▶ 2,775 available

lattice

ggplot2

The R Language

"freely available language and environment for statistical computing and graphics..."

CRAN

- ▶ Massive library of specialized packages
- ▶ 2,775 available

R Task Views

- ▶ 28 development areas
- ▶ Bayesian, ML, NLP,
Graphics

lattice

ggplot2

Data visualization in R

The R Language

"freely available language and environment for statistical computing and graphics..."

CRAN

- ▶ Massive library of specialized packages
- ▶ 2,775 available

R Task Views

- ▶ 28 development areas
- ▶ Bayesian, ML, NLP,
Graphics

Two popular visualization packages

- ▶ `lattice`
- ▶ `ggplot2`

`lattice`

`ggplot2`

The R Language

"freely available language and environment for statistical computing and graphics..."

CRAN

- ▶ Massive library of specialized packages
- ▶ 2,775 available

R Task Views

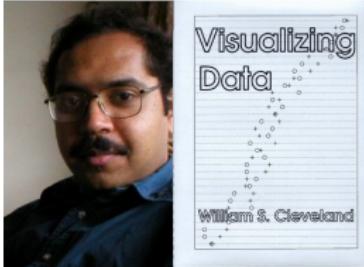
- ▶ 28 development areas
- ▶ Bayesian, ML, NLP,
Graphics

Two popular visualization packages

- ▶ *lattice*
- ▶ *ggplot2*

lattice

Developed by Deepayan Sarkar



ggplot2

Data visualization in R

The R Language

"freely available language and environment for statistical computing and graphics..."

CRAN

- ▶ Massive library of specialized packages
- ▶ 2,775 available

R Task Views

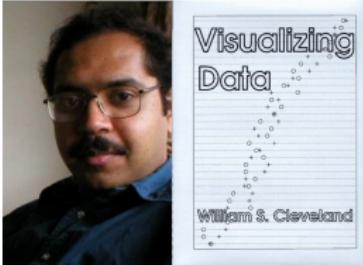
- ▶ 28 development areas
- ▶ Bayesian, ML, NLP,
Graphics

Two popular visualization packages

- ▶ *lattice*
- ▶ *ggplot2*

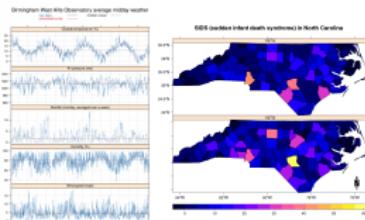
lattice

Developed by Deepayan Sarkar



ggplot2

- ▶ Implementation of Trellis graphics



Data visualization in R

The R Language

"freely available language and environment for statistical computing and graphics..."

CRAN

- ▶ Massive library of specialized packages
- ▶ 2,775 available

R Task Views

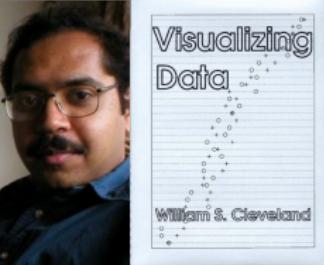
- ▶ 28 development areas
- ▶ Bayesian, ML, NLP, **Graphics**

Two popular visualization packages

- ▶ *lattice*
- ▶ *ggplot2*

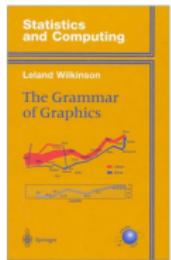
lattice

Developed by Deepayan Sarkar

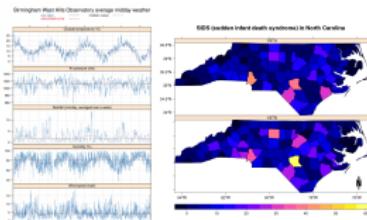


ggplot2

Developed by Hadley Wickham



- ▶ Implementation of Trellis graphics



Data visualization in R

The R Language

"freely available language and environment for statistical computing and graphics..."

CRAN

- ▶ Massive library of specialized packages
- ▶ 2,775 available

R Task Views

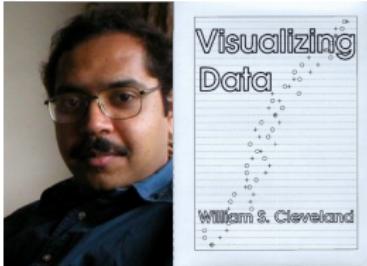
- ▶ 28 development areas
- ▶ Bayesian, ML, NLP, **Graphics**

Two popular visualization packages

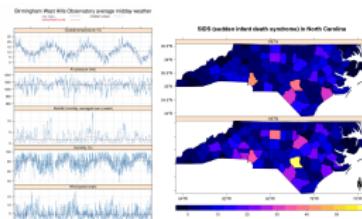
- ▶ **lattice**
- ▶ **ggplot2**

lattice

Developed by Deepayan Sarkar

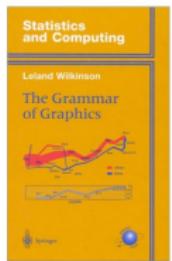
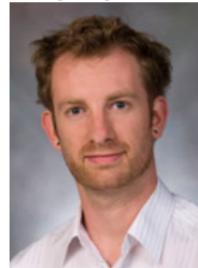


- ▶ Implementation of Trellis graphics



ggplot2

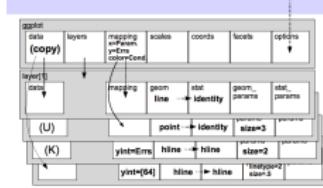
Developed by Hadley Wickham



- ▶ Visualizations are “grammatical layers”

you don't need to know this!

structure so far



December 3, 2008

Hadley. Harris

14

Image source: Harlan Harris

Data visualization in R

The R Language

"freely available language and environment for statistical computing and graphics..."

CRAN

- ▶ Massive library of specialized packages
- ▶ 2,775 available

R Task Views

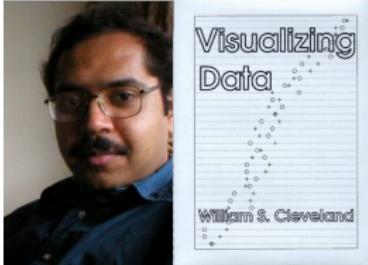
- ▶ 28 development areas
- ▶ Bayesian, ML, NLP, **Graphics**

Two popular visualization packages

- ▶ **lattice**
- ▶ **ggplot2**

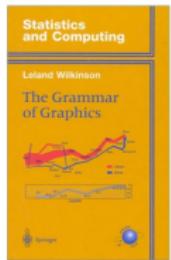
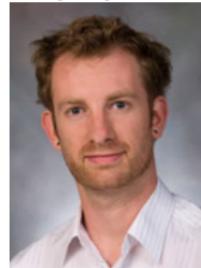
lattice

Developed by Deepayan Sarkar

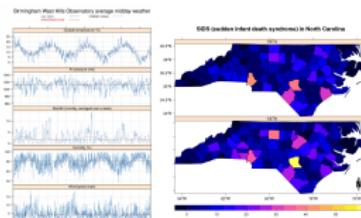


ggplot2

Developed by Hadley Wickham



- ▶ Implementation of Trellis graphics



- ▶ Visualizations are "grammatical layers"

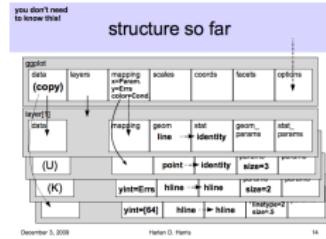


Image source: Harlan Harris

Creating a simple visualization

As an introduction to each environment we will make the same plot in both `matplotlib` and `ggplot2`

¹Image source: <http://mathworld.wolfram.com/NormalDistribution.html>

Creating a simple visualization

As an introduction to each environment we will make the same plot in both `matplotlib` and `ggplot2`

To begin, we'll generate canonical data and visualize it

- ▶ Histogram of 10,000 randomly generated numbers from a **standard Normal distribution**
- ▶ $\mu = 0, \sigma = 1$
- ▶ Then, overlay Normal density function to observe “fit”¹

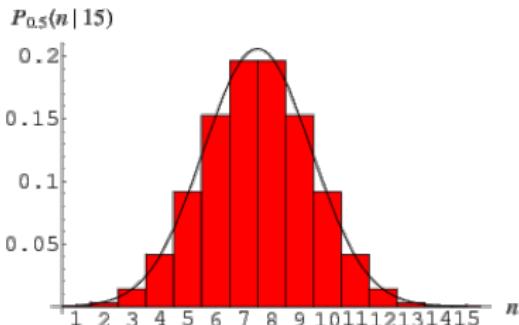
¹Image source: <http://mathworld.wolfram.com/NormalDistribution.html>

Creating a simple visualization

As an introduction to each environment we will make the same plot in both `matplotlib` and `ggplot2`

To begin, we'll generate canonical data and visualize it

- ▶ Histogram of 10,000 randomly generated numbers from a **standard Normal distribution**
- ▶ $\mu = 0, \sigma = 1$
- ▶ Then, overlay Normal density function to observe “fit”¹



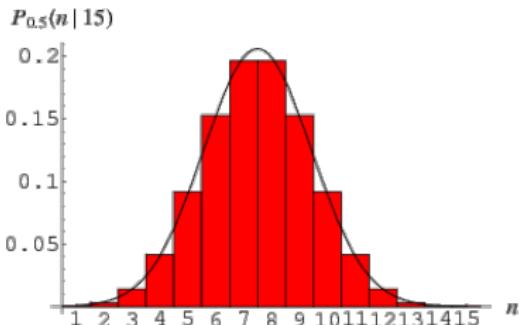
¹Image source: <http://mathworld.wolfram.com/NormalDistribution.html>

Creating a simple visualization

As an introduction to each environment we will make the same plot in both `matplotlib` and `ggplot2`

To begin, we'll generate canonical data and visualize it

- ▶ Histogram of 10,000 randomly generated numbers from a **standard Normal distribution**
- ▶ $\mu = 0, \sigma = 1$
- ▶ Then, overlay Normal density function to observe “fit”¹



We'll start by working in Python with `matplotlib`...

¹Image source: <http://mathworld.wolfram.com/NormalDistribution.html>

My first matplotlib visualization: 1/3

Our first steps are to load the libraries and generate data

matplotlib and the normal distribution

```
>>> import matplotlib.pyplot as plt  
>>> from scipy.stats import norm
```

Generate 10,000 random draws from a normal

```
>>> random_normal = norm.rvs(0,1,size=10000)
```

Create a figure to draw to

```
>>> fig=plt.figure(figsize = (8,6))
```

My first matplotlib visualization: 2/3

Next, we draw the draw to the figure

Add the histogram and Normal PDF

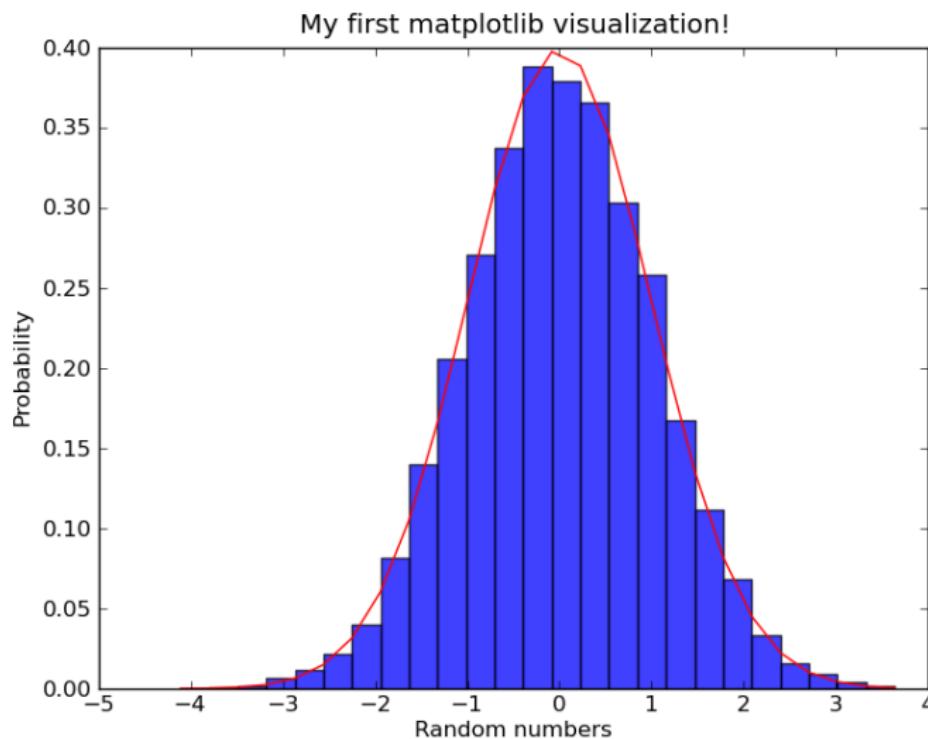
```
>>> n, bins, patches =  
      plt.hist(random_numbers, normed=True, bins=25,  
      alpha=0.75)  
>>> y = norm.pdf(bins)  
>>> plt.plot(bins, y, "r-")
```

Add plot labels, and save

```
>>> plt.xlabel("Random numbers")  
>>> plt.ylabel("Density")  
>>> plt.title("My first matplotlib visualization!")  
>>> plt.savefig("matplotlib_first.png")
```

My first matplotlib visualization: 3/3

Now, bask in the glory of your data visualization!



My first ggplot2 visualization 1/4

Again, first load library and create data

Load the ggplot2 package

```
> library(ggplot2)
```

Create our first data.frame

```
> random.numbers<-rnorm(10000,0,1)
> norm.dframe<-as.data.frame(list(Norm=random.numbers))
```

Create base ggplot2 layer

```
> norm.plt<-ggplot(norm.dframe,aes(Norm)) +
  geom_histogram(aes(y = ..density.., fill="blue",
  colour="black",alpha=0.75))
```

My first ggplot2 visualization 2/4

Next, we build up layers from the base

Add Normal PDF

```
> norm.plt<-norm.plt+stat_function(fun = dnorm,  
colour = "red")
```

Deal with colors and legends

```
> norm.plt<-norm.plt+scale_colour_manual(values =  
c("black"="black","red"="red"), legend = FALSE)  
> norm.plt<-norm.plt+scale_fill_manual(values =  
c("blue"="blue"), legend = FALSE)  
> norm.plt<-norm.plt+scale_alpha(legend = FALSE)+
```

My first ggplot2 visualization 3/4

Finally, add add labels and save

This time, we'll make a PDF

```
> norm.plt<-norm.plt+xlab("Random numbers")
> norm.plt<-norm.plt+ylab("Density")
> norm.plt<-norm.plt+opts(title=
  "My first ggplot2 visualization!")
> ggsave(plot = norm.plt, filename =
  "ggplot2_first.pdf", height = 6,
  width = 8)
```

My first ggplot2 visualization 4/4

Who's the baddest data visualizer?! You are!

