ggplot2

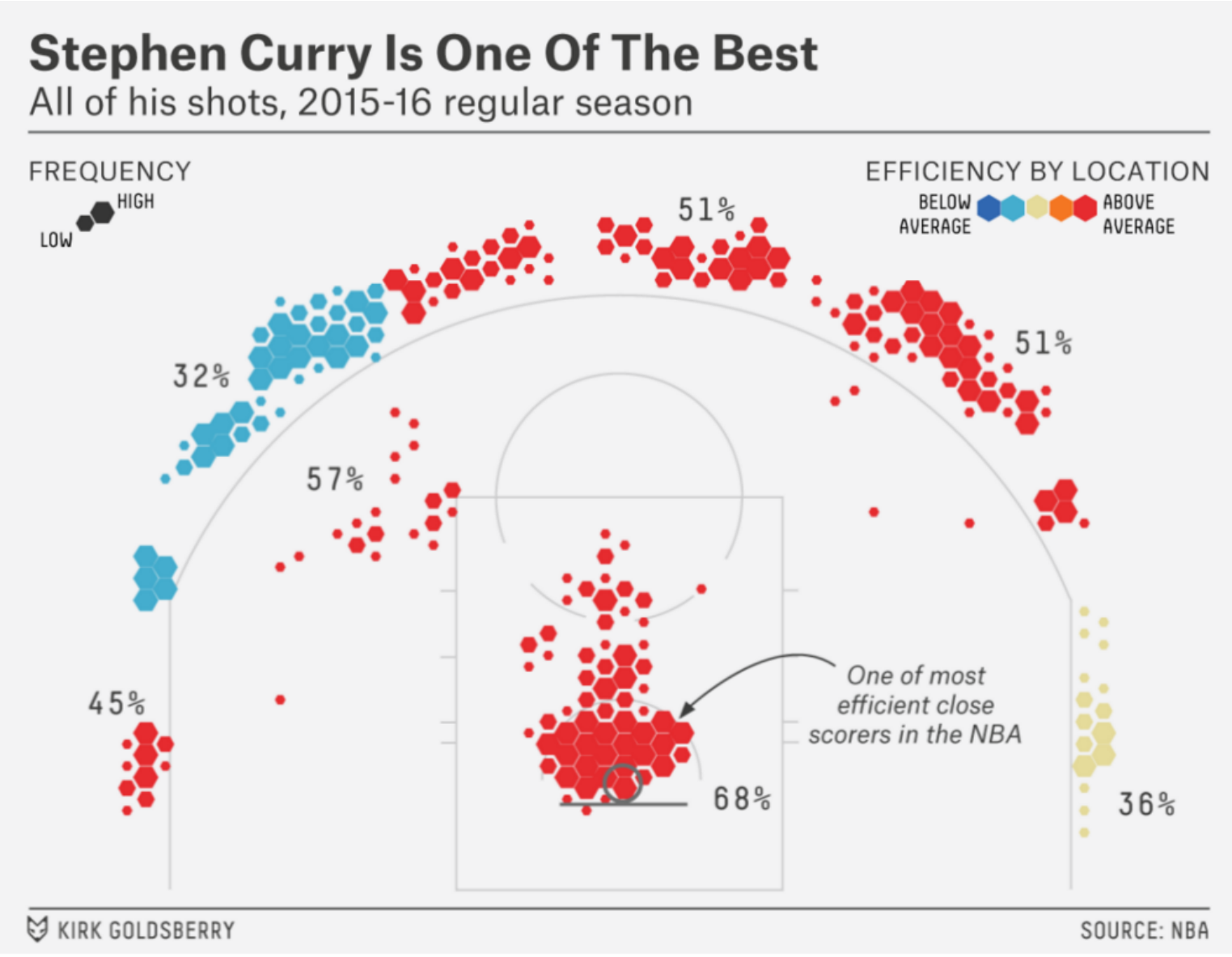
Zhenke Wu

Visualization for Individualized Health
Johns Hopkins Bloomberg School of Public Health, Johns Hopkins University

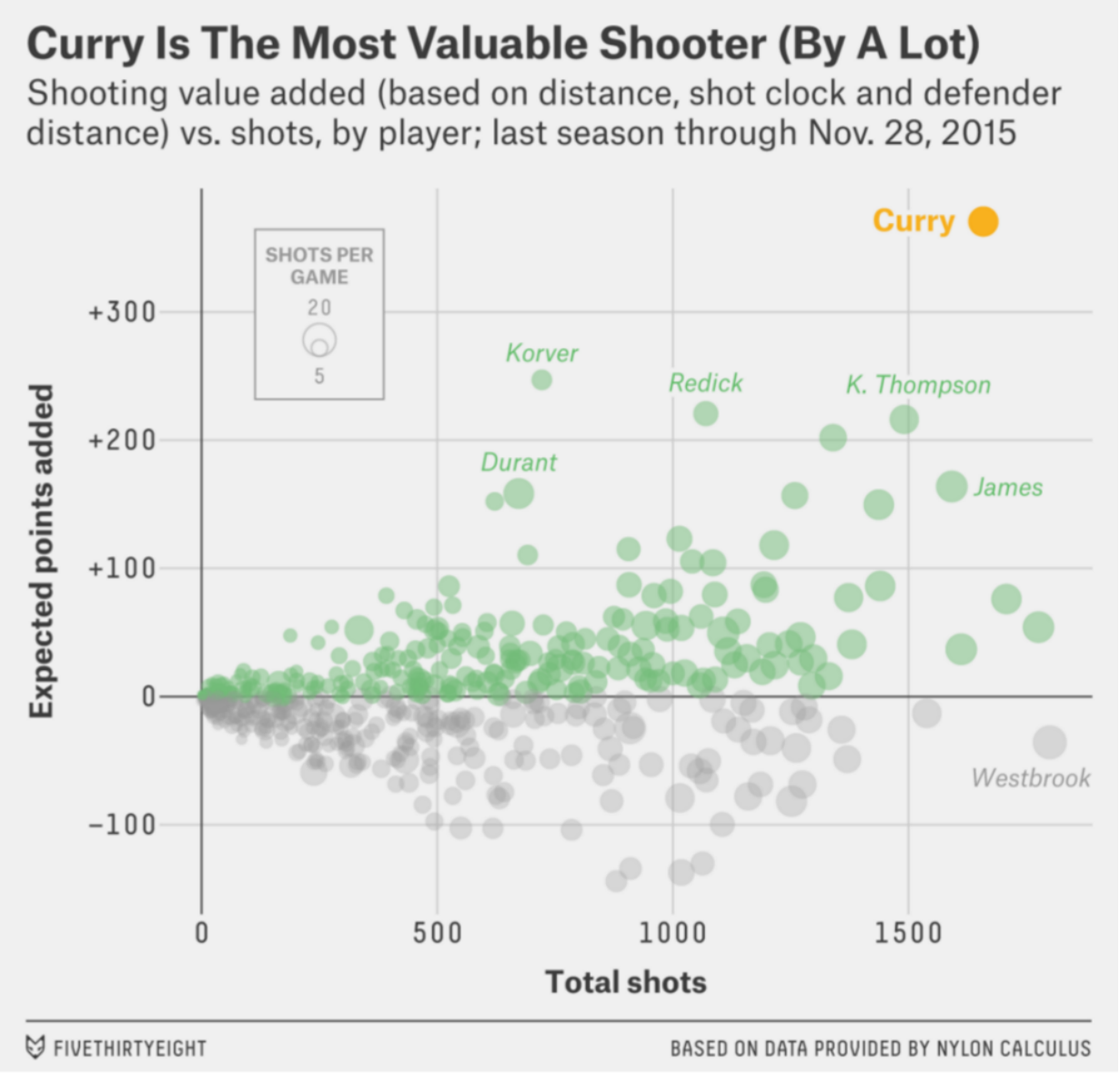
http://zhenkewu.com

2016-02-23

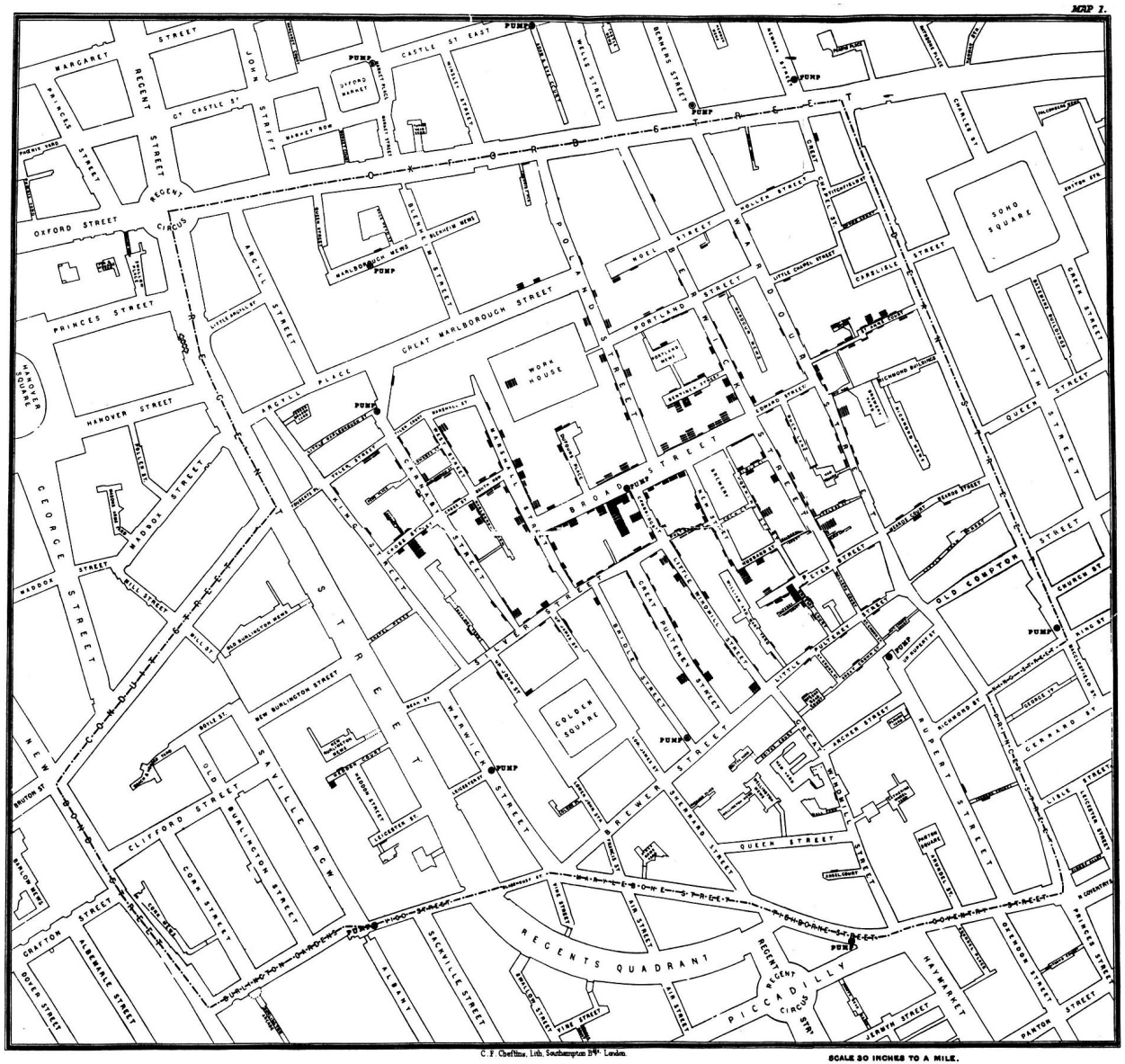
Statistical Graphic?



Statistical Graphic?

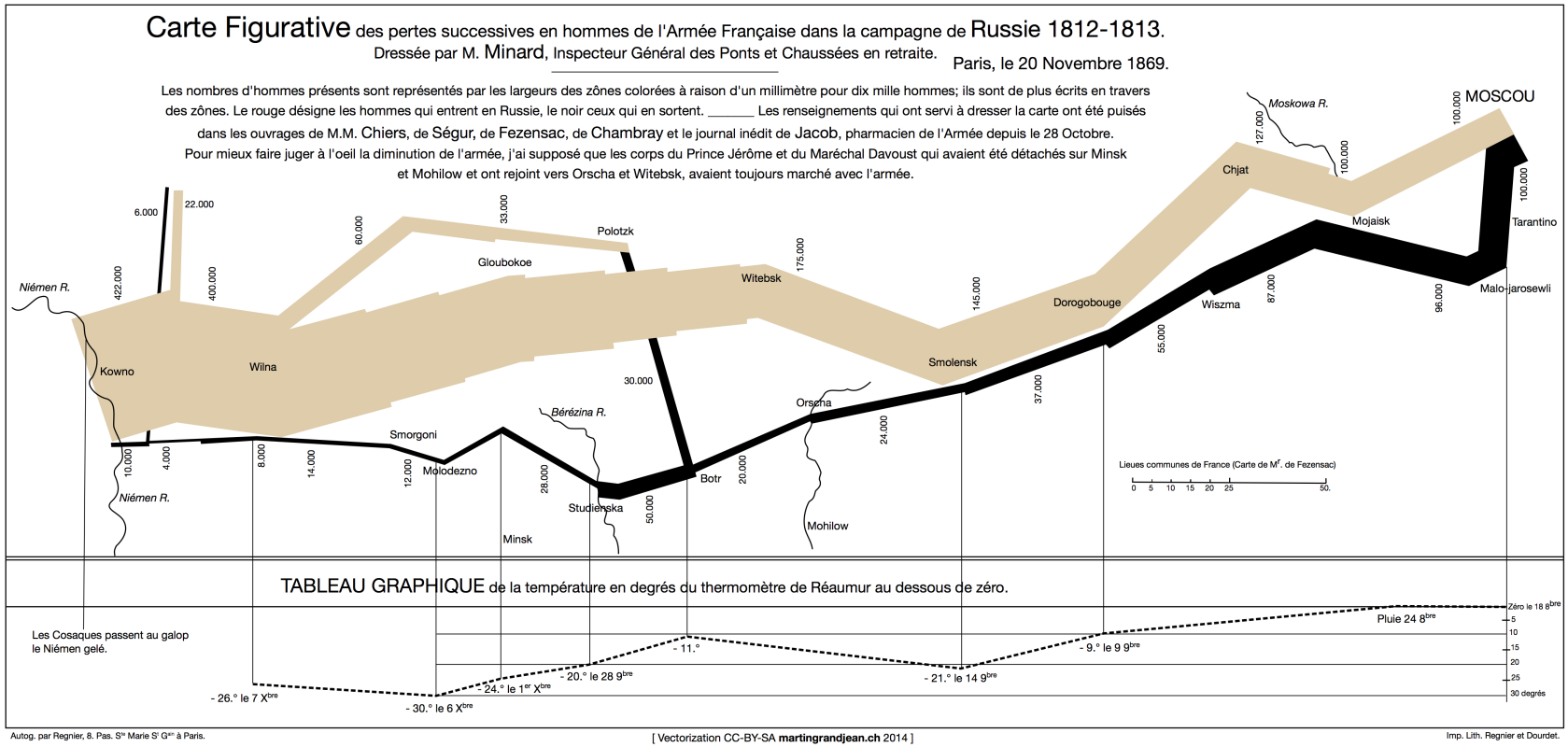


Statistical Graphic?



- John Snow's Cholera map in dot style; dots represent deaths from cholera in London in 1854 to detect the source of the disease

Statistical Graphic?



Charles Joseph Minard (1869), *Napoleon's March to Moscow - The War of 1812*

Important questions for statistical graphics

- What is a graphic?
- How can we succinctly describe a graphic?
- How can we create the graphic that we have described?

One approach: develop a grammar!

- Grammar: *the fundamental principles or rules of an art or science* (Oxford English Dictionary; Item 6)
  - Allows us to gain insights into the composition of complicated graphics
  - Reveals unexpected connections for understanding a diverse range of graphics
  - Guides us to produce sensical and well-formed graphics
- Analogy to the English language: good grammar is just the first step in creating a good sentence.

Existing R graphics tools

- base graphics (Ross Ihaka)
  - pen on paper model; cannot modify or delete existing content
  - no representation of the graphics, apart from their appearance on the screen
  - fast but with limited scope
- `grid` (Paul Murrell, 2000)
  - a much richer system of graphical primitives (only primitives; no tools for producing statistical graphics)
  - graph objects represented independently of the plot and can be modified later
  - a system of viewports to lay out complex graphics
- `lattice` package (Deepayan Sarkar, 2008)
  - uses `grid` to implement the trellis graphics system of Cleveland
  - can easily produce conditioned plots and some details (e.g., legends) are automatically taken care of
  - lacks a formal model; hard to extend

ggplot2: a framework for producing statistical graphics

- takes the good things from base and lattice graphics
- uses a strong underlying model with several principles (details to follow)

What we get:

- a compact syntax to describe a wide range of graphics
- independent components that are easily extensible

ggplot2 Scatterplot Example: **data**

```
# create a simple data set with 4 variables in the columns
dat0 <- as.data.frame(list(A = c(2,1,4,9),
                           B = c(3,2,5,10),
                           C = c(4,1,15,80),
                           D = c("a","a","b","b")))
dat0
```

```
##   A  B  C D
## 1 2  3  4 a
## 2 1  2  1 a
## 3 4  5 15 b
## 4 9 10 80 b
```

ggplot2 Scatterplot Example: *geom* aesthetics and **mapping**

- Scatterplot:
  - a point for each observation
  - position the point horizontally according to the value of A, vertically according to C
  - Here, we will also map categorical variable D to the shape of the points
- Aesthetics:
  - x-poistion: A
  - y-position: C
  - shape: D

```
##   x  y Shape
## 1 2  3     a
## 2 1  2     a
## 3 4  5     b
## 4 9 10     b
```

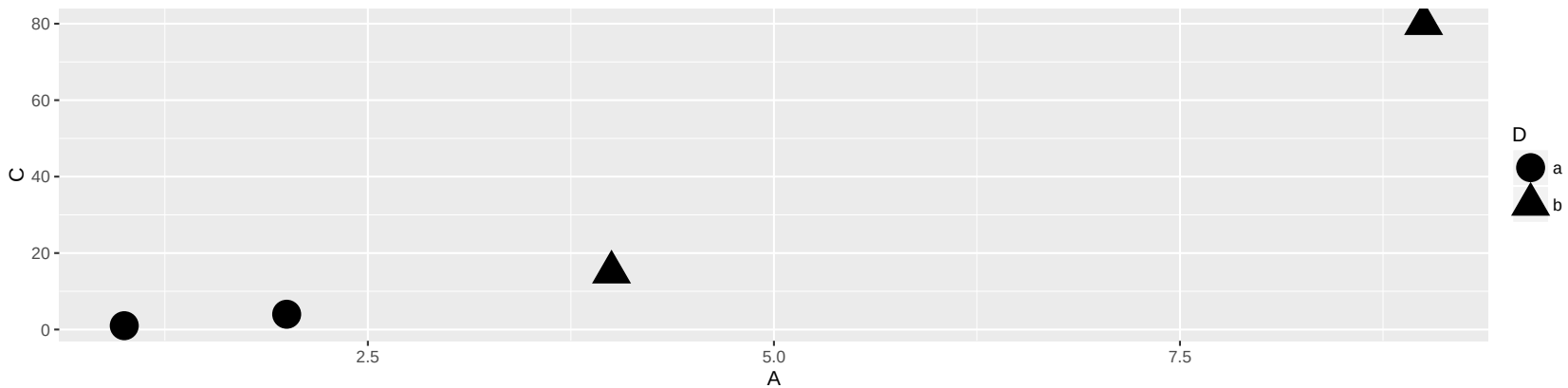
Example: mapping from data space to aesthetic space (controlled by **scale**)

```
# ggplot2 creates (internally) a simple data set with
# 3 variables in the columns:
dat_internal <- as.data.frame(list(x = c(25,0,75,200),
                                   y = c(11,20,53,300),
                                 Shape = c("circle","circle","square"
print(dat_internal)
```

```
##     x   y  Shape
## 1  25  11 circle
## 2   0  20 circle
## 3  75  53 square
## 4 200 300 square
```

Example: Plot the Geometric objects (**geom**)

```
library(ggplot2)
example <- ggplot(data    = dat0,
                  mapping = aes(x=A,y=C,shape=D))+
           # Set aesthetics to fixed value
           geom_point(size = 7)
example
```



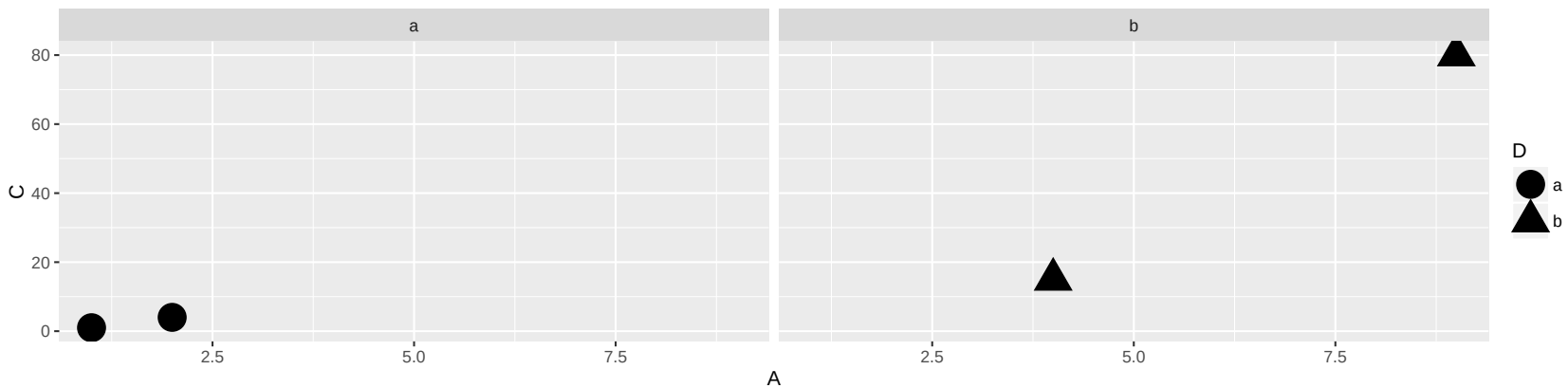

```
# run `?geom_point` geom_point understands the
# following aesthetics (required aesthetics are in bold).
```

Details about geometric objects, or **geom**

- Controls the type of the plot you create (a point **geom** creates a scatterplot; a line **geom** creates a line plot, etc.)
  - 0d: point, text,
  - 1d: path, line (ordered path),
  - 2d: polygon, interval.
- Are abstract and can be rendered in different ways (e.g., intervals).
- Require outputs from a statistic (e.g., x,y-positions in scatterplot; edges in boxplots)
- **Every *geom* has a default *stat*istic, and every *stat*istic a default *geom*.**
  - For example, the bin **stat**istic defaults to using the bar **geom** to produce a histogram.
- Each **geom** can only display certain aesthetics.
  - Try `?geom_point`
  - Different parameterizations may be useful (e.g., polar coordinate system).

Example: Faceting (**facet**)

```
library(ggplot2)
example <- ggplot(data    = dat0,
                  mapping = aes(x=A,y=C,shape=D))+
           # Set aesthetics to fixed value
           geom_point(size = 7)+facet_grid(~D)
example
```



What are the components in the previous example? layered grammer of graphics (Wickham, 2009)

- **data** and **mappings** (describe how variables in the data are mapped to aesthetic attributes that you can perceive)
- geometric objects (**geom**); what you actually see on the plot, e.g., points, lines, polygons, etc.
- statistical transformations, **stat**; summarize data in useful ways, e.g., binning and counting to create a histogram
- **scale**: maps values in the data space to values in an aesthetic space; **scale** draws a legend or axes to make it possible to read the original data values from the graph (**inverse mapping**: what does this mean?)
- A coordinate system: **coord**
- A **facet**ing specification: describes how to break up data into subsets and how to display them as small multiples; also known as *conditioning* or *latticing/trelissing*.

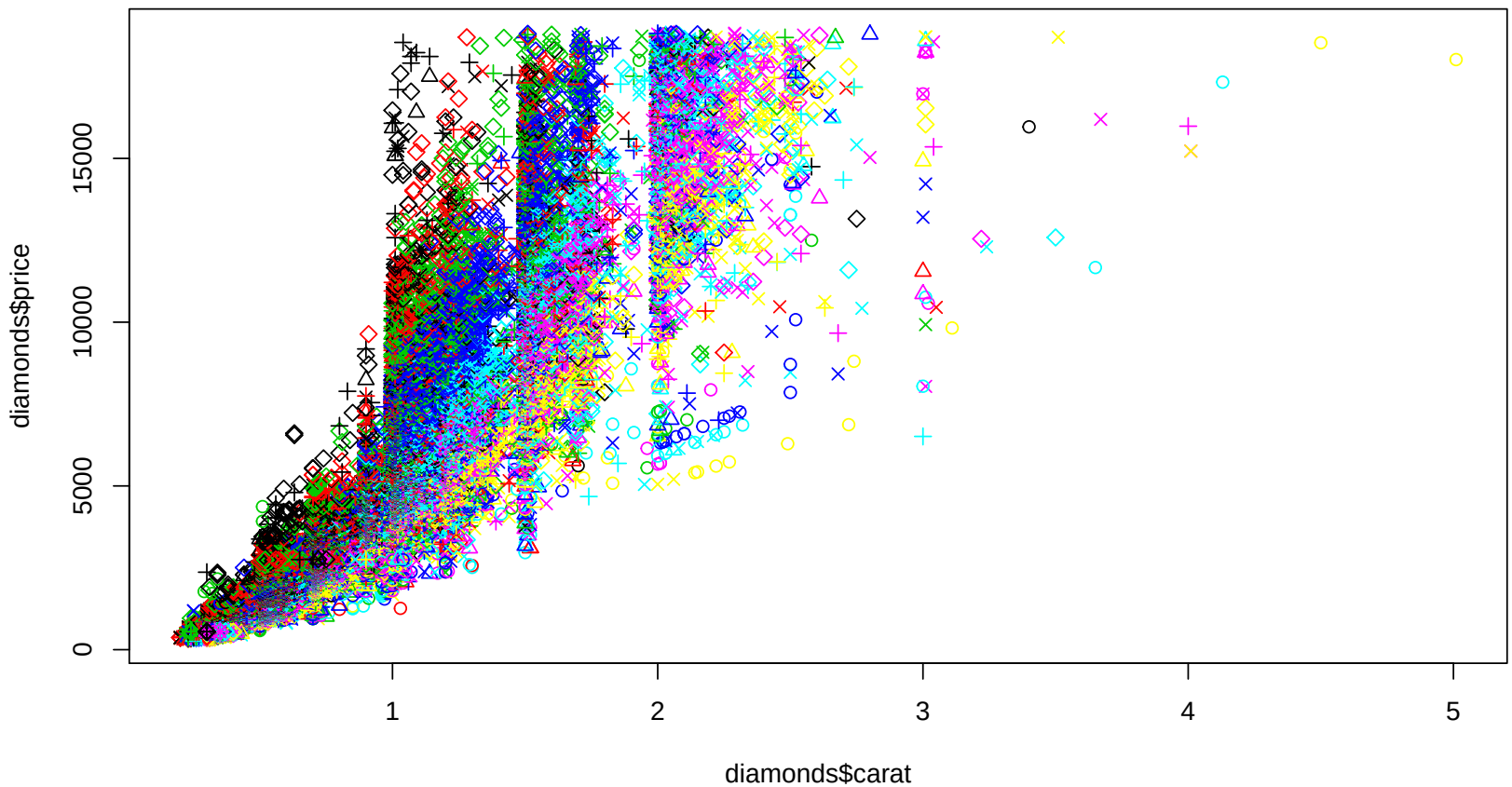
Diamond data

```
# just getting some data
library(ggplot2)
head(diamonds)
```

```
##   carat       cut color clarity depth table price    x
## 1  0.23     Ideal     E     SI2  61.5    55   326 3.95
## 2  0.21   Premium     E     SI1  59.8    61   326 3.89
## 3  0.23      Good     E     VS1  56.9    65   327 4.05
## 4  0.29   Premium     I     VS2  62.4    58   334 4.20
## 5  0.31      Good     J     SI2  63.3    58   335 4.34
## 6  0.24 Very Good     J    VVS2  62.8    57   336 3.94
```

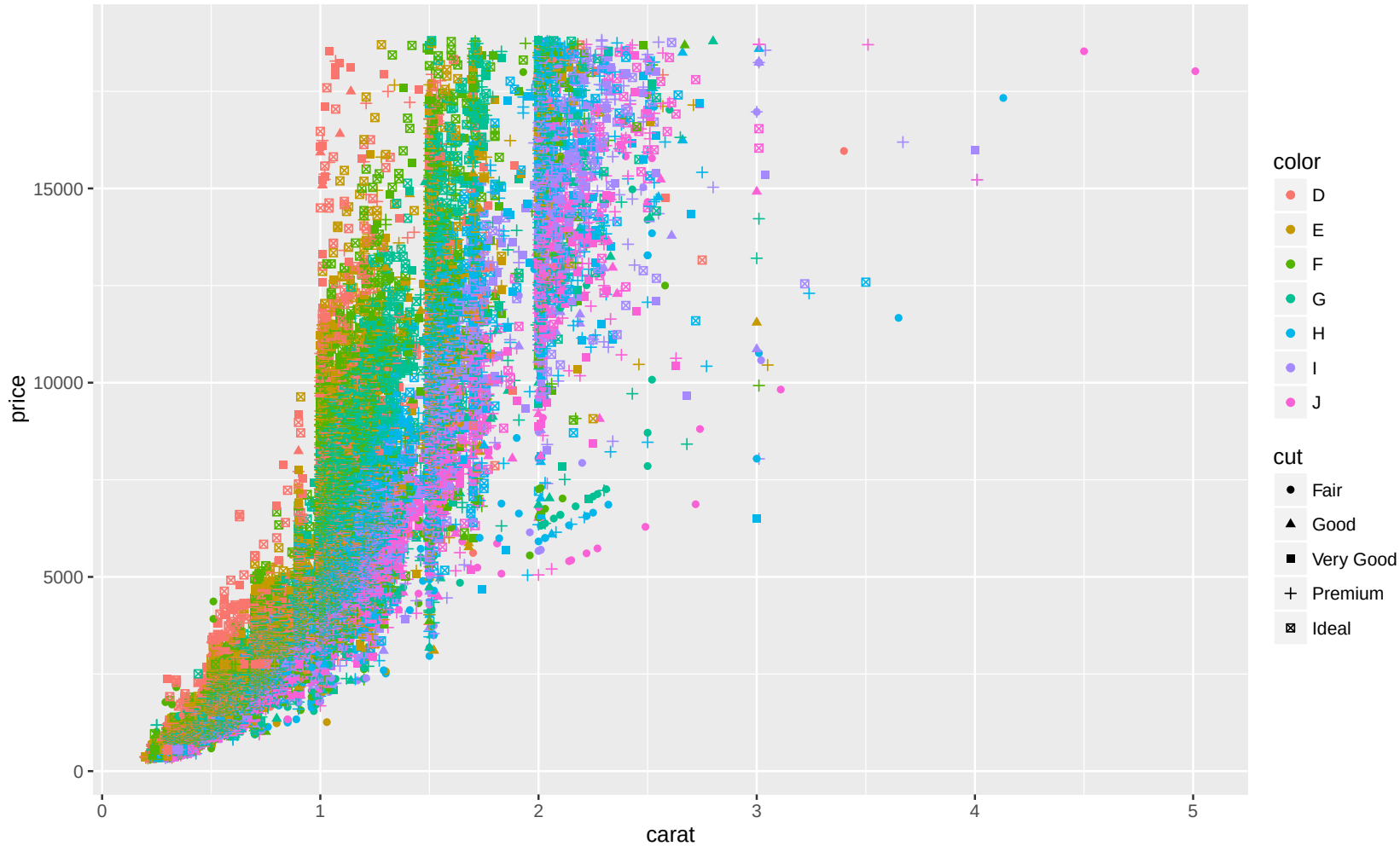
Diamond data plotted by base graphics

```
plot(diamonds$carat, diamonds$price, col = diamonds$color,
     pch = as.numeric(diamonds$cut))
```



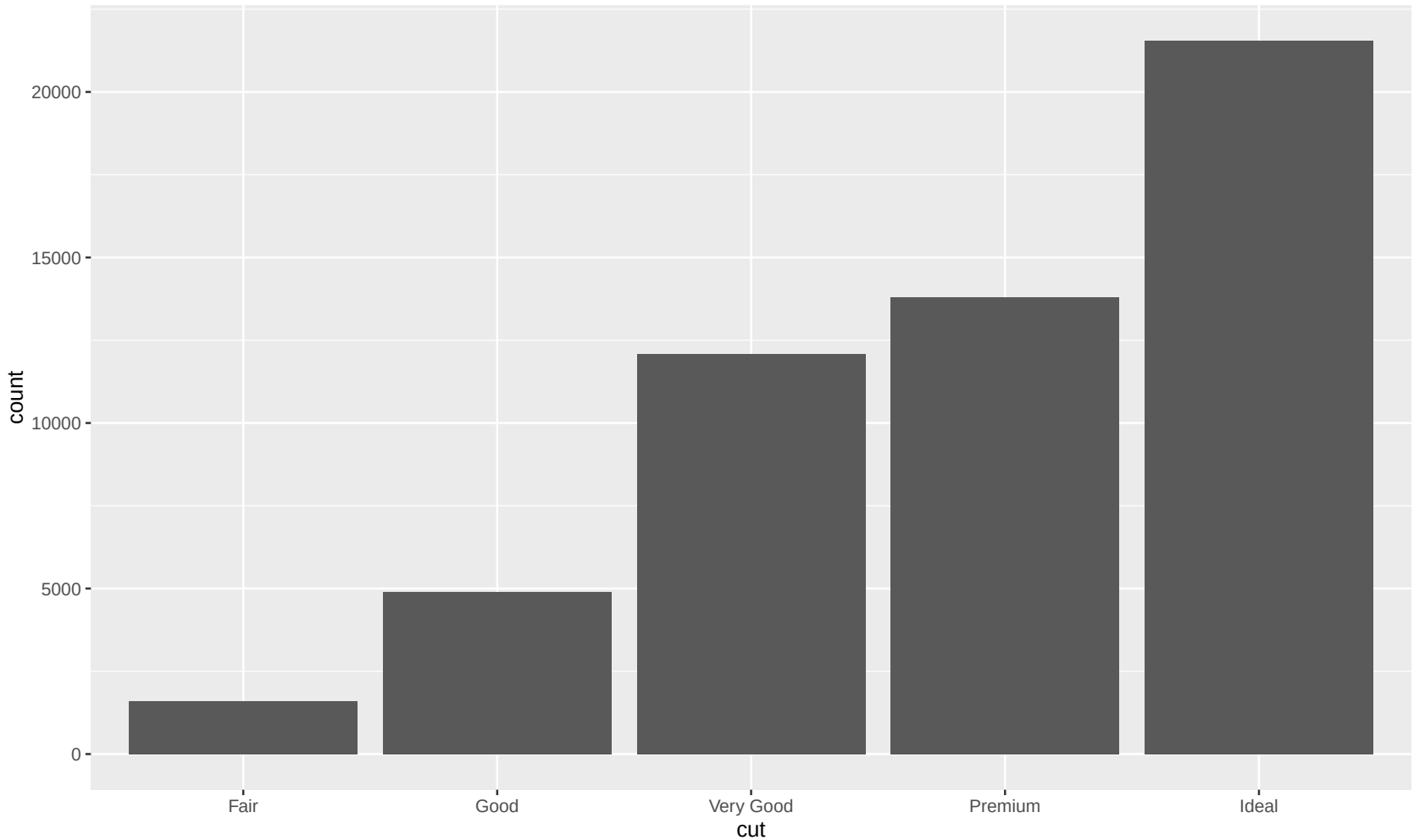
Diamond data plotted by ggplot2

```
ggplot(diamonds, aes(carat, price, col = color,
                     shape = cut)) +
    geom_point()
```



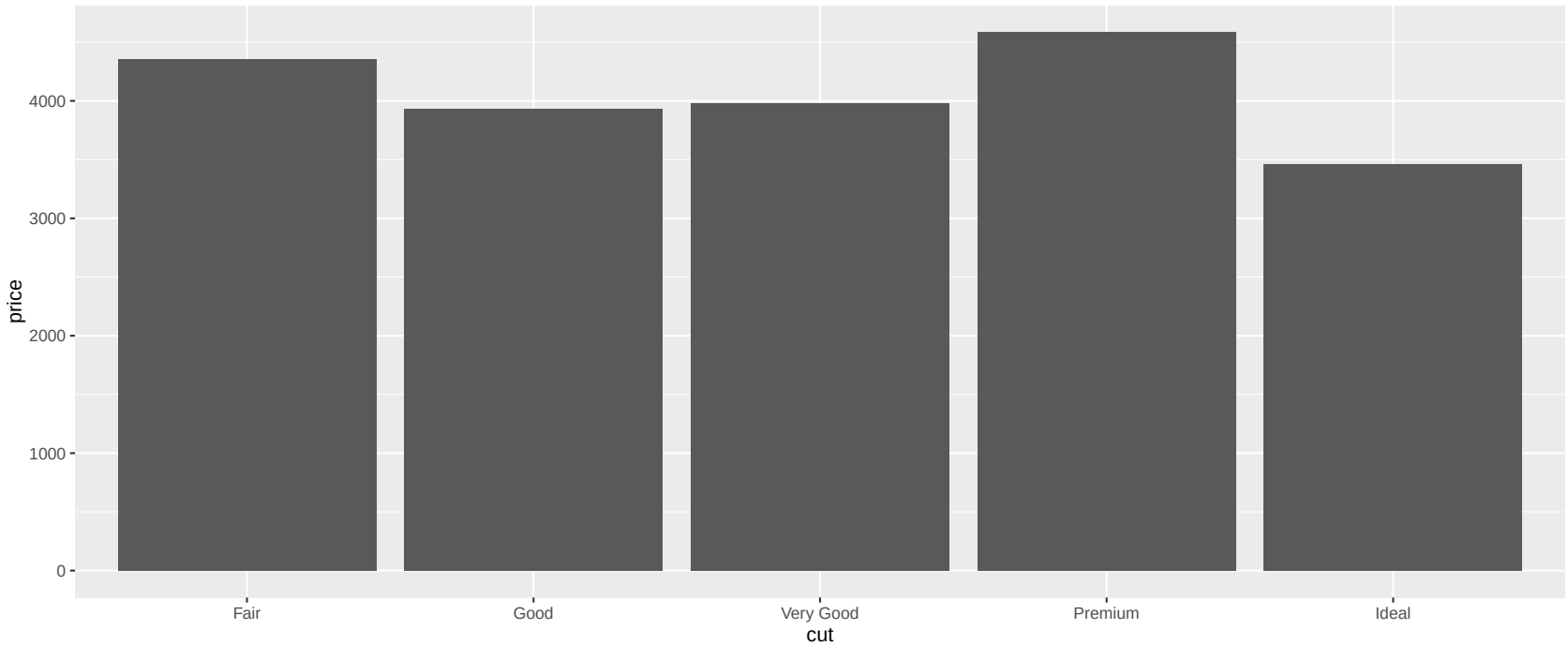
Diamond Example: count within each cut category

```
d <- ggplot(diamonds, aes(cut))
d + geom_bar()
```



Diamond Example: average prices within each cut category

```
d + stat_summary_bin(aes(y = price), fun.y = "mean",
                     geom = "bar")
```



Example: Napolean's March to Moscow

```
library(HistData)
head(Minard.troops)
```

```
##   long  lat survivors direction group
## 1 24.0 54.9    340000         A     1
## 2 24.5 55.0    340000         A     1
## 3 25.5 54.5    340000         A     1
## 4 26.0 54.7    320000         A     1
## 5 27.0 54.8    300000         A     1
## 6 28.0 54.9    280000         A     1
```

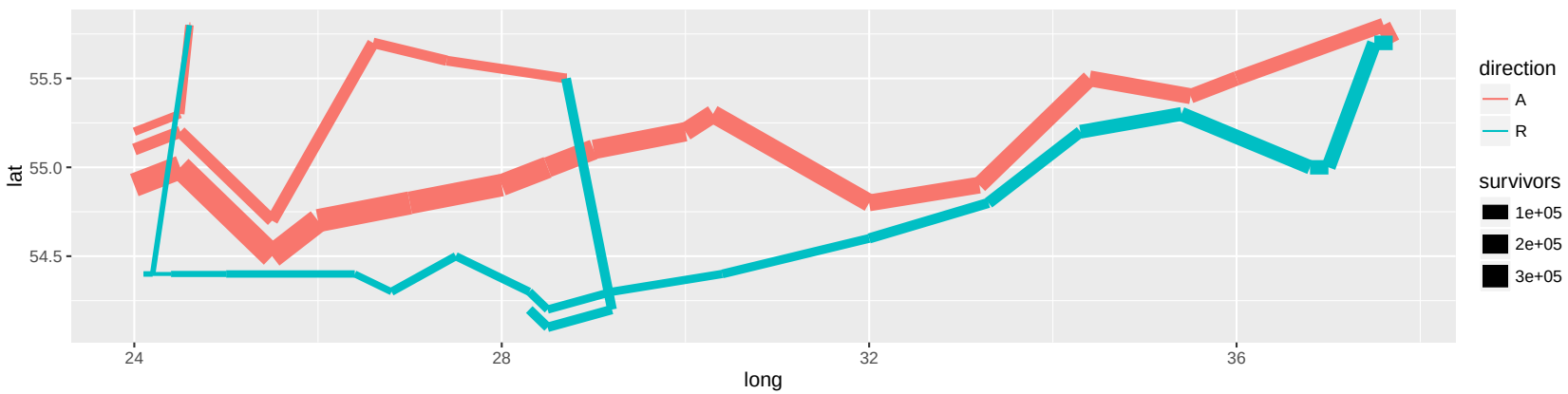
```
head(Minard.cities)
```

```
##   long  lat      city
## 1 24.0 55.0     Kowno
## 2 25.3 54.7     Wilna
## 3 26.4 54.4  Smorgoni
## 4 26.8 54.3 Moiodexno
```

Example: Napolean's March to Moscow

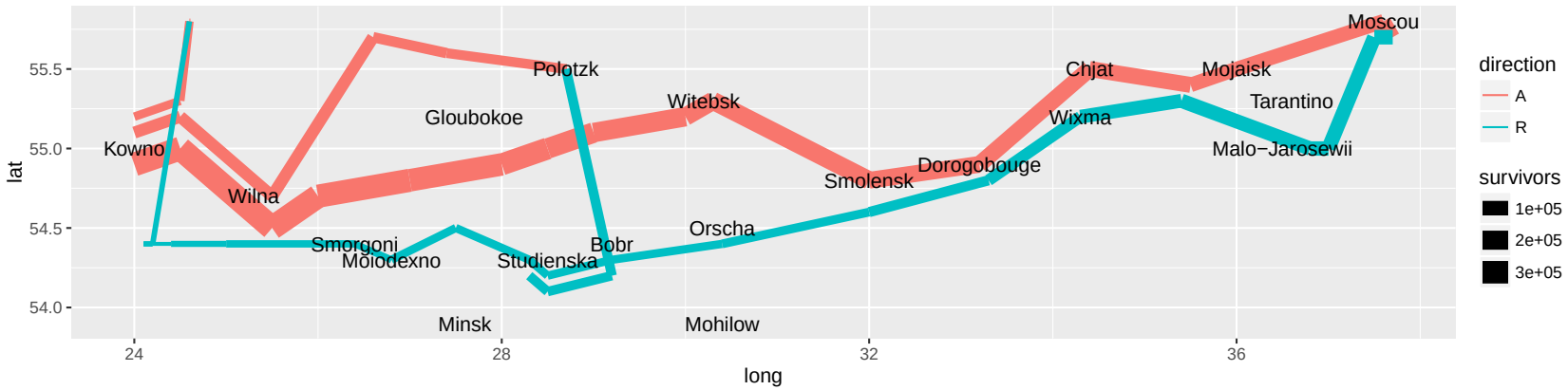
```
data(Minard.troops); data(Minard.cities)
library(ggplot2)
plot_troops <- ggplot(Minard.troops, aes(long, lat)) +
  geom_path(aes(size = survivors,
                colour = direction, group = group))

plot_troops
```



Example: Napolean's March to Moscow

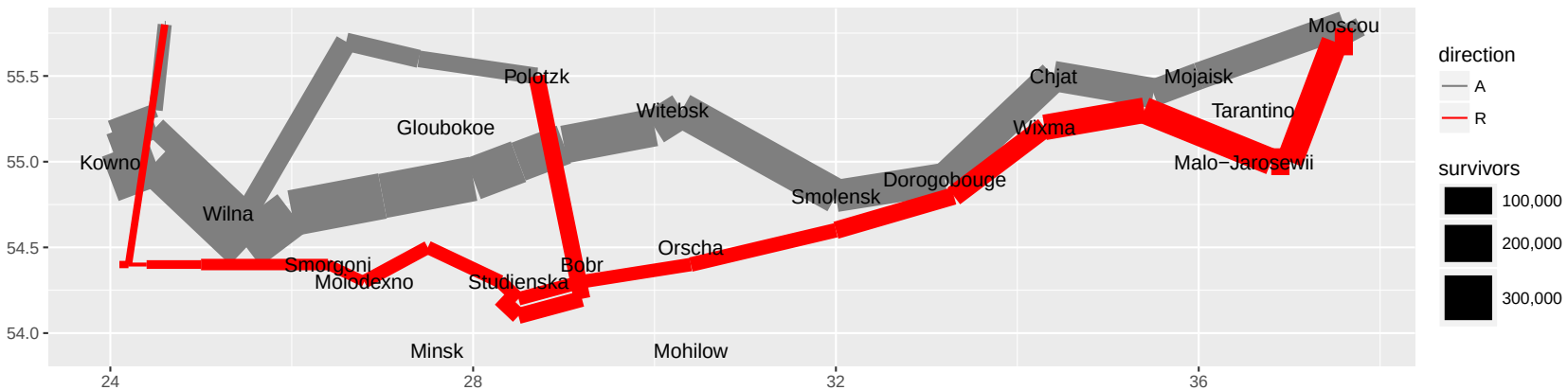
```
plot_both <- plot_troops +
  geom_text(aes(label = city), size = 4,
            data = Minard.cities)
plot_both
```



Example: Napolean's March to Moscow

```
plot_polished <- plot_both +
  scale_size(range = c(1, 12),
             breaks = c(1, 2, 3) * 10^5,
             labels = scales::comma(c(1, 2, 3) * 10^5)) +
  scale_colour_manual(values = c("grey50","red")) +
  xlab(NULL) +
  ylab(NULL)

plot_polished
```



What grammar of graphics doesn't do

- It doesn't suggest what graphics you should use to answer the questions you are interested in.
  - `ggplot2` focuses on how to produce the plots you want, not knowing what plots to produce.
- Grammar doesn't specify what a graphic should look like and how to make a plot attractive.
  - Finer details, e.g., font size, background color are not specified by the grammar.
  - `ggplot2` uses its theming system
- No real-time interaction; other dynamic and interactive graphics packages exist:
  - rCharts: http://rcharts.io/
  - clickme: https://github.com/nachocab/clickme
  - D3: Data-Driven Documents: https://d3js.org/

"Ins and Outs"

- Data manipulation (get your data into the form required by `ggplot2`). You will shortly encounter at least these two R packages written by the same author of `ggplot2`:
  - `reshape2`
  - `plyr`
- Make figures publishable
  - comprehensive theming system in `ggplot2`

Readings

- Wickham H(2009). A Layered Grammar of Graphics. *Journal of Computational and Graphical Statistics*

Optional:

- Examples of statistical graphics used in sport analytics:
  - Stephen Curry's Bombs Are Too Good To Be True - I mean, they have to be, right? (FiveThirtyEight.com, 2015)
  - Lionel Messi Is Impossible (FiveThirtyEight.com, 2014)
- Notes by Wickham himself:
  - `ggplot2` short courses by Wickham: http://courses.had.co.nz/11-rice/
  - `ggplot2` cheatsheet
- A book-length introduction:
  - Wickham (2010) `ggplot2`: *Elegant Graphics for Data Analysis (Use R!)*