An introduction to `ggplot2`

BISC 888–1 Simon Fraser University

Sean C. Anderson
sean@seananderson.ca

October 21, 2013

1 The `ggplot2` philosophy: rapid data exploration

`ggplot2` is an R package that implements Wilkinson's Grammar of Graphics.[1] Hadley Wickham wrote the package as a chapter of his PhD thesis. Many people now participate in developing the package.

The emphasis of `ggplot2` is on rapid exploration of data, and especially high-dimensional data. Think of base graphic functions as drawing with data[2]. You have complete control over every pixel in a plot (once you learn the arcane world of `par`) but it can take a lot of time and code to produce a complex plot.

Although `ggplot2` can be fully customized, I find it reaches a point of diminishing returns. I tend to use `ggplot2` and base graphics for what they excel at: `ggplot2` for rapid data exploration and base graphics for polished and fully-customized plots for publication (Figure 1).

The idea is simple: good graphical displays of data require rapid iteration and lots of exploration. If it takes you hours to code a plot in base graphics, you're unlikely to throw it out and try something else. If it takes you hours to code a plot in base graphics, you're unlikely to explore other ways of visualizing the data or all the dimensions of the data.

[1] Wilkinson, L. (2005). *The Grammar of Graphics*. Springer, 2^{2nd} edition.

[2] Examples of base graphic functions are `plot`, `points`, and `lines`.

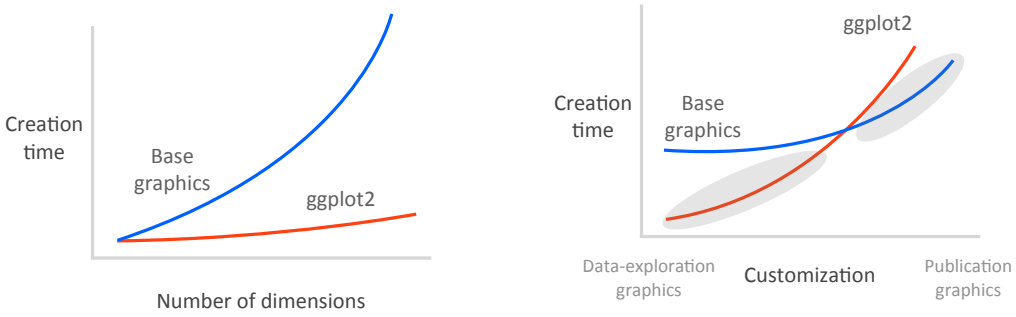


Figure 1: Creation time vs. data dimensions and customization level for base graphics (blue) and `ggplot2` (red). (Left panel) It's remarkably easy to plot high-dimensional data in `ggplot2` with, for example, colours, sizes, shapes, and panels. (Right panel) `ggplot2` excels at rapid visual exploration of data, but has some limitations in how it can be customized. Base graphics are fully customizable but can take longer to set up. I try and exploit the grey shaded areas: I use `ggplot2` for data exploration and once I've decided on a small number of key plots, I'll use base graphics to make fully-customized plots if needed.

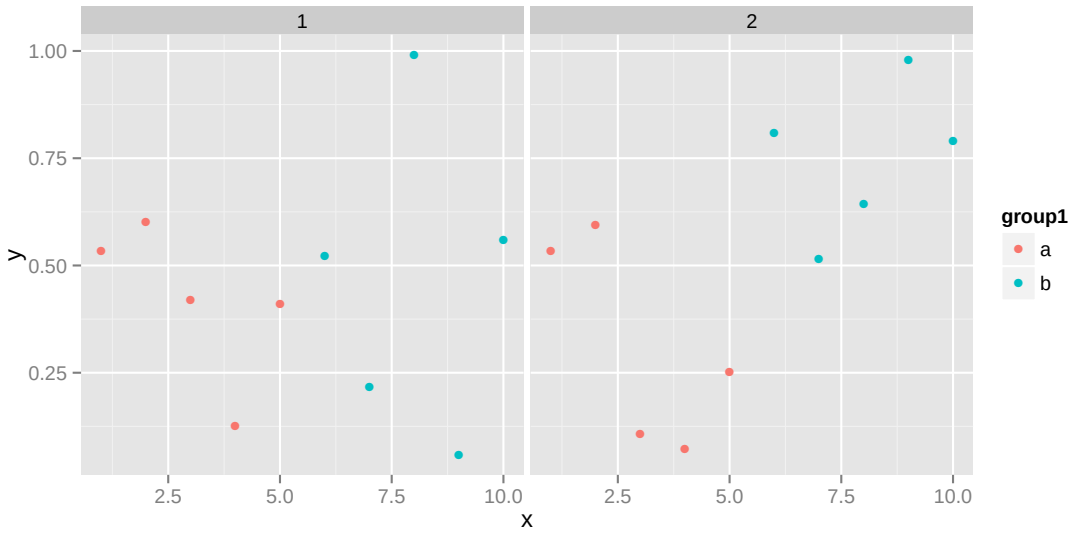
2 `qplot` vs. `ggplot`

There are two main plotting functions in the `ggplot2` package: `qplot` and `ggplot`. `qplot` is short for "quick plot" and is made to mimic the format of `plot` from base R. `qplot` requires less syntax for many common tasks, but has limitations — it's essentially a wrapper for `ggplot`. The `ggplot` function itself isn't complicated and will work in all cases. I prefer to work with just the `ggplot` syntax and will focus on it here.

3 Basics of the grammar

Let's look at some illustrative `ggplot2` code:

```
library(ggplot2)
d <- data.frame(x = c(1:10, 1:10), y = runif(20),
  group1 = rep(gl(2, 5, labels = c("a", "b")), 2),
  group2 = gl(2, 10))
ggplot(d) + geom_point(aes(x, y, colour = group1)) +
  facet_grid(~group2)
```



The basic format in this example is:

1. `ggplot()`: start a `ggplot` object and specify the data
2. `geom_point()`: we want a scatter plot; this is called a `geom`
3. `aes()`: specifies the "aesthetic" elements; a legend is automatically created
4. `facet_grid()`: specifies the panel layout

There are also statistics, scales, and annotation options, among others. At a minimum, you must specify the data, some aesthetics, and a geom. I will elaborate on these below. Yes, `ggplot2` combines elements with `+` symbols! This may seem non-standard, although it has the advantage of allowing `ggplot2` plots to be proper R objects, which can modified, inspected, and re-used.

4 Geoms

geom refers to a geometric object. It determines the "shape" of the plot elements. Some common geoms:

geom	description
geom_point	Points, e.g. a scatterplot
geom_line	Lines
geom_ribbon	Ribbons, y range with continuous x values
geom_polygon	Polygon, a filled path
geom_pointrange	Vertical line with a point in the middle
geom_linerange	An interval represented by a vertical line
geom_path	Connect observations in original order
geom_histogram	Histograms
geom_text	Textual annotations
geom_violin	Violin plot
geom_map	Polygons from a map

5 Aesthetics

Aesthetics refer to the attributes of the data you want to display. They map the data to an attribute (such as the size or shape of a symbol) and generate an appropriate legend. Aesthetics are specified with the aes function.

As an example, the aesthetics available for geom_point are: x, y, alpha, colour, fill, shape, and size.[3] Read the help files to see the aesthetic options for the geom you're using. They're generally self explanatory.

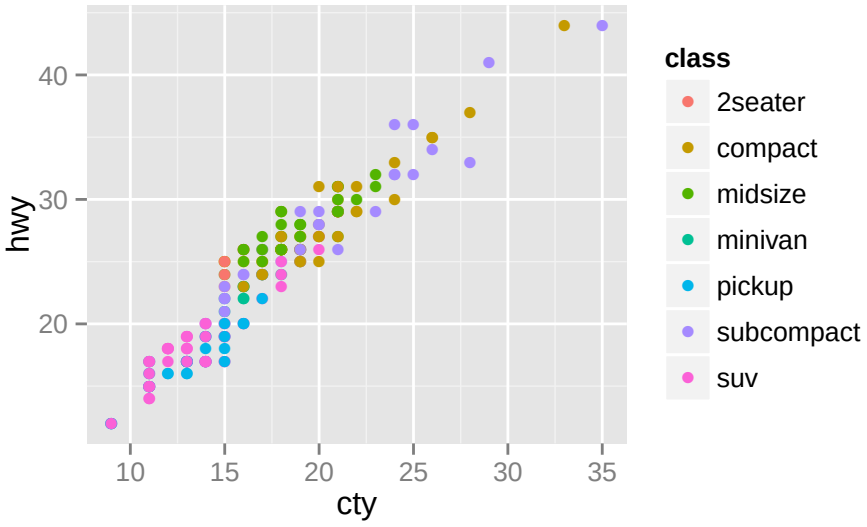
Aesthetics can be specified within the data function or within a geom. If they're specified within the data function then they apply to all geoms you specify.

Note the important difference between specifying characteristics like colour and shape inside or outside the aes function — those inside the aes function are assigned the colour or shape automatically based on the data. If characteristics like colour or

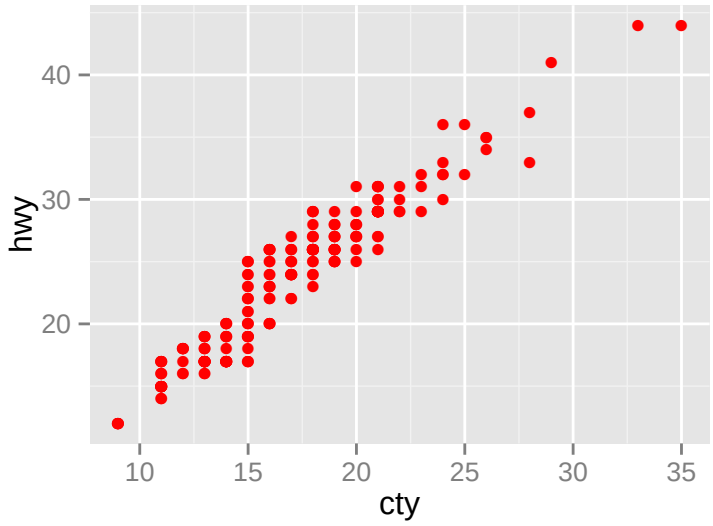
[3]Note that ggplot2 tries to accommodate the user who's never "suffered" through base graphics before by using intuitive arguments like colour, size, and linetype, but ggplot will also accept arguments such as col, cex, and lty.

shape are defined outside the `aes` function, then the characteristic is not mapped to data. Example:

```
ggplot(mpg, aes(cty, hwy)) + geom_point(aes(colour = class))
```



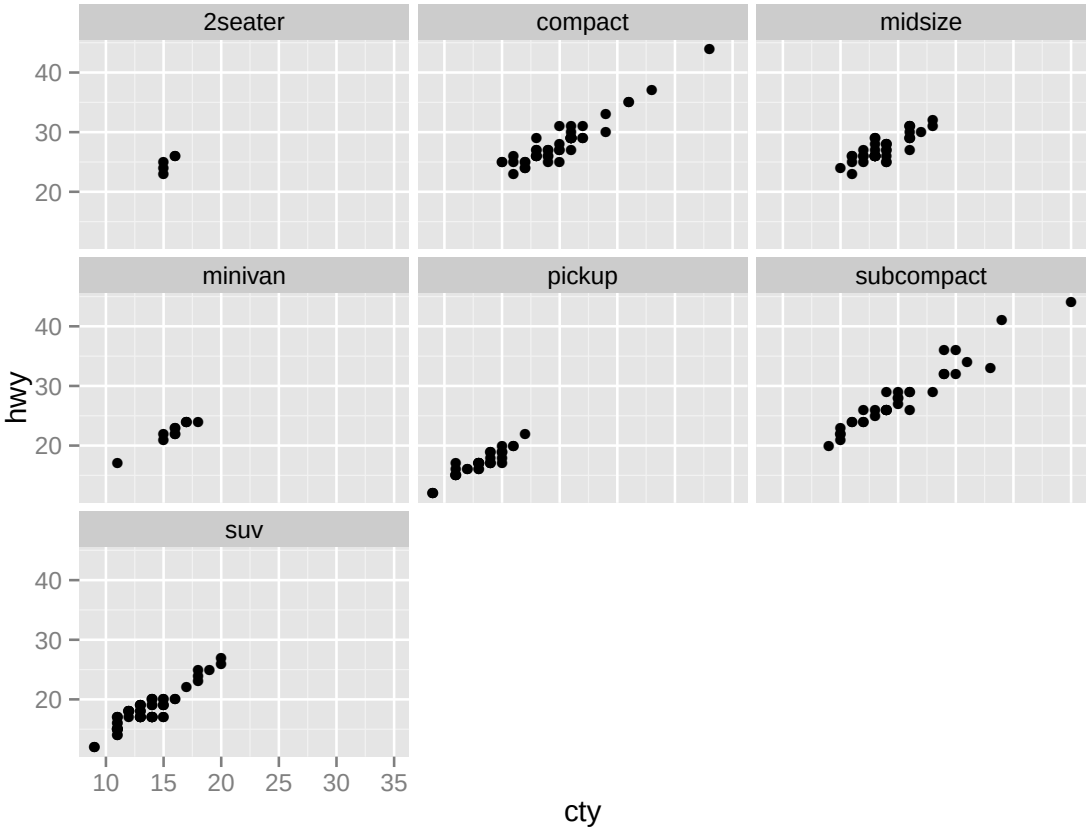

```
ggplot(mpg, aes(cty, hwy)) + geom_point(colour = "red")
```



6 Small multiples

In `ggplot2` parlance, small multiples are referred to as facets. There are two kinds: `facet_wrap` and `facet_grid`. This is where `ggplot2` really shines.

```
ggplot(mpg, aes(cty, hwy)) + geom_point() + facet_wrap(~class)
```



```
ggplot(mpg, aes(cty, hwy)) + geom_point() + facet_grid(year~class)
```

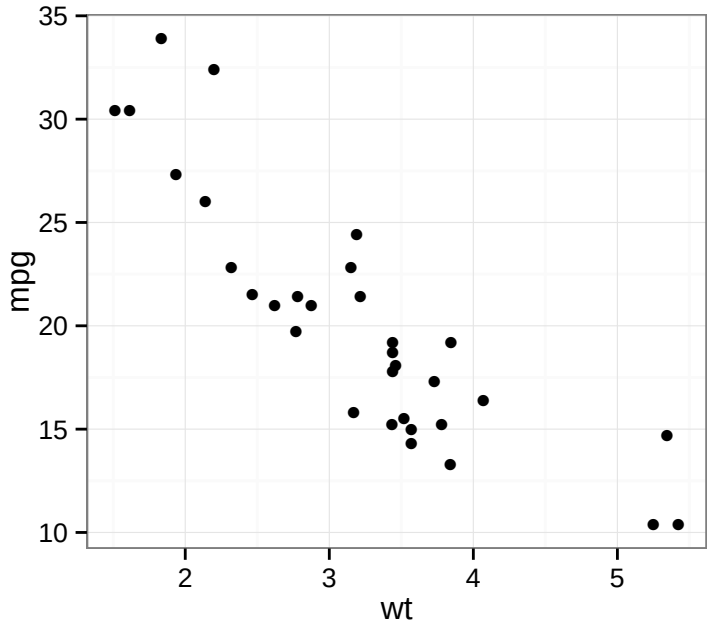
`face_wrap` plots the panels in the order of the factor levels. When it gets to the end of a column it wraps to the next column. You can specify the number of columns and rows with `nrow` and `ncol`. `facet_grid` lays out the panels in a grid with an explicit x and y position.

By default all x and y axes will be shared among panels. You could, for example, specify "free" y axes with `face_wrap(scales = "free_y")`.

7 Themes

A useful theme built into `ggplot2` is `theme_bw`:

```
dsamp <- diamonds[sample(nrow(diamonds), 1000), ]
ggplot(mtcars, aes(wt, mpg)) + geom_point() + theme_bw()
```

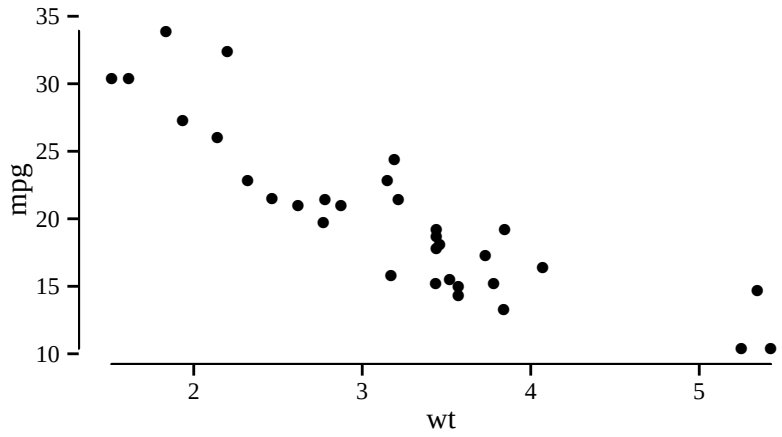


A powerful aspect of `ggplot2` is that you can write your own themes. This feature of `ggplot2` was recently expanded, and I imagine we'll see more themes developed and shared in the future. See the `ggthemes` package for some examples.[4]

[4]Install the R package from: `https://github.com/jrnold/ggthemes`

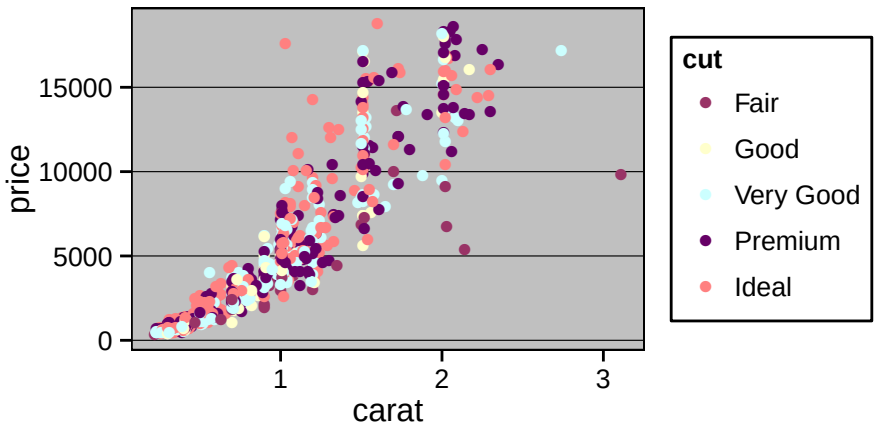
An Edward Tufte-like theme:

```
library("ggthemes")
ggplot(mtcars, aes(wt, mpg)) + geom_point() + geom_rangeframe() +
 theme_tufte()
```



Just what you wanted:

```
qplot(carat, price, data = dsamp, colour = cut) + theme_excel() +
 scale_colour_excel()
```



You can customize just about every aspect of a `ggplot2` plot. We won't get into that today, but see the additional help resources at the end of this document.

8 ggplot2's dirty little secret

1. ggplot2 is easy to learn, however ...
2. you need to be a data-manipulation ninja to effectively use it

With base graphics, you can work with almost any data structure you'd like, providing you can write the code to work with it. ggplot2 requires you to think carefully about the data structure and then write one line of code.

ggplot works with "long" format data with each aesthetic or facet variable in its own column. So, for example, if we wanted a panel for each level of a factor called fishstock then we'd need a column named fishstock with all the different values of fishstock in that column.

With the reshape2 and plyr packages, combined with merge (or join from the plyr package), you can get almost any dataset into shape for ggplot2 in a few lines. Sometimes this will take some serious thought along with pen and paper.

9 Random tips

Jittering and statistics
ggplot2 has lots of built in niceties like automatic position jittering and the addition of basic statistical models to your plots. Have a look through the help resources listed at the end of this document.

Axis labels
```
xlab("Your x-axis label")
```

Suppressing the legend
```
theme(legend.position = "none")
```

Exploiting the object-oriented nature of `ggplot2`

Save the basic plot to an object and then experiment with different aesthetics, geoms, and theme adjustments.

```
# Build the basic object:
p <- ggplot(d) + geom_point(aes(x, y, colour = group1))
p + facet_grid(~group1) # try one way
p + facet_grid(~group2) # try another way
```

Horizontal error bars

Say you want to make a coefficient plot with the coefficients down the y-axis. You can either build the plot piece by piece with points and segments, or you can use `point_range()` and then rotate the axes with `+ coord_flip()`.

Axis limits and zooming

`ggplot2` has two ways of adjusting the axis limits: `+ xlim(2, 5)` will "cut" the data at `2` and `5` and plot the data. `coord_cartesian(xlim = c(2, 5))` will zoom in on the plot while retaining the original data. This will, for example, affect colour scales.

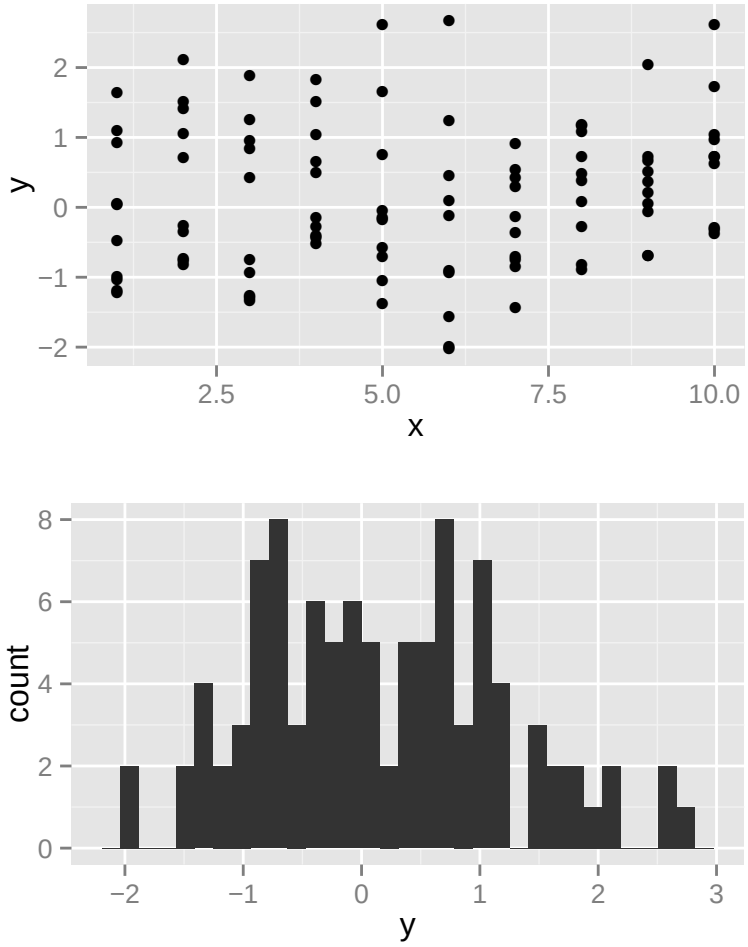
Displaying and saving `ggplot2` plots

If `ggplot2` plots are generated in a function, they will be need to be wrapped in `print()` to display. There is a convenience function `ggsave("filename.pdf")`, which will save the last plot to a pdf and guess at reasonable dimensions. You can, of course specify which plot to save and the dimensions of the pdf. You can also use all the same methods of saving `ggplot2` plots that you can use for base graphics.

Combining multiple `ggplot2` panels

`ggplot2` makes it easy to create multipanel figures with `facet_grid` and `facet_wrap`. But, sometimes you need to combine different kinds of plots in one figure or plots that require different data. One easy way to do this is with the `grid.arrange` function from the `gridExtra` package. For example:

```
df <- data.frame(x = 1:10, y = rnorm(100))
p1 <- ggplot(df, aes(x, y)) + geom_point()
p2 <- ggplot(df, aes(y)) + geom_histogram()
gridExtra::grid.arrange(p1, p2)
```



10 Help

The best (and nearly essential) help source is the website, which is largely based off the package help files. However, the website also shows the example plots and is easier to navigate:
`http://docs.ggplot2.org/`
Don't be afraid to keep it open whenever you're using `ggplot2`.

There's also an active `ggplot2` discussion group:
`http://groups.google.com/group/ggplot2`

`ggplot2` is heavily featured on stackoverflow:
`http://stackoverflow.com/questions/tagged/ggplot2`

Hadley wrote a book on `ggplot2`: `http://ggplot2.org/book/`. It's quite thorough but doesn't feature some of the newer additions to the package.