Why GGplot2

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Why ggplot2?

Advantages of ggplot2

- consistent underlying grammar of graphics (Wilkinson, 2005) * plot specification at a high level of abstraction * very flexible * theme system for polishing plot appearance * mature and complete graphics system * many users, active mailing list * That said, there are some things you cannot (or should not) do With ggplot2:

3-dimensional graphics (see the rgl package) Graph-theory type graphs (nodes/edges layout; see the igraph package) Interactive graphics (see the ggvis package)

What Is The Grammar Of Graphics?

The basic idea: independently specify plot building blocks and combine them to create just about any kind of graphical display you want. Building blocks of a graph include:

- data * aesthetic mapping * geometric object * statistical transformations *scales* coordinate system * position adjustments * faceting

Lets load data:

```
setwd("~/Dropbox/ubehjælpelige forsøg på programmering/Assignment1")
housing <- read.csv("Rgraphics/dataSets/landdata-states.csv")
head(housing[1:5])
```

```
##   State region    Date Home.Value Structure.Cost
## 1    AK   West 2010.25     224952         160599
## 2    AK   West 2010.50     225511         160252
## 3    AK   West 2009.75     225820         163791
## 4    AK   West 2010.00     224994         161787
## 5    AK   West 2008.00     234590         155400
## 6    AK   West 2008.25     233714         157458
```

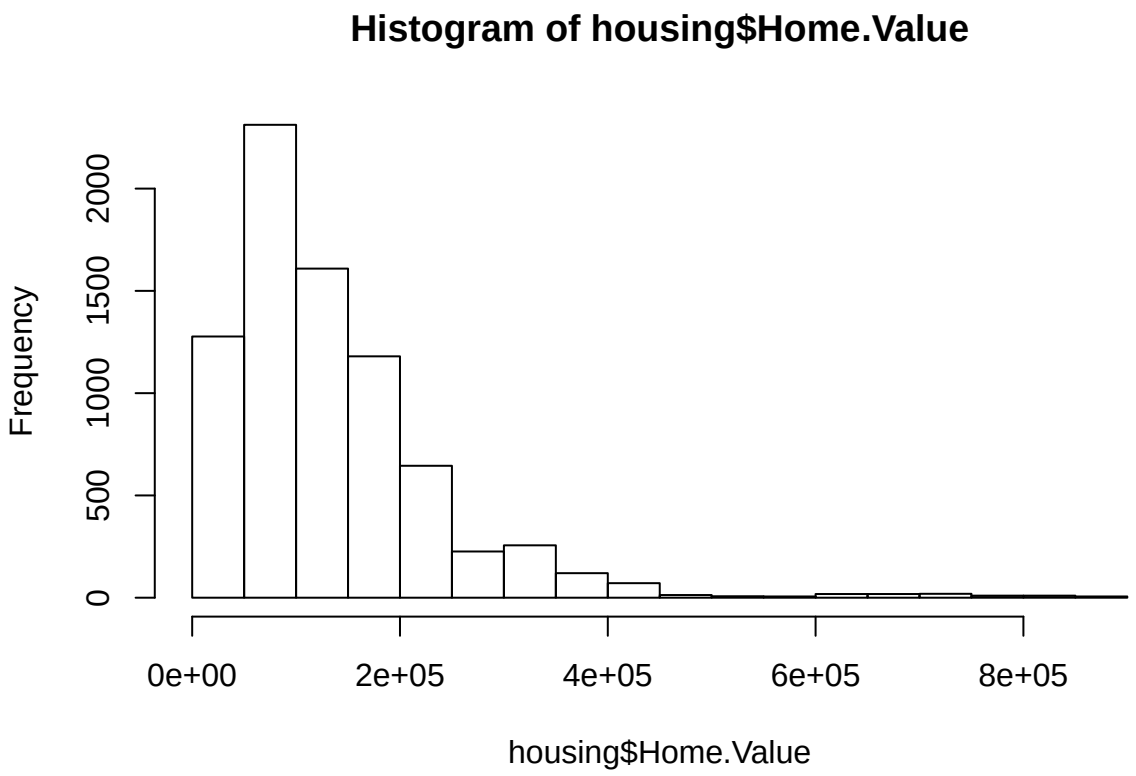
ggplot2 VS Base Graphics

Compared to base graphics, ggplot2

- is more verbose for simple / canned graphics * is less verbose for complex / custom graphics * does not have methods (data should always be in a data.frame)
- uses a different system for adding plot elements * ggplot2 VS Base for simple graphs

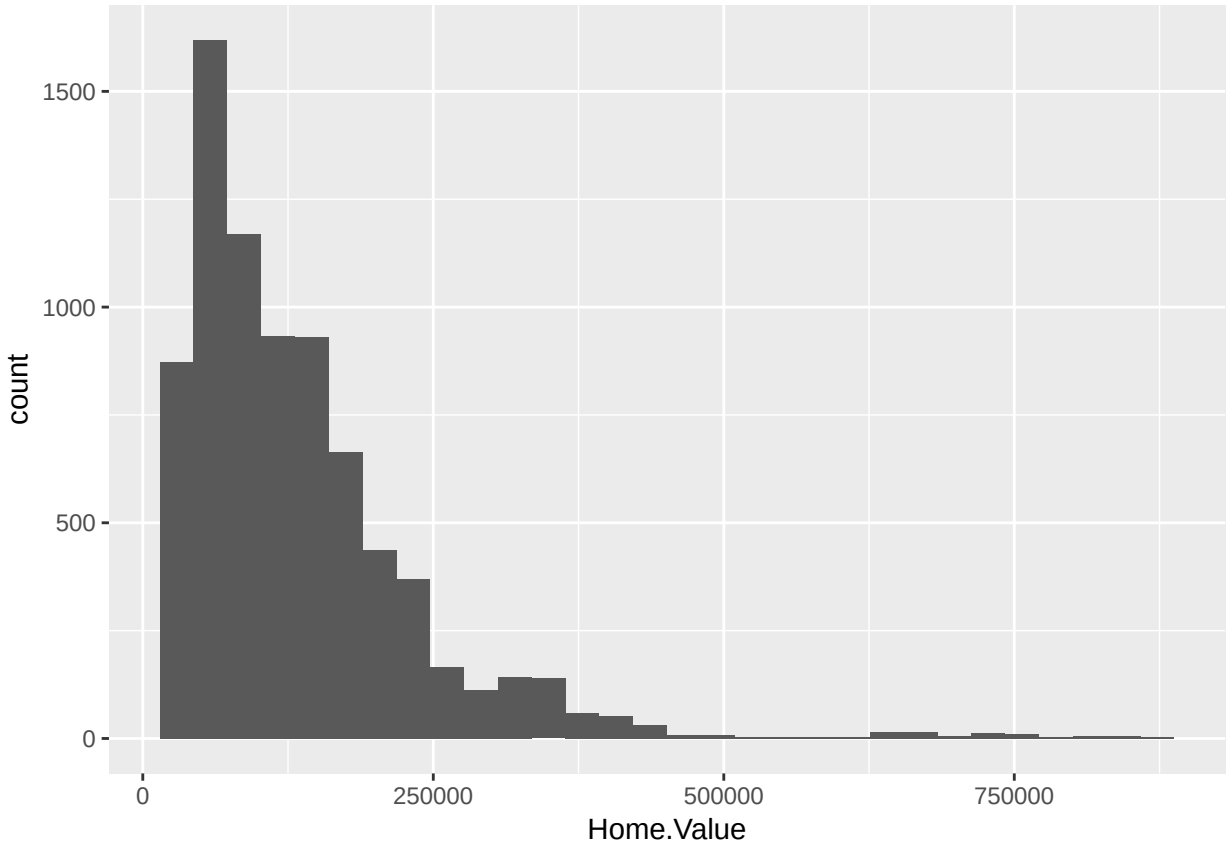
Base graphics histogram example:

```
hist(housing$Home.Value)
```



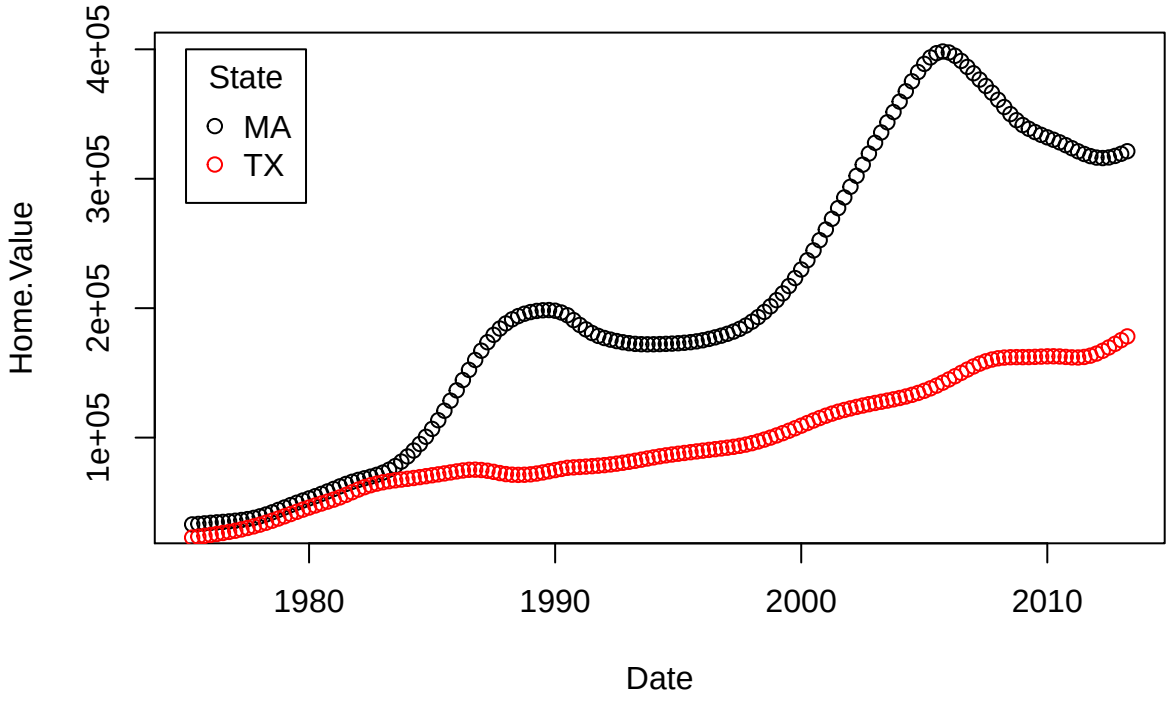
```
library(ggplot2)
ggplot(housing, aes(x = Home.Value)) +
geom_histogram()
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



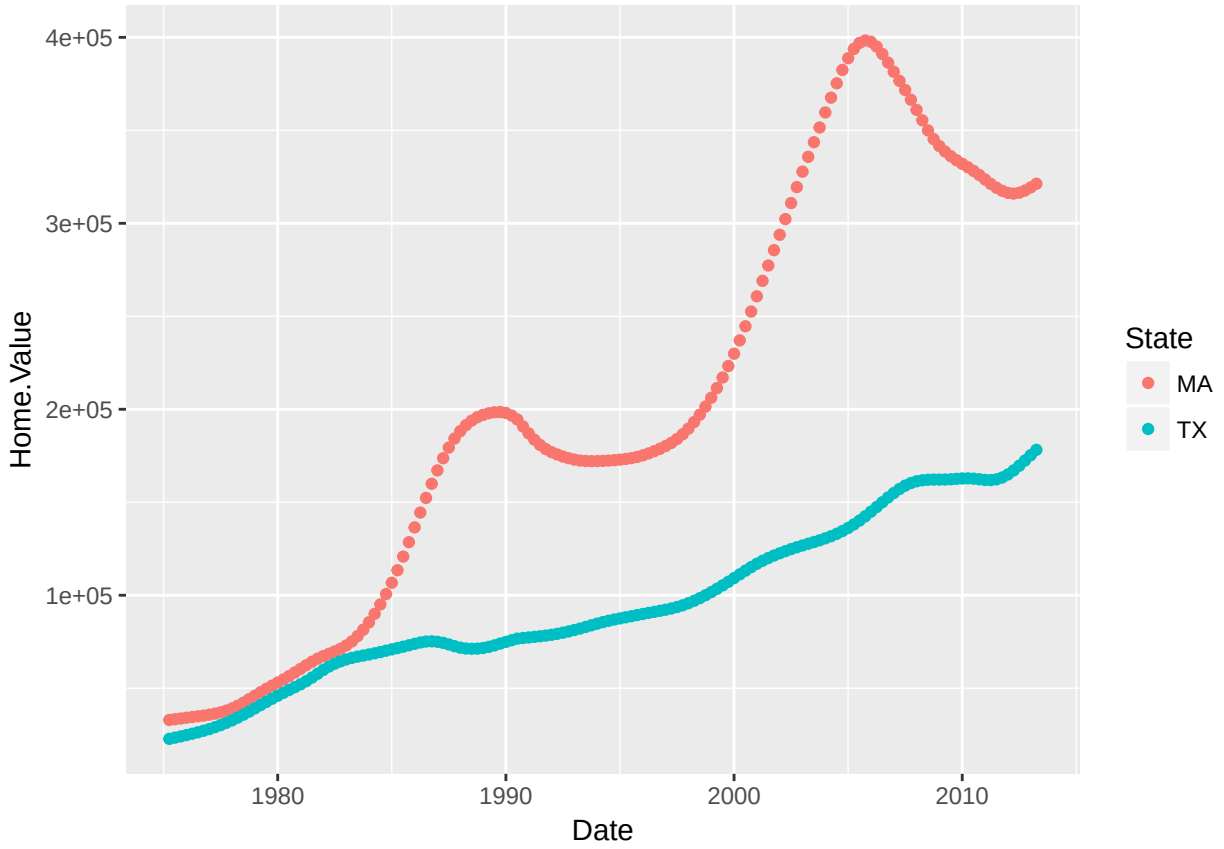
Base colored scatter plot example:

```
plot(Home.Value ~ Date, data=subset(housing, State == "MA"))
points(Home.Value ~ Date, col="red", data=subset(housing, State == "TX"))
legend(1975, 400000, c("MA", "TX"), title="State", col=c("black", "red"), pch=c(1, 1))
```



ggplot2 colored scatter plot example:

```
ggplot(subset(housing,
State %in% c("MA", "TX")), aes(x=Date, y=Home.Value, color=State))+ geom_point()
```



ggplot2 wins!

Geometric Objects And Aesthetics

Aesthetic Mapping

In ggplot land aesthetic means "something you can see". Examples include:

- position (i.e., on the x and y axes) * color ("outside" color) * fill ("inside" color) * shape (of points) * linetype * size

Each type of geom accepts only a subset of all aesthetics–refer to the geom help pages to see what mappings each geom accepts. Aesthetic mappings are set with the aes() function.

Geometic Objects (geom)

Geometric objects are the actual marks we put on a plot. Examples include:

- points (geom_point, for scatter plots, dot plots, etc) * lines (geom_line, for time series, trend lines, etc) boxplot (geom_boxplot, for, well, boxplots!) A plot must have at least one geom; there is no upper limit. You can add a geom to a plot using the + operator

You can get a list of available geometric objects using the code below:

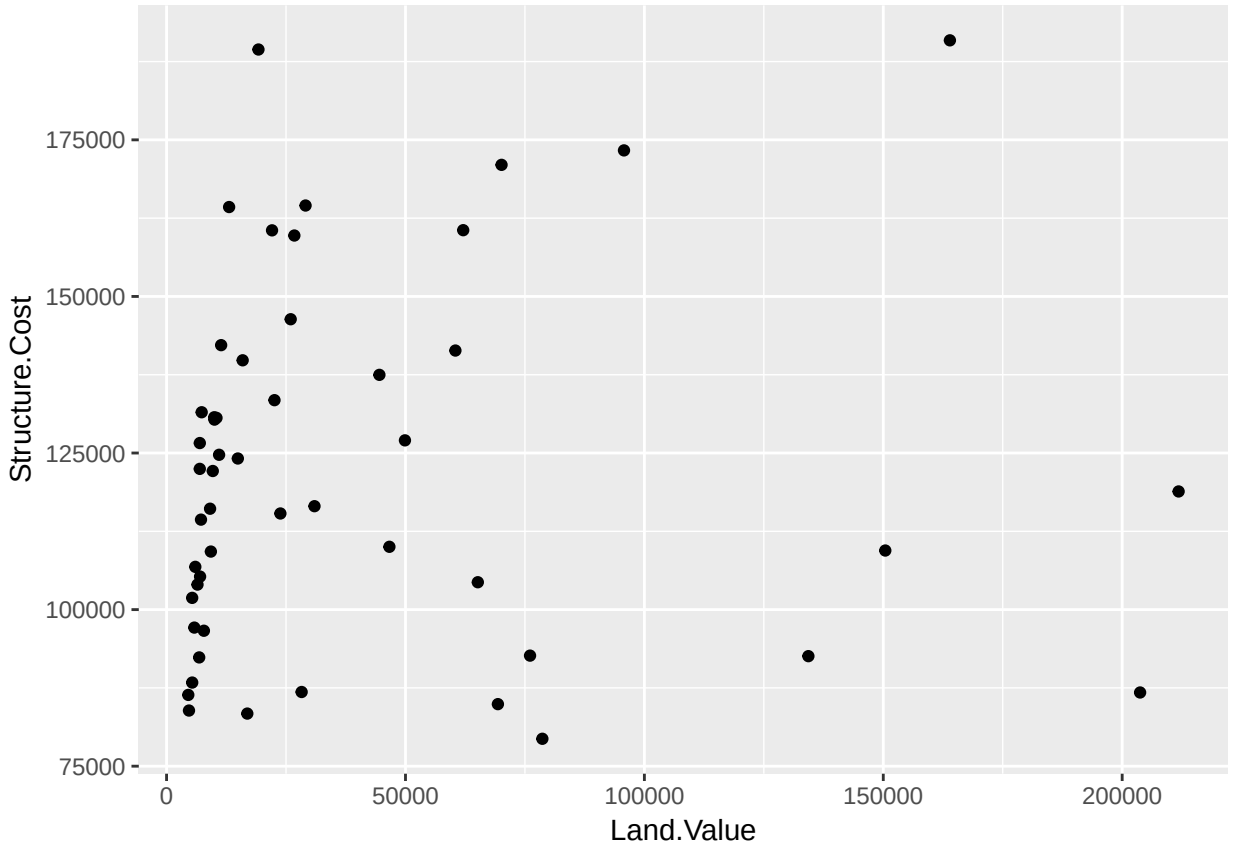
help.search("geom_", package = "ggplot2")

or simply type geom_ in any good R IDE (such as Rstudio or ESS) to see a list of functions starting with geom_.

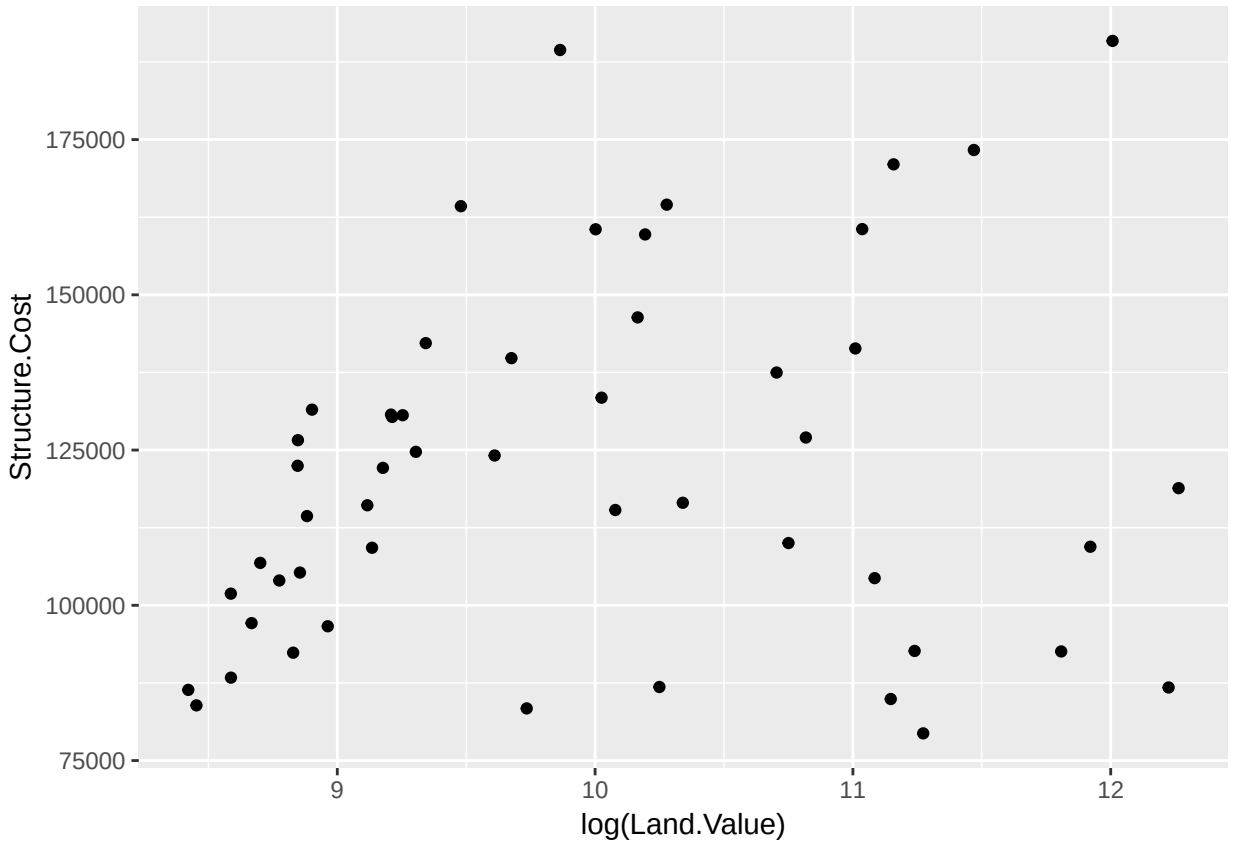
Points (Scatterplot)

Now that we know about geometric objects and aesthetic mapping, we can make a ggplot. geom_point requires mappings for x and y, all others are optional.

```
hp2001Q1 <- subset(housing, Date == 2001.25)
ggplot(hp2001Q1, aes(y = Structure.Cost, x = Land.Value)) + geom_point()
```




```
ggplot(hp2001Q1, aes(y = Structure.Cost, x = log(Land.Value))) + geom_point()
```


175000
150000
125000
100000
75000
Structure.Cost
9
10
11
12
log(Land.Value)

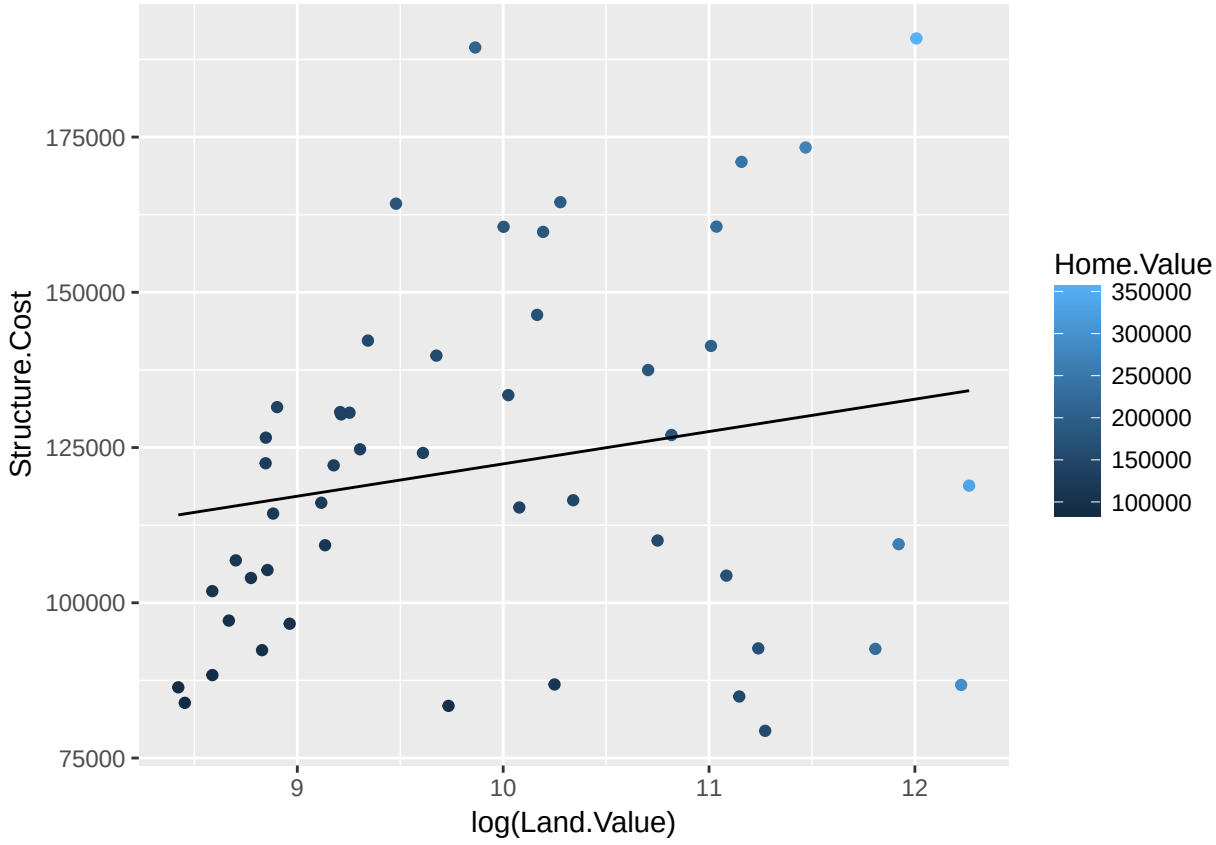
##Lines (Prediction Line)

A plot constructed with ggplot can have more than one geom. In that case the mappings established in the ggplot() call are plot defaults that can be added to or overridden. Our plot could use a regression line:

```
hp2001Q1$pred.SC <-
predict(lm(Structure.Cost ~ log(Land.Value), data = hp2001Q1))

p1 <- ggplot(hp2001Q1, aes(x = log(Land.Value), y = Structure.Cost))

p1 + geom_point(aes(color = Home.Value)) + geom_line(aes(y = pred.SC))
```

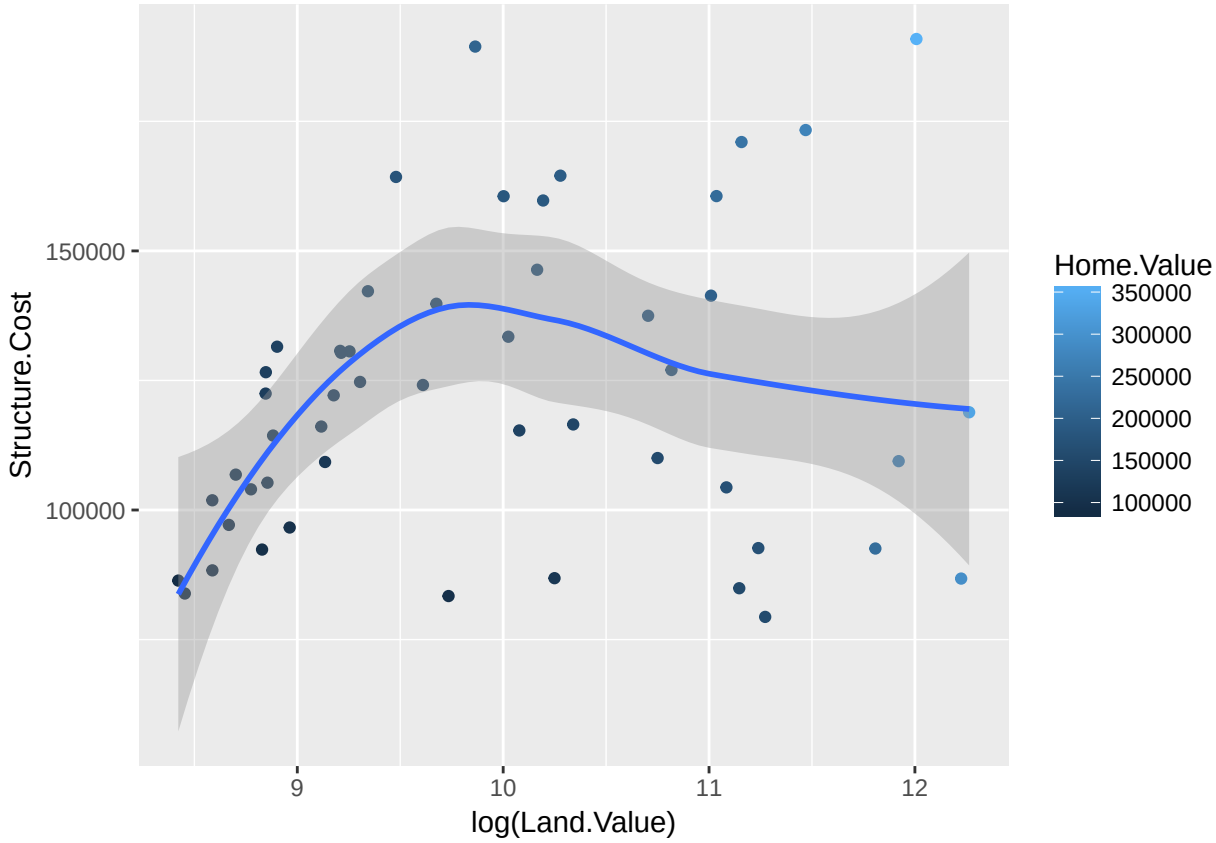


Smoothers

Not all geometric objects are simple shapes–the smooth geom includes a line and a ribbon.

```
p1 + geom_point(aes(color = Home.Value)) + geom_smooth()
```

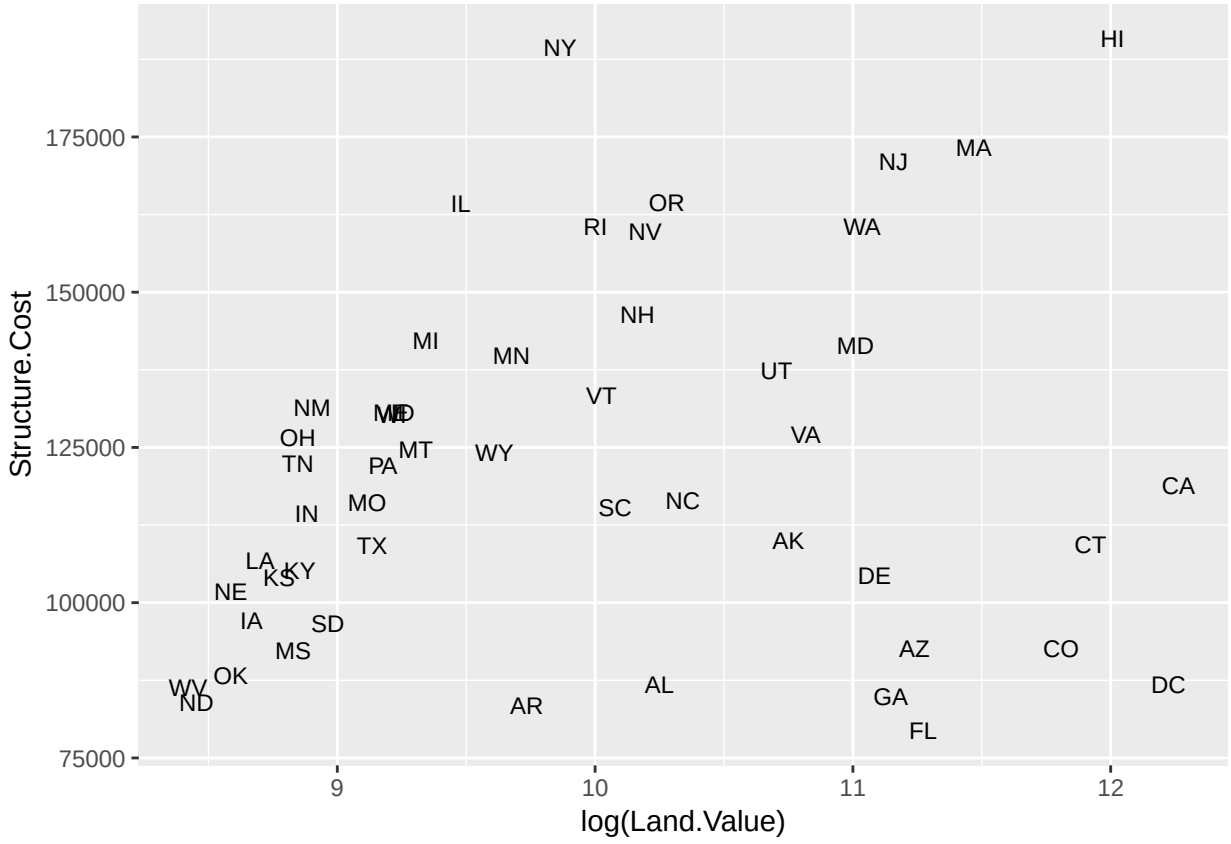
```
## `geom_smooth()` using method = 'loess'
```



Text (Label Points)

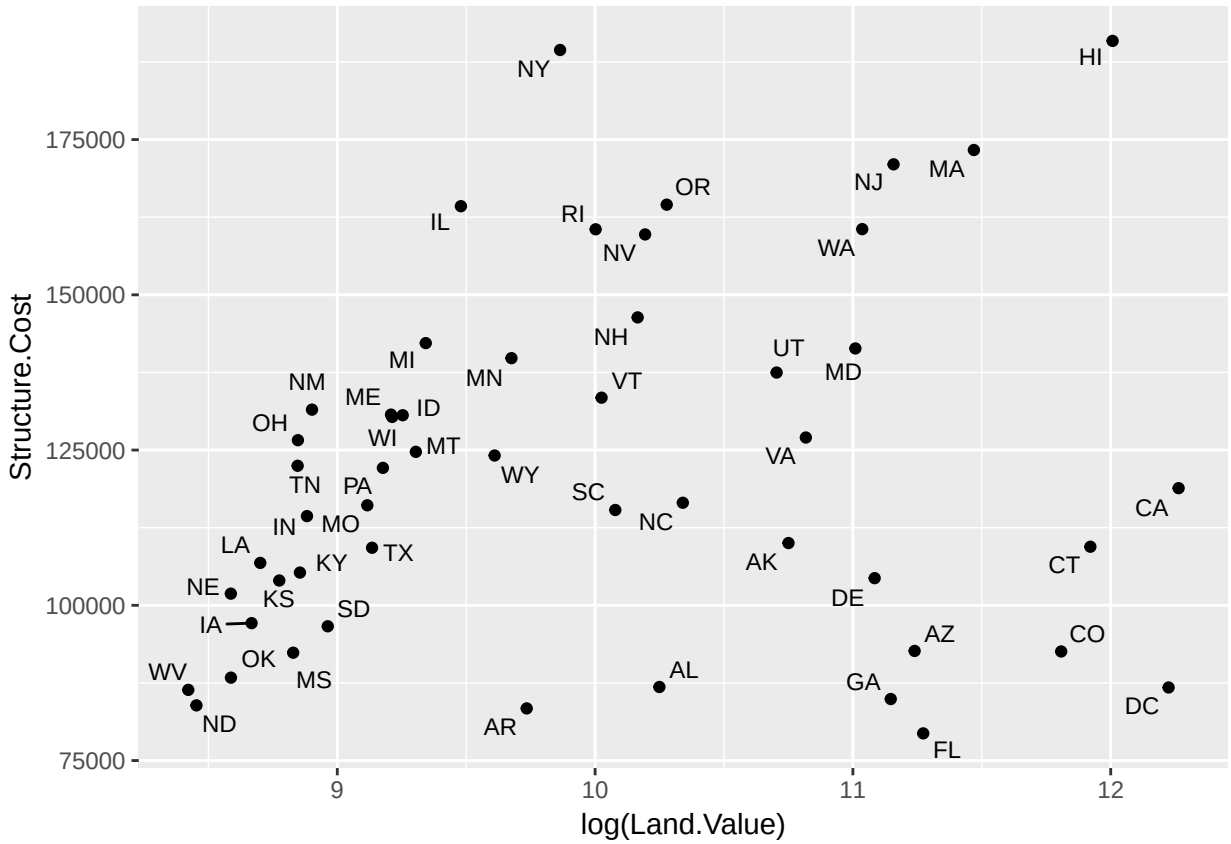
Each geom accepts a particualar set of mappings–for example geom_text() accepts a labels mapping.

```
p1 + geom_text(aes(label=State), size = 3)
```



install.packages("ggrepel")

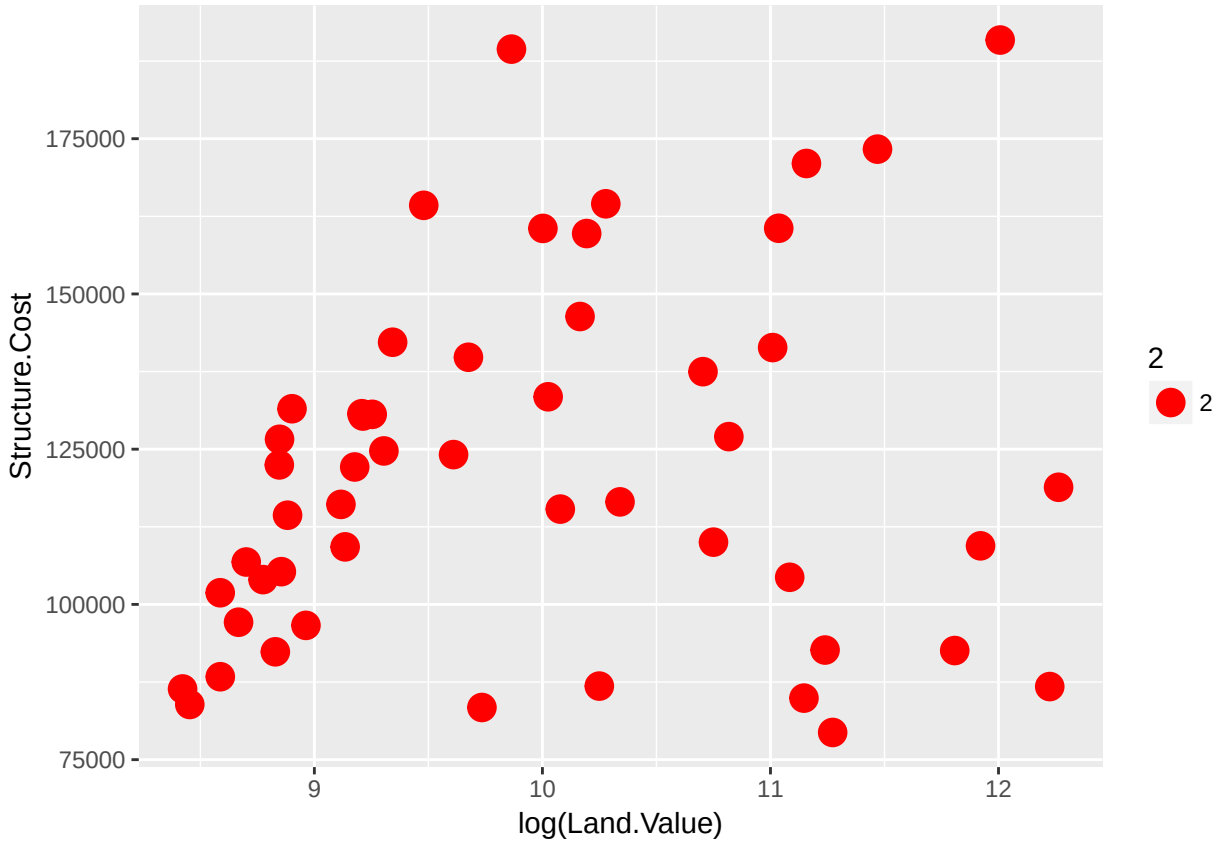
```
library("ggrepel")
p1 + geom_point() + geom_text_repel(aes(label=State), size = 3)
```


Structure.Cost
log(Land.Value)
175000
150000
125000
100000
75000
9
10
11
12
NY
HI
MA
NJ
OR
IL
RI
NV
WA
NH
UT
MD
MI
MN
VT
NM
ME
ID
OH
WI
MT
VA
WY
TN
PA
SC
CA
NC
IN
MO
LA
TX
AK
CT
KY
NE
KS
DE
SD
IA
AZ
CO
OK
WV
MS
AL
GA
DC
ND
AR
FL

Aesthetic Mapping VS Assignment

Note that variables are mapped to aesthetics with the aes() function, while fixed aesthetics are set outside the aes() call. This sometimes leads to confusion, as in this example:

```
p1 + geom_point(aes(size = 2),# incorrect! 2 is not a variable
color="red") # this is fine -- all points red
```

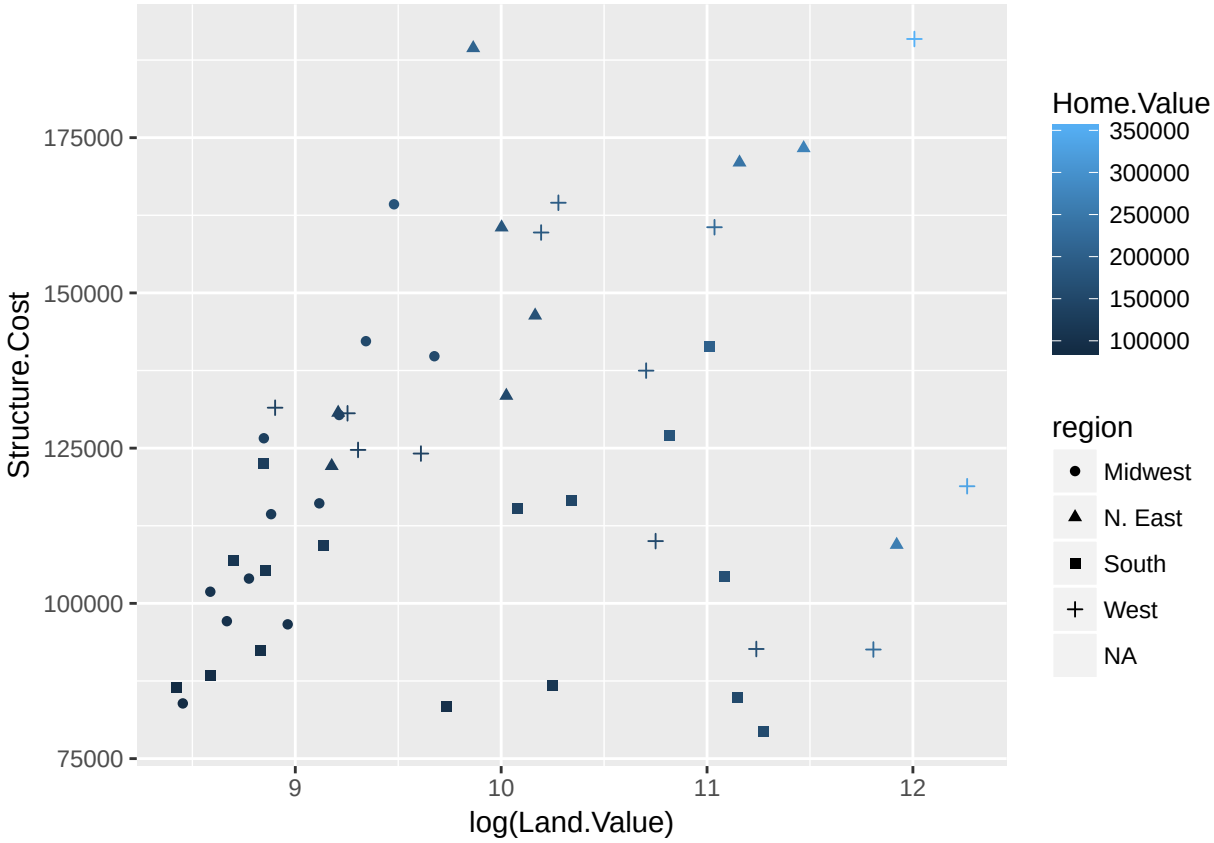


Mapping Variables To Other Aesthetics

Other aesthetics are mapped in the same way as x and y in the previous example.

```
p1 + geom_point(aes(color=Home.Value, shape = region))
```

```
## Warning: Removed 1 rows containing missing values (geom_point).
```



Excercise 1

The data for the exercises is available in the dataSets/EconomistData.csv file. Read it in with

dat <- read.csv("dataSets/EconomistData.csv") head(dat)

ggplot(dat, aes(x = CPI, y = HDI, size = HDI.Rank)) + geom_point()

dat <- read.csv("dataSets/EconomistData.csv")

These data consist of Human Development Index and Corruption Perception Index scores for several countries.

Create a scatter plot with CPI on the x axis and HDI on the y axis. Color the points blue. Map the color of the the points to Region. Make the points bigger by setting size to 2 Map the size of the points to HDI.Rank

Statistical Transformations

Some plot types (such as scatterplots) do not require transformations–each point is plotted at x and y coordinates equal to the original value. Other plots, such as boxplots, histograms, prediction lines etc. require statistical transformations:

- for a boxplot the y values must be transformed to the median and 1.5(IQR)
- for a smoother smother the y values must be transformed into predicted values

Each geom has a default statistic, but these can be changed. For example, the default statistic for geom_bar is stat_bin:

```
args(geom_histogram)
```

```
## function (mapping = NULL, data = NULL, stat = "bin", position = "stack",
##     ..., binwidth = NULL, bins = NULL, na.rm = FALSE, show.legend = NA,
##     inherit.aes = TRUE)
## NULL
```

```
args(stat_bin)
```

```
## function (mapping = NULL, data = NULL, geom = "bar", position = "stack",
##     ..., binwidth = NULL, bins = NULL, center = NULL, boundary = NULL,
##     breaks = NULL, closed = c("right", "left"), pad = FALSE,
##     na.rm = FALSE, show.legend = NA, inherit.aes = TRUE)
## NULL
```

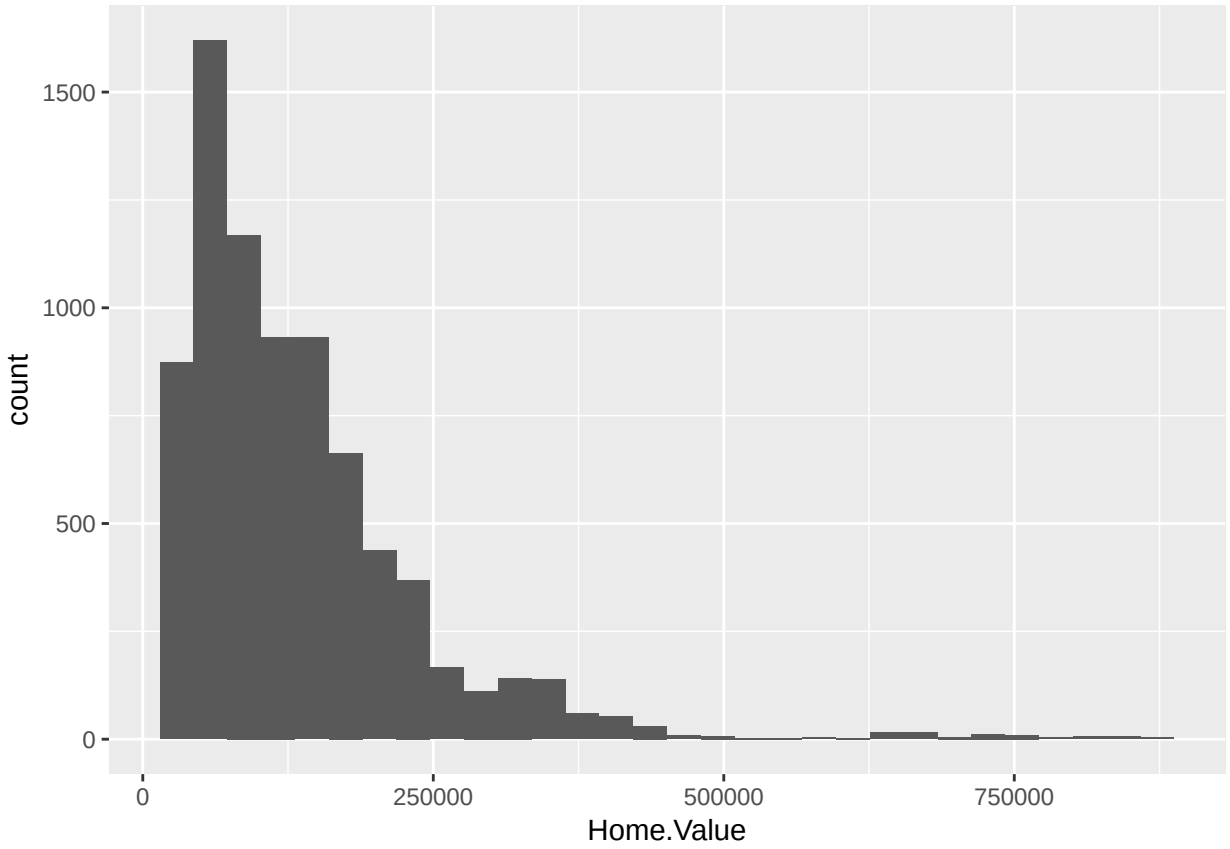
etting Statistical Transformation Arguments

Arguments to stat_ functions can be passed through geom_ functions. This can be slightly annoying because in order to change it you have to first determine which stat the geom uses, then determine the arguments to that stat.

For example, here is the default histogram of Home.Value:

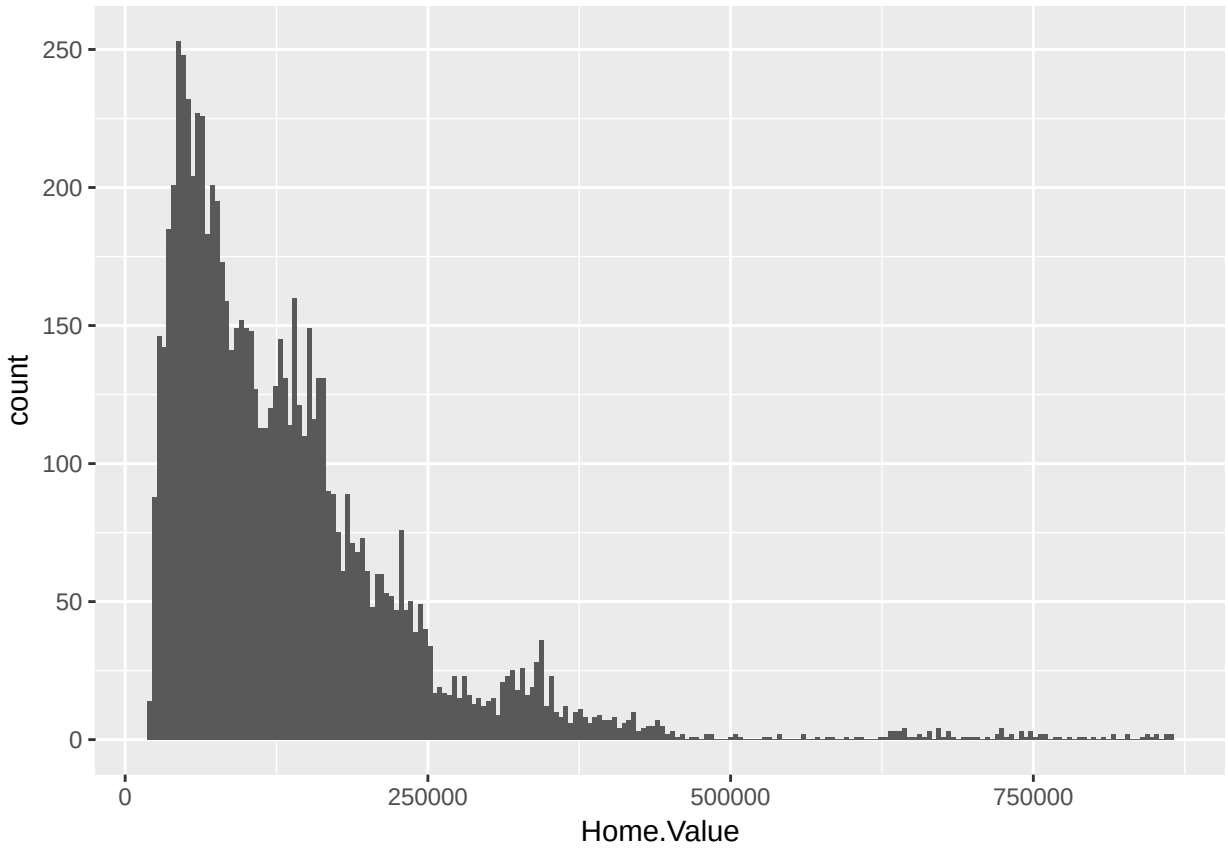
```
p2 <- ggplot(housing, aes(x = Home.Value))
p2 + geom_histogram()
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



reasonable by default, but we can change it by passing the binwidth argument to the stat_bin function:

```
p2 + geom_histogram(stat = "bin", binwidth=4000)
```


250
200
150
100
50
0
count
0
250000
500000
750000
Home.Value

Changing The Statistical Transformation

Sometimes the default statistical transformation is not what you need. This is often the case with pre-summarized data:

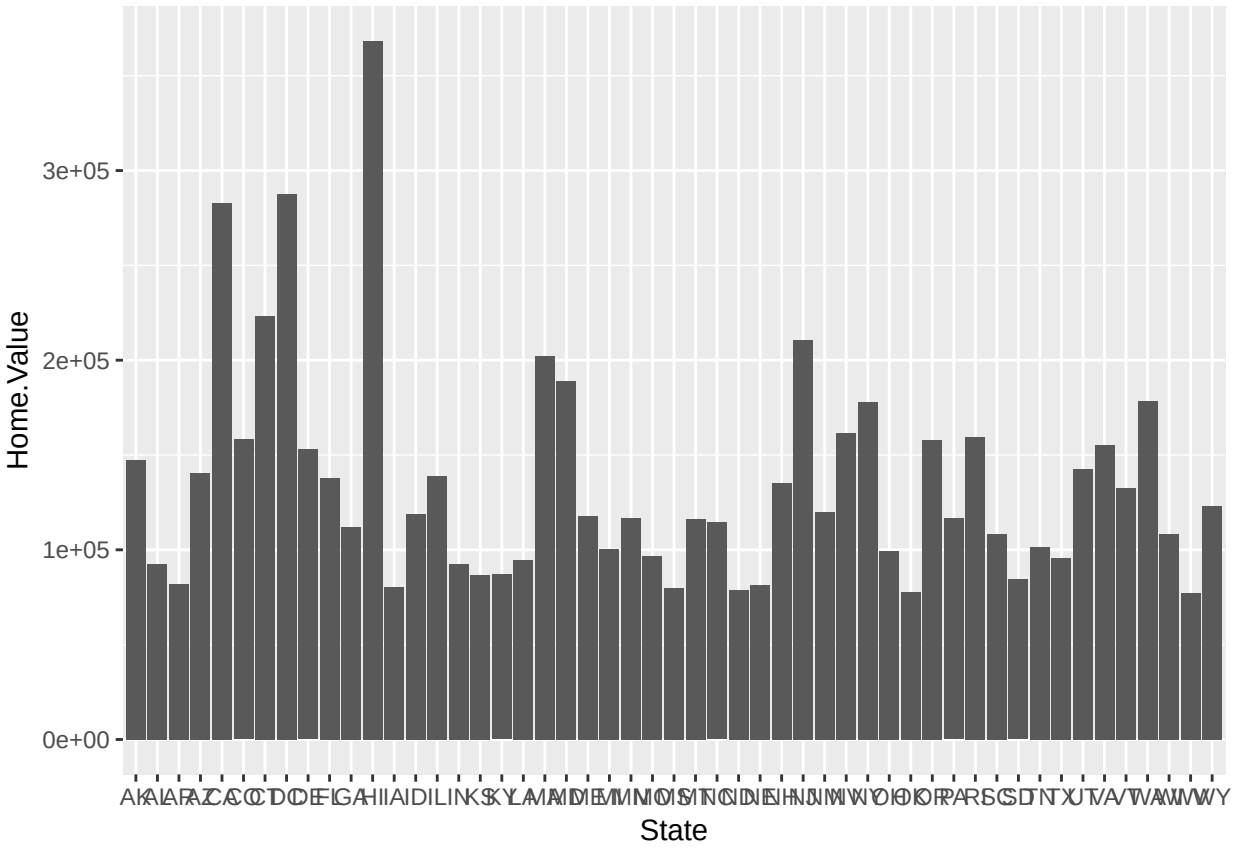
```
housing.sum <- aggregate(housing["Home.Value"], housing["State"], FUN=mean)
rbind(head(housing.sum), tail(housing.sum))
```

```
##    State Home.Value
## 1     AK  147385.14
## 2     AL   92545.22
## 3     AR   82076.84
## 4     AZ  140755.59
## 5     CA  282808.08
## 6     CO  158175.99
## 46    VA  155391.44
## 47    VT  132394.60
## 48    WA  178522.58
## 49    WI  108359.45
## 50    WV   77161.71
## 51    WY  122897.25
```

ggplot(housing.sum, aes(x=State, y=Home.Value)) + geom_bar() ggplot(housing.sum, aes(x=State, y=Home.Value)) + geom_bar() Error: stat_count() must not be used with a y aesthetic.

What is the problem with the previous plot? Basically we take binned and summarized data and ask ggplot to bin and summarize it again (remember, geom_bar defaults to stat = stat_count); obviously this will not work. We can fix it by telling geom_bar to use a different statistical transformation function:

```
ggplot(housing.sum, aes(x=State, y=Home.Value)) +
  geom_bar(stat="identity")
```


Home.Value
3e+05
2e+05
1e+05
0e+00
State

Exercise II

Re-create a scatter plot with CPI on the x axis and HDI on the y axis (as you did in the previous exercise). Overlay a smoothing line on top of the scatter plot using geom_smooth. Overlay a smoothing line on top of the scatter plot using geom_smooth, but use a linear model for the predictions. Hint: see ?stat_smooth. Overlay a smoothing line on top of the scatter plot using geom_line. Hint: change the statistical transformation. BONUS: Overlay a smoothing line on top of the scatter plot using the default loess method, but make it less smooth. Hint: see ?loess.

Scales: Controlling Aesthetic Mapping

Aesthetic mapping (i.e., with aes()) only says that a variable should be mapped to an aesthetic. It doesn't say how that should happen. For example, when mapping a variable to shape with aes(shape = x) you don't say what shapes should be used. Similarly, aes(color = z) doesn't say what colors should be used. Describing what colors/shapes/sizes etc. to use is done by modifying the corresponding scale. In ggplot2 scales include

- position
- color and fill
- size
- shape
- line type

Scales are modified with a series of functions using a scale_ *naming scheme. Try typing scale* to see a list of scale modification functions.

Common Scale Arguments

The following arguments are common to most scales in ggplot2:

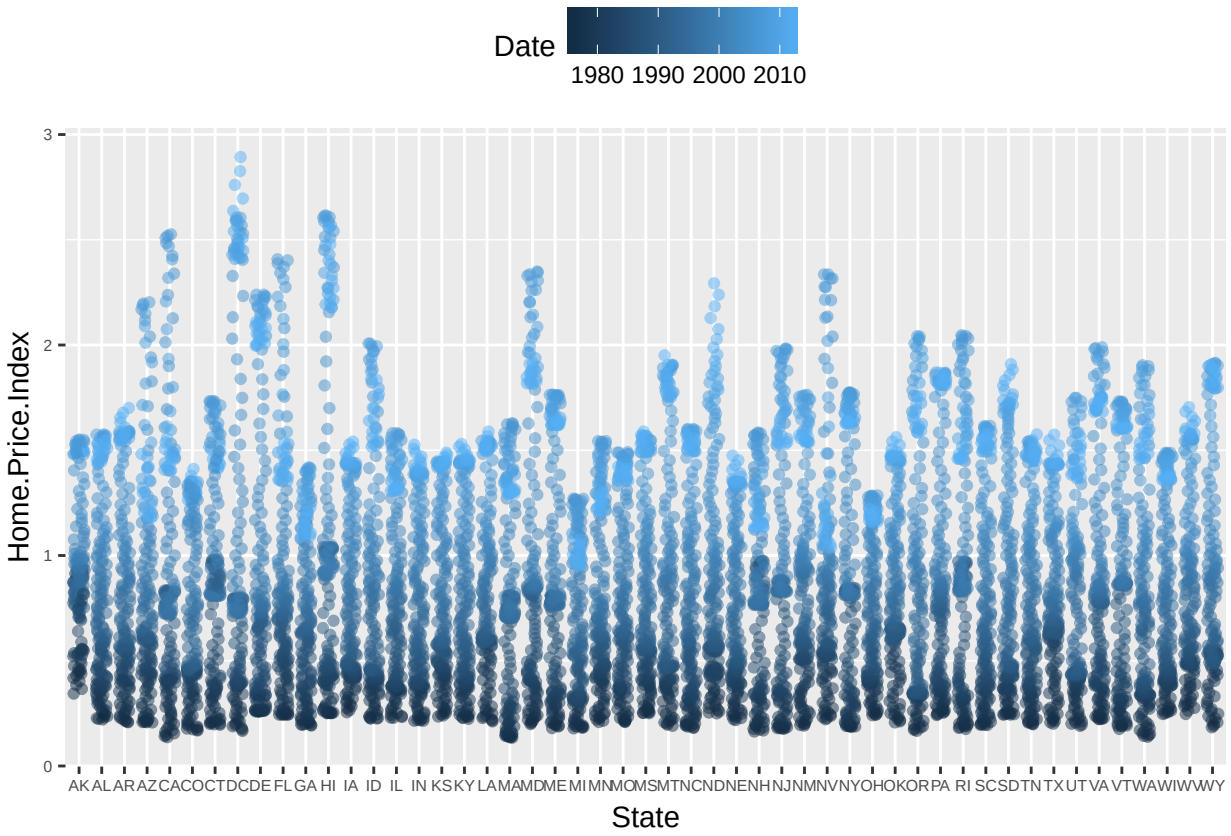
- name the first argument gives the axis or legend title
- limits the minimum and maximum of the scale
- breaks the points along the scale where labels should appear
- labels the labels that appear at each break

Specific scale functions may have additional arguments; for example, the scale_color_continuous function has arguments low and high for setting the colors at the low and high end of the scale.

Scale Modification Examples

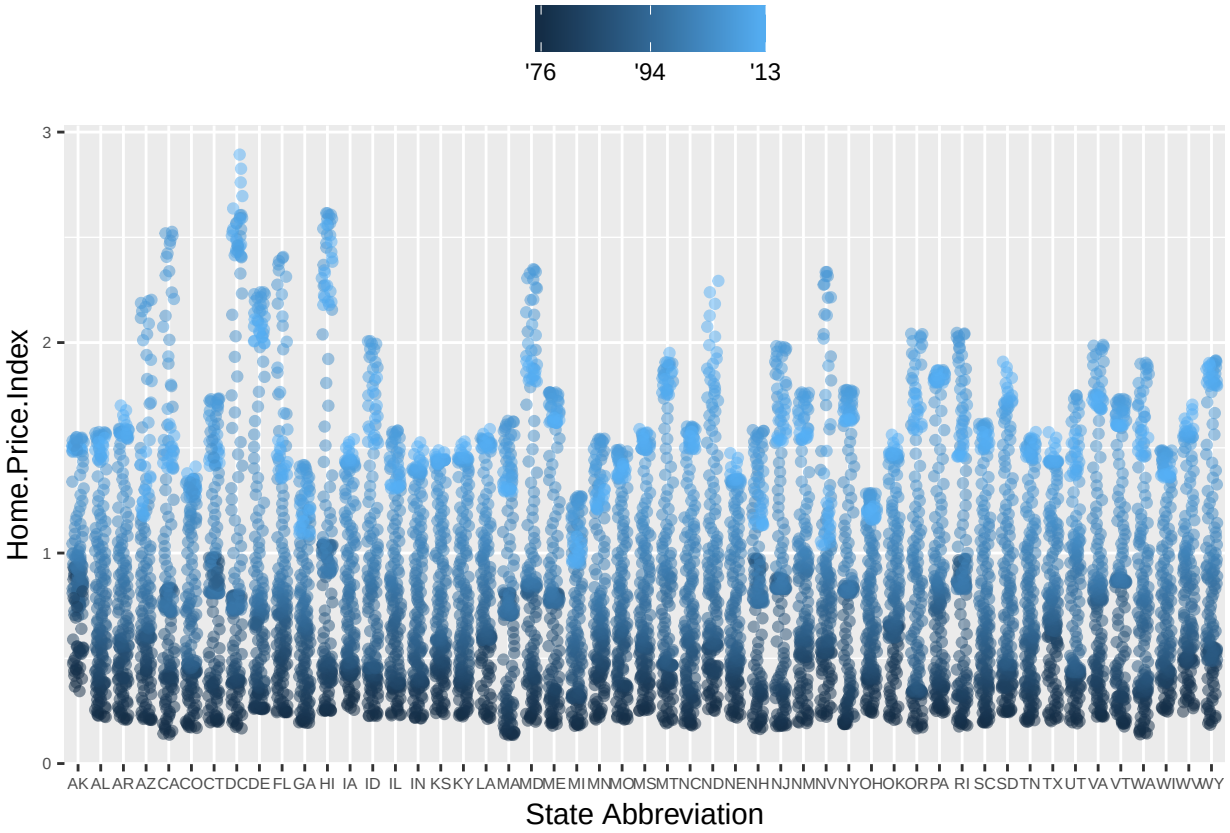
Start by constructing a dotplot showing the distribution of home values by Date and State.

```
p3 <- ggplot(housing,
             aes(x = State,
                 y = Home.Price.Index)) +
       theme(legend.position="top",
             axis.text=element_text(size = 6))
(p4 <- p3 + geom_point(aes(color = Date),
                       alpha = 0.5,
                       size = 1.5,
                       position = position_jitter(width = 0.25, height = 0)))
```



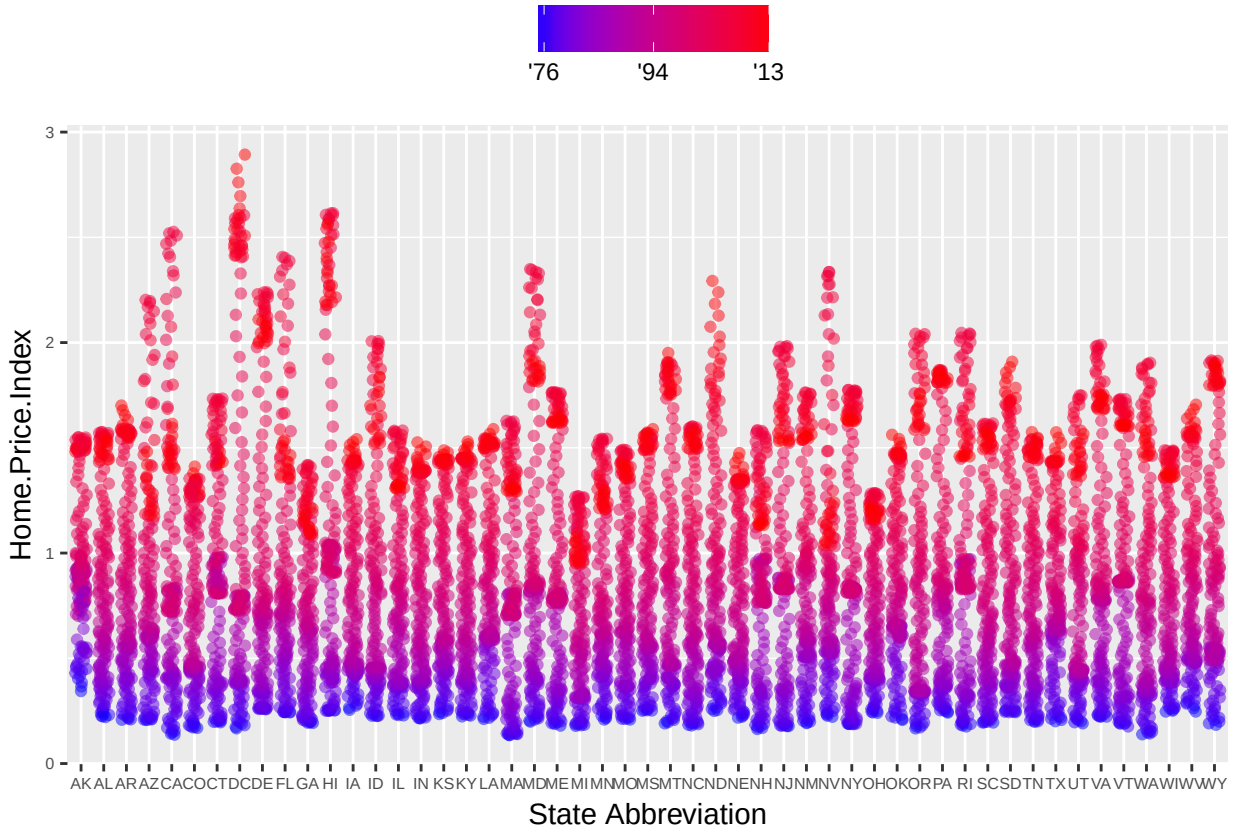
Now modify the breaks for the x axis and color scales

```
p4 + scale_x_discrete(name="State Abbreviation") +
  scale_color_continuous(name="",
                         breaks = c(1976, 1994, 2013),
                         labels = c("'76", "'94", "'13"))
```

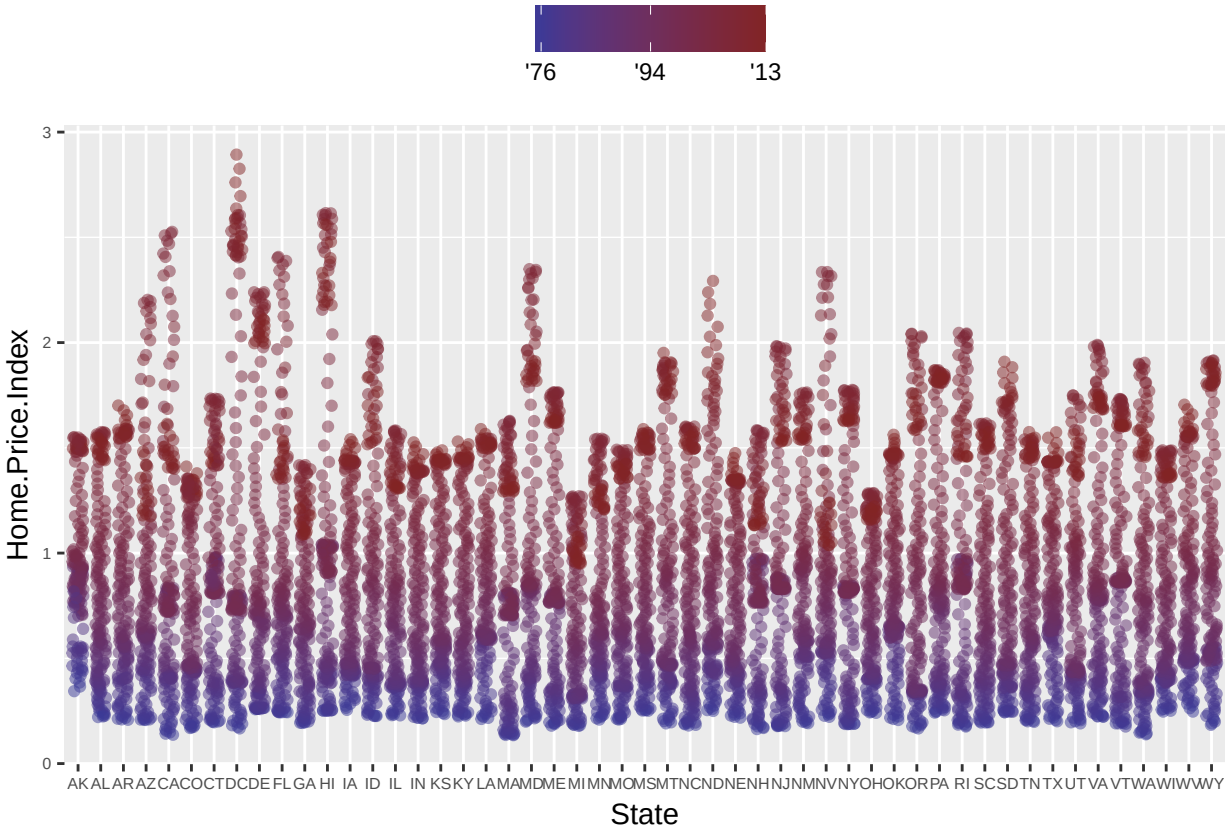


Next change the low and high values to blue and red:

```
p4 +
  scale_x_discrete(name="State Abbreviation") +
  scale_color_continuous(name="",
                         breaks = c(1976, 1994, 2013),
                         labels = c("'76", "'94", "'13"),
                         low = "blue", high = "red")
```



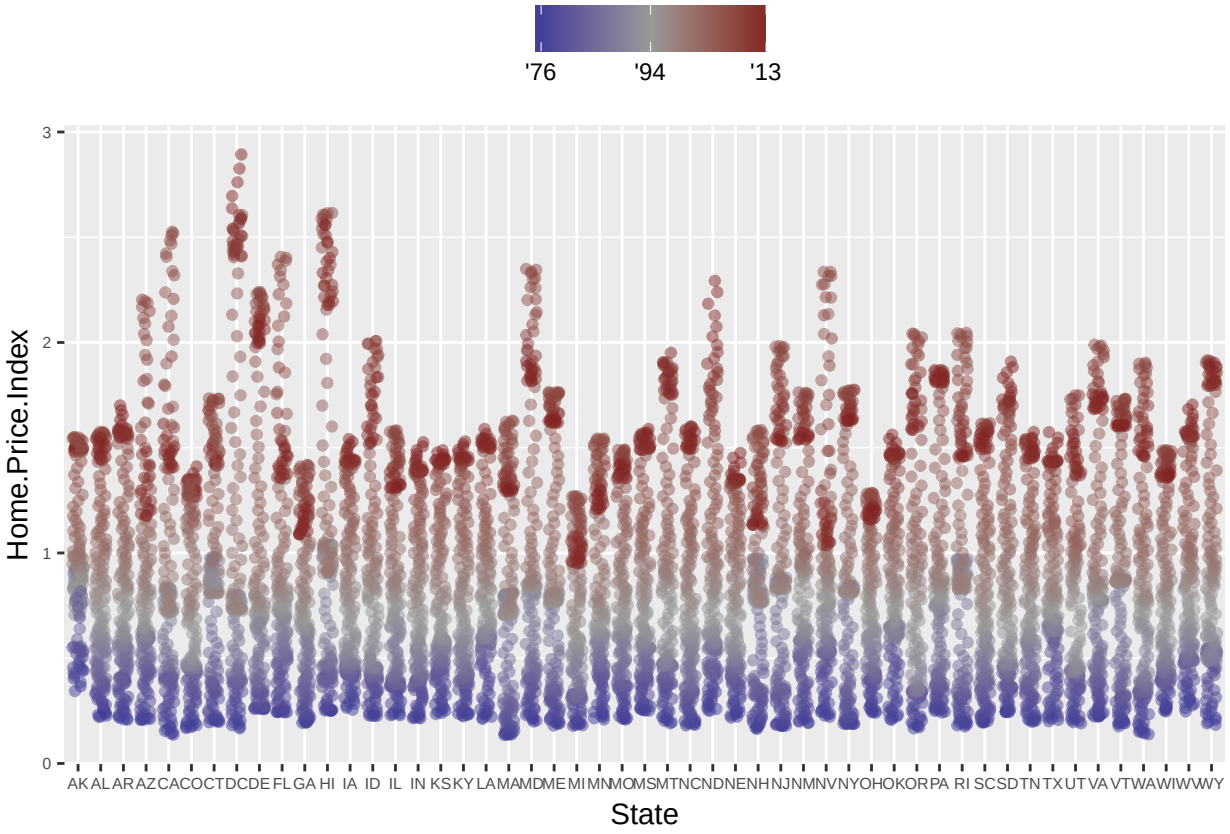

```
library(scales)
p4 + scale_color_continuous(name="",
                            breaks = c(1976, 1994, 2013),
                            labels = c("'76", "'94", "'13"),
                            low = muted("blue"), high = muted("red"))
```


'76
'94
'13
Home.Price.Index
3
2
1
0
AK AL AR AZ CA CO CT DC DE FL GA HI IA ID IL IN KS KY LA MA MD ME MI MN MO MS MT NC ND NE NH NJ NM NV NY OH OK OR PA RI SC SD TN TX UT VA VT WA WI WV WY
State

Using different color scales

ggplot2 has a wide variety of color scales; here is an example using scale_color_gradient2 to interpolate between three different colors.

```
p4 +
  scale_color_gradient2(name="",
                        breaks = c(1976, 1994, 2013),
                        labels = c("'76", "'94", "'13"),
                        low = muted("blue"),
                        high = muted("red"),
                        mid = "gray60",
                        midpoint = 1994)
```



Exercise III

Create a scatter plot with CPI on the x axis and HDI on the y axis. Color the points to indicate region. Modify the x, y, and color scales so that they have more easily-understood names (e.g., spell out "Human development Index" instead of "HDI"). Modify the color scale to use specific values of your choosing. Hint: see ?scale_color_manual.

Faceting

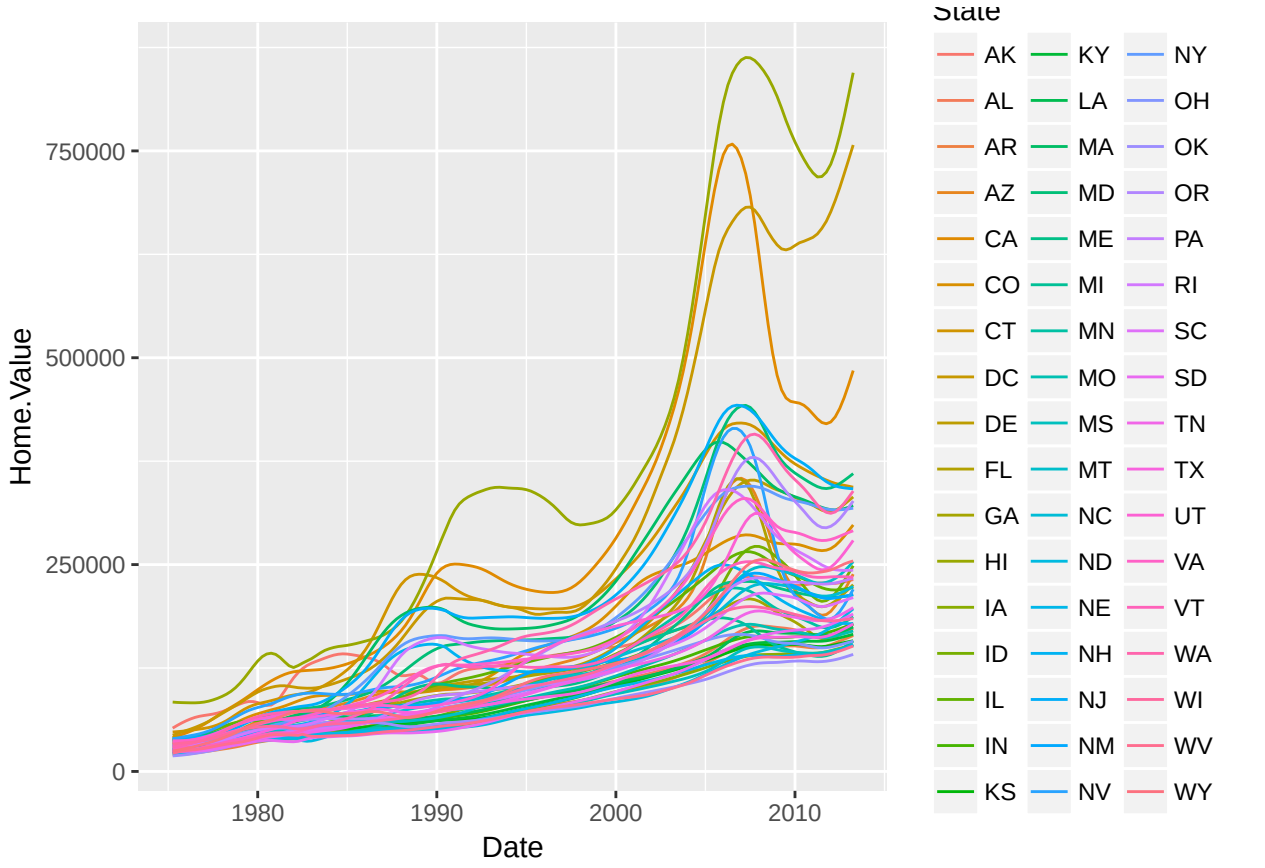
Faceting

Faceting is ggplot2 parlance for small multiples The idea is to create separate graphs for subsets of data ggplot2 offers two functions for creating small multiples: facet_wrap(): define subsets as the levels of a single

grouping variable facet_grid(): define subsets as the crossing of two grouping variables Facilitates comparison among plots, not just of geoms within a plot What is the trend in housing prices in each state?

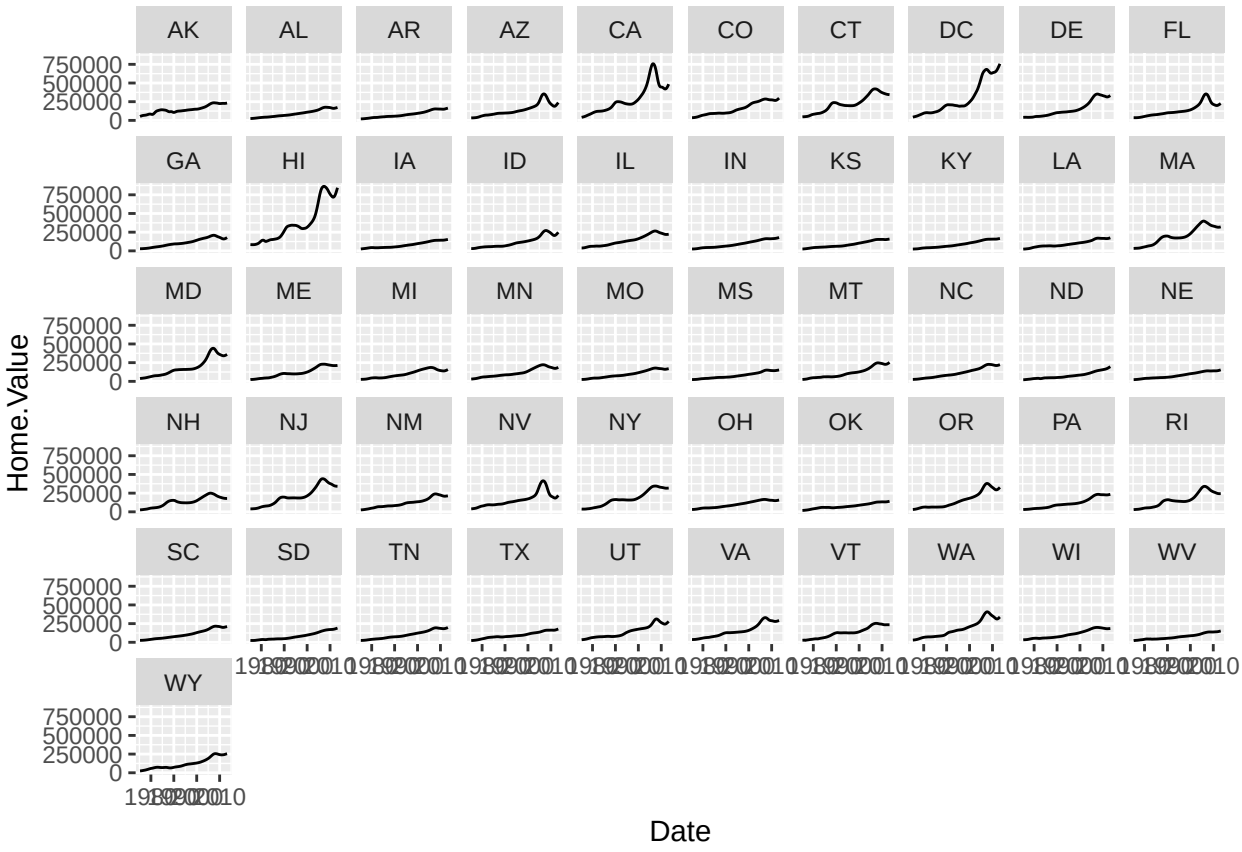
Start by using a technique we already know–map State to color:

```
p5 <- ggplot(housing, aes(x = Date, y = Home.Value))
p5 + geom_line(aes(color = State))
```



There are two problems here–there are too many states to distinguish each one by color, and the lines obscure one another. We can remedy the deficiencies of the previous plot by faceting by state rather than mapping state to color.

```
(p5 <- p5 + geom_line() +
   facet_wrap(~State, ncol = 10))
```



There is also a facet_grid() function for faceting in two dimensions.

Themes

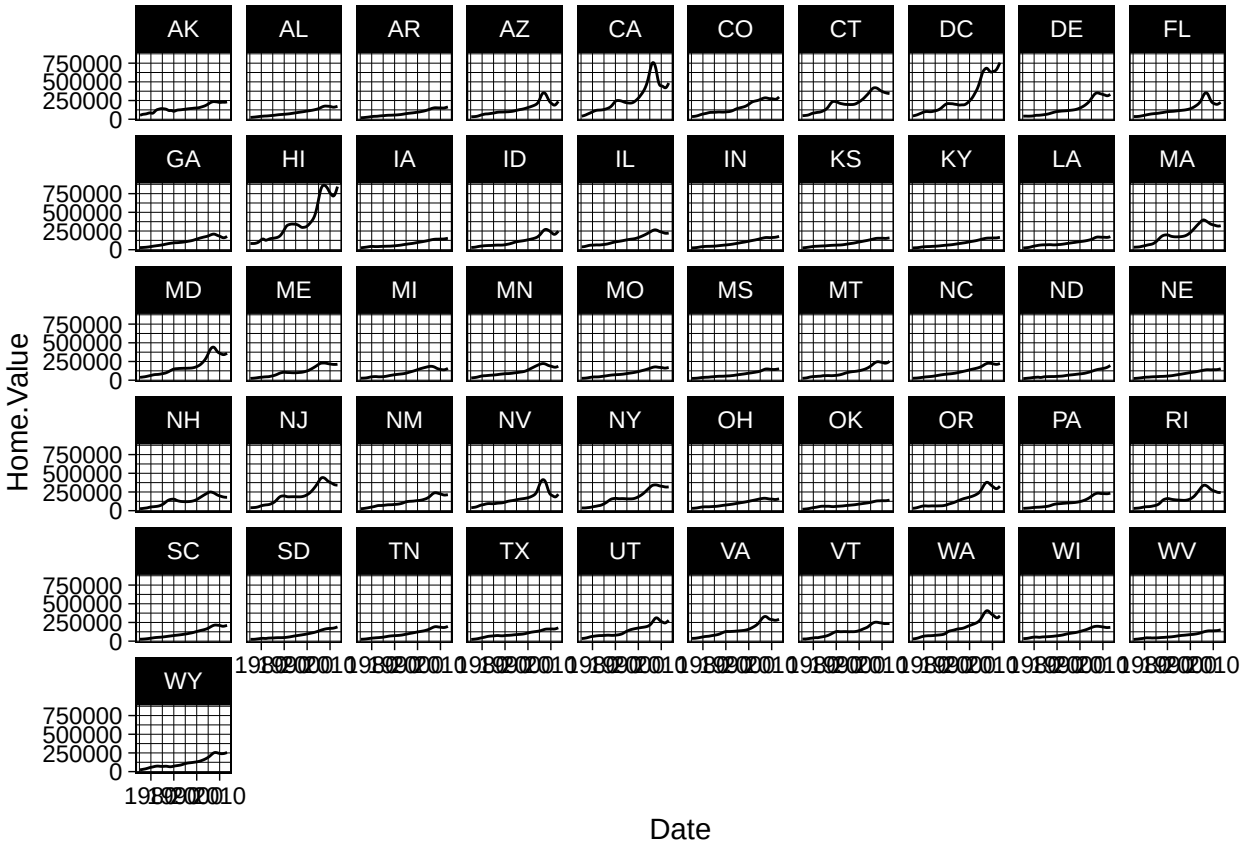
Themes

The ggplot2 theme system handles non-data plot elements such as

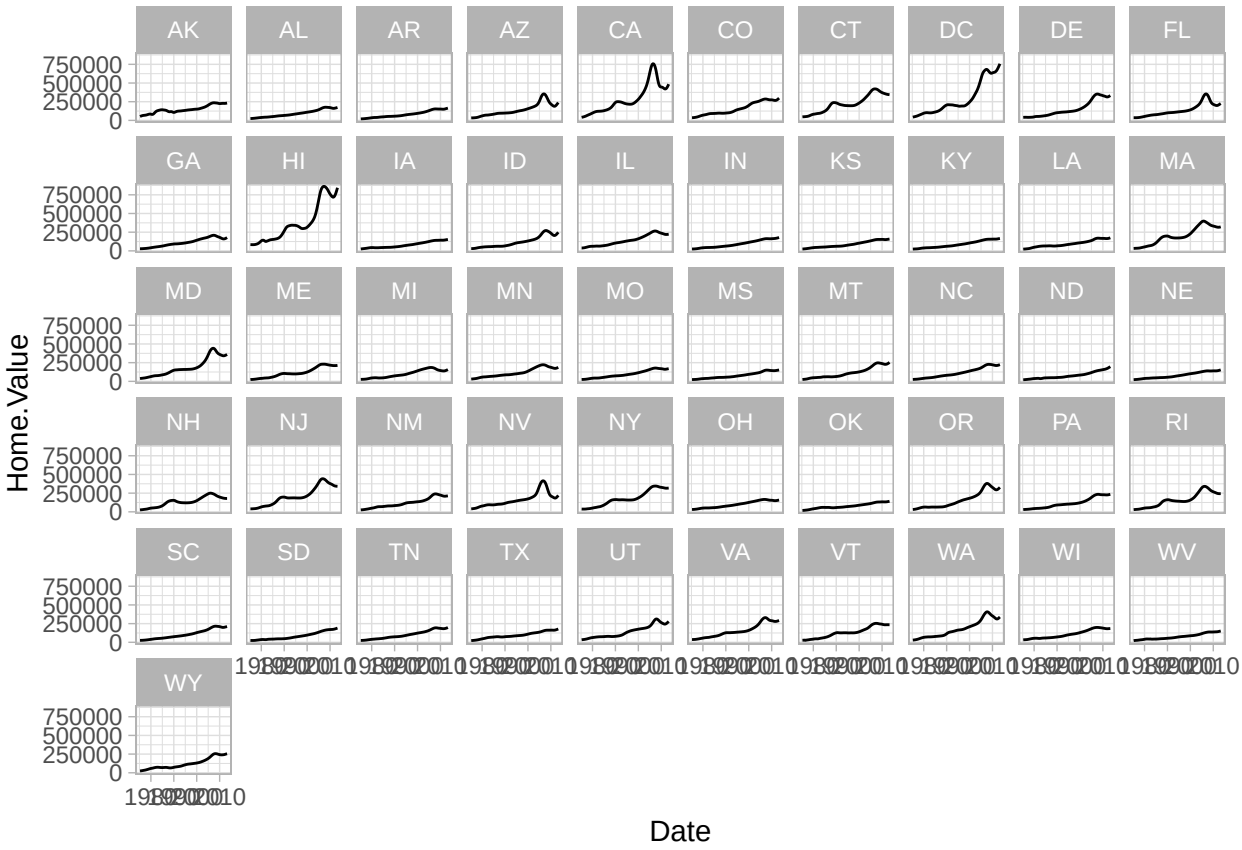
Axis labels Plot background Facet label backround Legend appearance Built-in themes include:

theme_gray() (default) theme_bw() theme_classc()

```
p5 + theme_linedraw()
```




```
p5 + theme_light()
```


AK
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OR
PA
RI
SC
SD
TN
TX
UT
VA
VT
WA
WI
WV
WY
750000
500000
250000
0
Home.Value
Date

Overriding theme defaults

Specific theme elements can be overridden using theme(). For example:

```
p5 + theme_minimal() +
  theme(text = element_text(color = "turquoise"))
```

All theme options are documented in ?theme.

Creating and saving new themes

You can create new themes, as in the following example:

this code proved difficult and it appears to be because of problems with the built in letter types“‘{r}

theme_new <- theme_bw() + theme(plot.background = element_rect(size = 1, color = “blue”, fill = “black”), text=element_text(size = 12, family = “Serif”, color = “ivory”), axis.text.y = element_text(colour = “purple”), axis.text.x = element_text(colour = “red”), panel.background = element_rect(fill = “pink”), strip.background = element_rect(fill = muted(“orange”)))

p5 + theme_new “‘

The #1 FAQ

Map Aesthetic To Different Columns

The most frequently asked question goes something like this: I have two variables in my data.frame, and I’d like to plot them as separate points, with different color depending on which variable it is. How do I do that?

Wrong

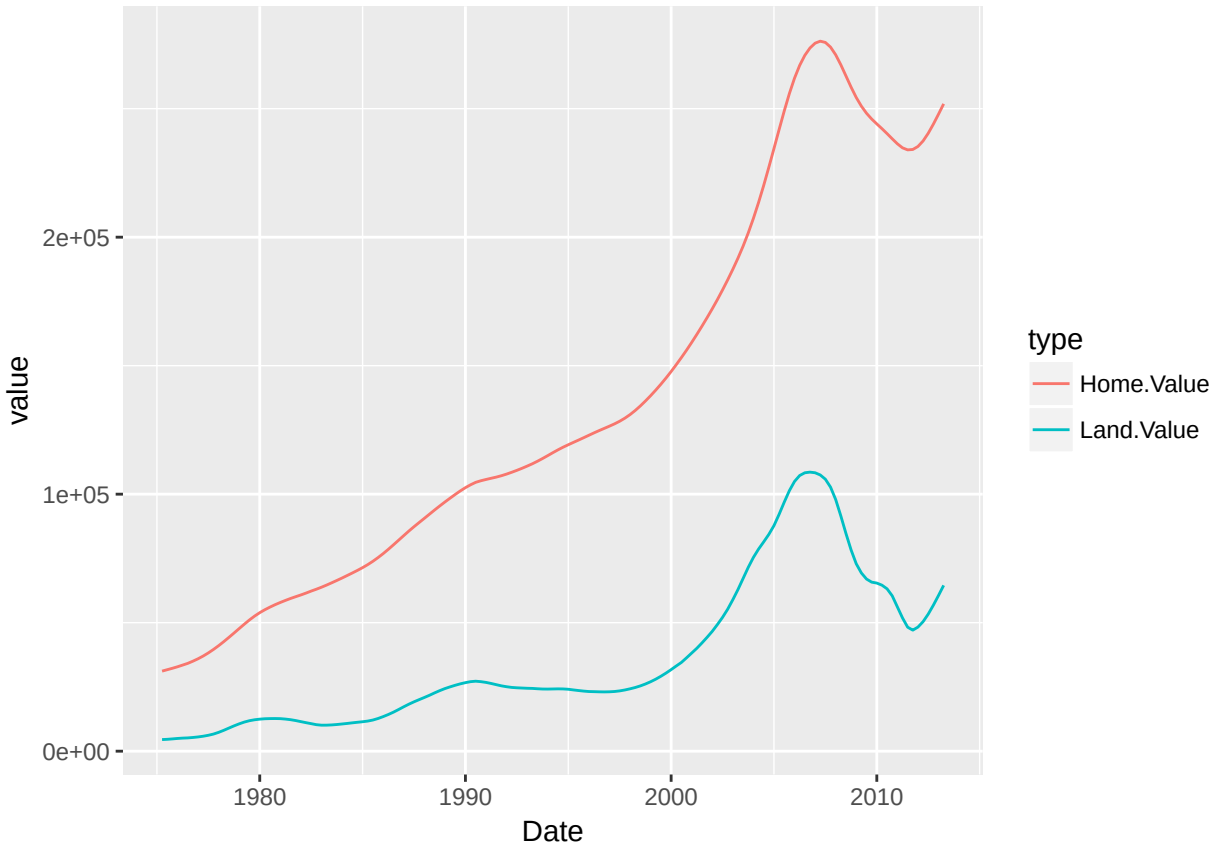
```
housing.byyear <- aggregate(cbind(Home.Value, Land.Value) ~ Date, data = housing, mean)
ggplot(housing.byyear,
       aes(x=Date)) +
  geom_line(aes(y=Home.Value), color="red") +
  geom_line(aes(y=Land.Value), color="blue")
```

right

```
library(tidyr)
home.land.byyear <- gather(housing.byyear,
                           value = "value",
                           key = "type",
                           Home.Value, Land.Value)
```

```
## Warning: Installed Rcpp (0.12.7) different from Rcpp used to build dplyr (0.12.11).
## Please reinstall dplyr to avoid random crashes or undefined behavior.
```

```
ggplot(home.land.byyear,
       aes(x=Date,
           y=value,
           color=type)) +
  geom_line()
```



Putting It All Together

Challenge: Recreate This Economist Graph

images/Economist1.pdf

Graph source: http://www.economist.com/node/21541178

Building off of the graphics you created in the previous exercises, put the finishing touches to make it as close as possible to the original economist graph. http://tutorials.iq.harvard.edu/R/Rgraphics/images/Economist1.png