การจัดการความรู้

Introduction to R

การนำเสนอข้อมูลและผลงานวิจัย
เพื่อสร้างจินตทัศน์

สถาบันวิจัยสังคม

จุฬาลงกรณ์มหาวิทยาลัย

โครงการอบรม Introduction to R

วันจันทร์ที่ 8 มิถุนายน พ.ศ. 2563 เวลา 09.00 - 16.00 น.

ห้องประชุมจั๊คส์ อัมโยต์ ชั้น 4 อาคารวิศิษฐ์ ประจวบเหมาะ

สถาบันวิจัยสังคม จุฬาลงกรณ์มหาวิทยาลัย

หลักการและเหตผล

โปรแกรม R เป็นโปรแกรมสำหรับการนำเสนอข้อมูล ผลงานวิจัยที่ช่วยสร้างจินตทัศน์ ที่เป็นการกล่าวถึงการสร้างภาพ แผนผัง หรือภาพเคลื่อนไหว ใช้ในการสื่อสารแทนข้อความ โดยวิธีการนี้สามารถใช้ได้ทั้งในทางรูปธรรม และนามธรรม ซึ่งทำให้เกิดการนำเสนอผลการวิจัยที่มีประสิทธิภาพ และเป็นประโยชน์ต่อการนำผลการวิจัยไปประยุกต์ใช้

ที่ผ่านมาจะพบว่าบุคลากรของสถาบันยังขาดประสบการณ์ ความรู้ และทักษะในการเตรียมนำเสนอข้อมูล และผลงานวิจัยที่ช่วยสร้างจินตทัศน์ ปรากฏการณ์นี้ทำให้ไม่สามารถสื่อสารข้อมูล และผลการวิจัยได้อย่างลึกซึ้ง โดยเฉพาะในงานที่มีความซับซ้อนของข้อมูลและเป็นนามธรรมสูง ซึ่งส่งผลต่อการนำข้อมูลไปใช้ประโยชน์ได้อย่างเต็มศักยภาพ ดังนั้นแนวทางในการเตรียมนำเสนอข้อมูล และผลงานวิจัยที่ช่วยสร้างจินตทัศน์จึงมีความจำเป็นอย่างมากสำหรับบุคลากรของสถาบัน ดังนั้นสถาบันวิจัยสังคม ได้จัดอบรมโครงการอบรม Introduction to R เพื่อเป็นการส่งเสริมทักษะดังกล่าวให้กับบุคลากรของสถาบันวิจัยสังคม

วัตถุประสงค์

1. บุคลากรสามารถเข้าใจหลักการพื้นฐานโปรแกรม R
2. บุคลากรสามารถใช้โปรแกรม R เพื่อนำเสนอข้อมูลที่มีความซับซ้อนได้
3. เกิดการพัฒนาศักยภาพของบุคลากรของสถาบันวิจัยสังคม

กลุ่มเป้าหมาย

อาจารย์ นักวิจัย บุคลากรสายสนับสนุน และผู้ช่วยนักวิจัยสถาบันวิจัยสังคม จำนวน 12-15 คน

กำหนดการ

โครงการอบรม Introduction to R

วันจันทร์ที่ 8 มิถุนายน พ.ศ. 2563 เวลา 09.00 - 16.00 น.

ห้องประชุมจั๊คส์ อัมโยต์ ชั้น 4 อาคารวิศิษฐ์ ประจวบเหมาะ

สถาบันวิจัยสังคม จุฬาลงกรณ์มหาวิทยาลัย

09.00 - 09.15 น.	ลงทะเบียน
09.15 - 09.30 น.	ชี้แจงโครงการ วัตถุประสงค์
09.30 - 12.00 น.	หลักการพื้นฐานการทำความเข้าใจเกี่ยวกับโปรแกรม R
12.00 - 13.00 น.	รับประทานอาหารกลางวัน
13.00 - 16.00 น.	ฝึกการปฏิบัติงานบนโปรแกรม R (การเขียนคำสั่ง)

หมายเหตุ : พักรับประทานอาหารว่าง เวลา 10.15 - 10.30 น. และเวลา 14.30 - 14.45 น.

Visualizing Demographic Data - Static Plots

Guy J. Abel

R graphics Package

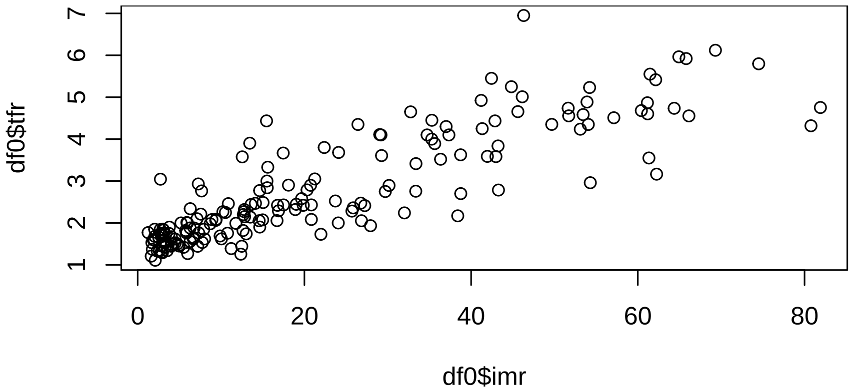
- R has fantastic graphic capabilities.
  - There are many approaches and packages designed for this specific task.
  - The `graphics` package (loaded when start R) has many plotting functions.
  - Simple look, may not be consistent across different types of plots

R graphics Package

```
> df0
# A tibble: 179 x 8
   name  region_name area_name   imr   tfr sex_ratio developed
   <chr> <chr>       <chr>     <dbl> <dbl>     <dbl> <chr>
 1 Buru~ Eastern Af~ Africa     42.4  5.45      1.03 Less
 2 Como~ Eastern Af~ Africa     53.1  4.24      1.05 Less
 3 Djib~ Eastern Af~ Africa     33.4  2.76      1.04 Less
 4 Erit~ Eastern Af~ Africa     34.7  4.1       1.05 Less
 5 Ethi~ Eastern Af~ Africa     37    4.3       1.04 Less
 6 Kenya Eastern Af~ Africa     36.3  3.52      1.03 Less
 7 Mada~ Eastern Af~ Africa     29.0  4.11      1.03 Less
 8 Mala~ Eastern Af~ Africa     41.3  4.25      1.03 Less
 9 Maur~ Eastern Af~ Africa     11.2  1.39      1.04 Less
10 Moza~ Eastern Af~ Africa     53.9  4.89      1.02 Less
# ... with 169 more rows, and 1 more variable: growth_policy <chr>
```

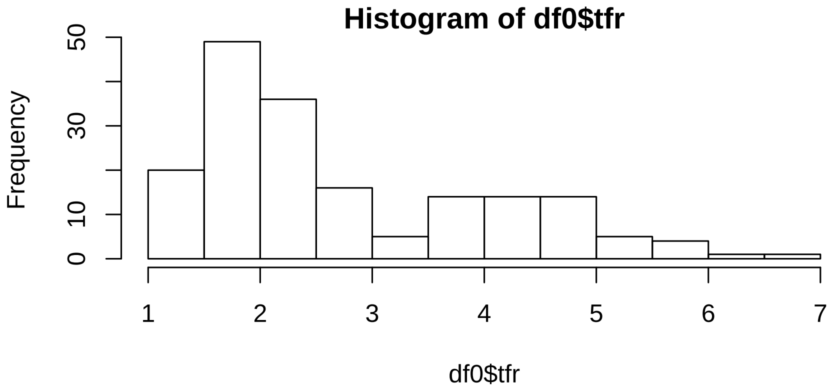
R graphics Package

```
> head(x = df0, n = 2)
# A tibble: 2 x 8
  name  region_name area_name   imr   tfr sex_ratio developed growth_policy
  <chr> <chr>       <chr>     <dbl> <dbl>     <dbl> <chr>     <chr>
1 Buru~ Eastern Af~ Africa     42.4  5.45      1.03 Less      Lower
2 Como~ Eastern Af~ Africa     53.1  4.24      1.05 Less      Lower
>
> plot(x = df0$imr, y = df0$tfr)
```



R graphics Package

```
> head(x = df0, n = 2)
# A tibble: 2 x 8
  name   region_name area_name    imr   tfr sex_ratio developed growth_policy
  <chr>  <chr>       <chr>      <dbl> <dbl>     <dbl> <chr>     <chr>
1 Buru~ Eastern Af~ Africa      42.4  5.45      1.03 Less      Lower
2 Como~ Eastern Af~ Africa      53.1  4.24      1.05 Less      Lower
>
> hist(df0$tfr)
```

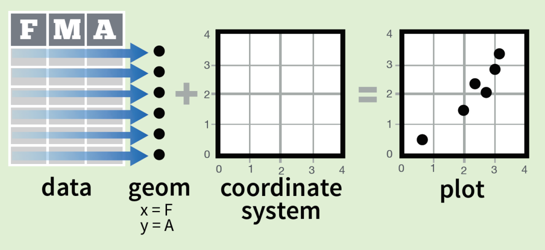


Grammar of Graphics

- The `ggplot2` package by Hadley Wickham implements the grammar of graphics, a coherent system for describing and building graphs.
  - One of the most beautiful and most versatile.
  - Flexible and consistent approach across different plots
  - Do more faster as a single learning one system for all plots types that you can apply in many data situations.
- Included in the tidyverse package (more on tidyverse later)
  - `library(tidyverse)` loads `ggplot2` along with other useful packages

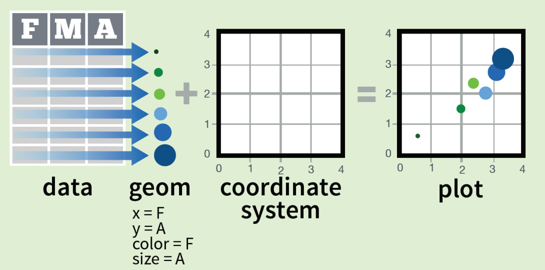
Grammar of Graphics

- The grammar of graphics builds every graph from the same components:
  - data set
  - coordinate system
  - geoms (visual marks that represent data points)



Grammar of Graphics

- When variables are mapped to data they can take different visual properties of the geom (aesthetics) like size, color, and x and y locations.
  - Aesthetics meaning something you can see.



Grammar of Graphics

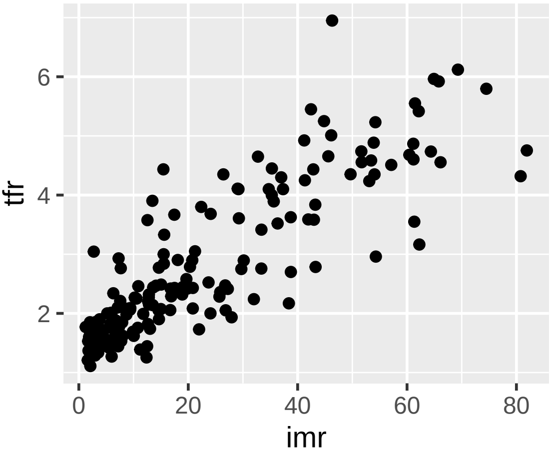
- The R code follows a common template

```
ggplot(data = <DATA>) +
  <GEOM_FUNCTION>(
     mapping = aes(<MAPPINGS>),
     stat = <STAT>,
     position = <POSITION>
  ) +
  <COORDINATE_FUNCTION> +
  <FACET_FUNCTION> +
  <SCALE_FUNCTION> +
  <THEME_FUNCTION>
```

- **Required** (the `ggplot(data = …)`, `<GEOM_FUNCTION>` and `mapping = aes(…)` lines)
- Not required, sensible defaults supplied (`stat`, `position`, and the coordinate, facet, scale and theme functions)

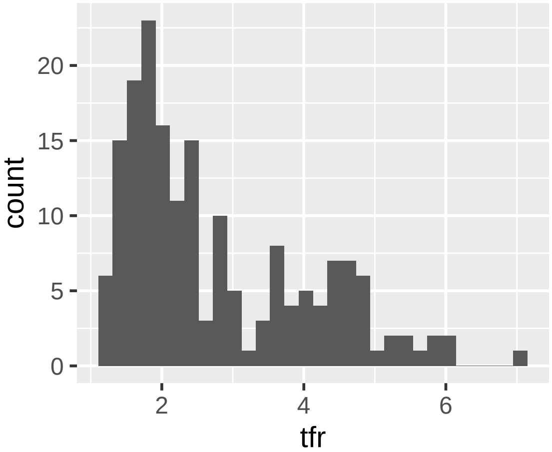
Grammar of Graphics

```
> library(tidyverse)
> ggplot(data = df0, mapping = aes(x = imr, y = tfr)) +
+   geom_point()
```



Grammar of Graphics

```
> ggplot(data = df0, mapping = aes(x = tfr)) +
+   geom_histogram()
```



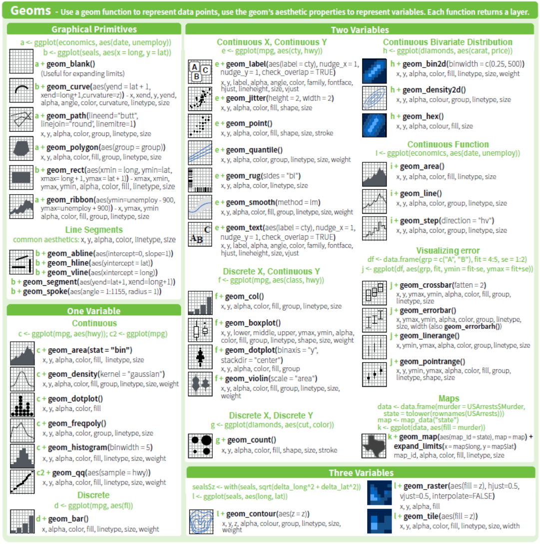
Grammar of Graphics

- The function `ggplot()` creates a coordinate system to add layers onto.
- The first argument of `ggplot()` is the data set used to graph
  - For example, `ggplot(data = swiss)` creates an empty graph that will use the `swiss` data set.
  - Can then build on the empty graphs by adding one or more layers to `ggplot()`.
- The geom functions adds a layer of points to your plot.
  - The `ggplot2` library comes with many geom functions
  - Each add a different type of layer to a plot.
  - Each geom function in ggplot2 takes a `mapping` argument.
- The `mapping` argument explains where your points should go
  - Set in the `mapping` argument with a call to the `aes()` function.
  - For example the `x` and `y` arguments of `aes()` explain which variables to map to the x- and y-axes of your plot.
  - The `ggplot()` function looks for those variables in your data set.
  - The `mapping` arguments are different for each geom function

Geom

- The ggplot2 package provides over 30 geom functions
  - Further packages provide even more.
- Each geom function is suitable for visualizing a certain type of data or relationship.
  - Listed on the first page of the ggplot cheat sheet.
  - Next to geom is a visual representation of the geom.
  - Beneath geom is a list of aesthetics that apply to the geom.
  - Required aesthetics are in bold.

Geoms



Geoms - Use a geom function to represent data points, use the geom's aesthetic properties to represent variables. Each function returns a layer.

Graphical Primitives

a <- ggplot(economics, aes(date, unemploy))
b <- ggplot(seals, aes(x = long, y = lat))

a + **geom_blank()**
(Useful for expanding limits)

b + **geom_curve**(aes(yend = lat + 1, xend=long+1,curvature=z)) - x, xend, y, yend, alpha, angle, color, curvature, linetype, size

a + **geom_path**(lineend="butt", linejoin="round", linemitre=1)
x, y, alpha, color, group, linetype, size

a + **geom_polygon**(aes(group = group))
x, y, alpha, color, fill, group, linetype, size

b + **geom_rect**(aes(xmin = long, ymin=lat, xmax= long + 1, ymax = lat + 1)) - xmax, xmin, ymax, ymin, alpha, color, fill, linetype, size

a + **geom_ribbon**(aes(ymin=unemploy - 900, ymax=unemploy + 900)) - x, ymax, ymin alpha, color, fill, group, linetype, size

Line Segments

common aesthetics: x, y, alpha, color, linetype, size

b + **geom_abline**(aes(intercept=0, slope=1))
b + **geom_hline**(aes(yintercept = lat))
b + **geom_vline**(aes(xintercept = long))
b + **geom_segment**(aes(yend=lat+1, xend=long+1))
b + **geom_spoke**(aes(angle = 1:1155, radius = 1))

One Variable

Continuous

c <- ggplot(mpg, aes(hwy)); c2 <- ggplot(mpg)

c + **geom_area(stat = "bin")**
x, y, alpha, color, fill, linetype, size

c + **geom_density**(kernel = "gaussian")
x, y, alpha, color, fill, group, linetype, size, weight

c + **geom_dotplot()**
x, y, alpha, color, fill

c + **geom_freqpoly()**
x, y, alpha, color, group, linetype, size

c + **geom_histogram**(binwidth = 5)
x, y, alpha, color, fill, linetype, size, weight

c2 + **geom_qq**(aes(sample = hwy))
x, y, alpha, color, fill, linetype, size, weight

Discrete

d <- ggplot(mpg, aes(fl))

d + **geom_bar()**
x, alpha, color, fill, linetype, size, weight

Two Variables

Continuous X, Continuous Y

e <- ggplot(mpg, aes(cty, hwy))

e + **geom_label**(aes(label = cty), nudge_x = 1, nudge_y = 1, check_overlap = TRUE)
x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

e + **geom_jitter**(height = 2, width = 2)
x, y, alpha, color, fill, shape, size

e + **geom_point()**
x, y, alpha, color, fill, shape, size, stroke

e + **geom_quantile()**
x, y, alpha, color, group, linetype, size, weight

e + **geom_rug**(sides = "bl")
x, y, alpha, color, linetype, size

e + **geom_smooth**(method = lm)
x, y, alpha, color, fill, group, linetype, size, weight

e + **geom_text**(aes(label = cty), nudge_x = 1, nudge_y = 1, check_overlap = TRUE)
x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

Discrete X, Continuous Y

f <- ggplot(mpg, aes(class, hwy))

f + **geom_col()**
x, y, alpha, color, fill, group, linetype, size

f + **geom_boxplot()**
x, y, lower, middle, upper, ymax, ymin, alpha, color, fill, group, linetype, shape, size, weight

f + **geom_dotplot**(binaxis = "y", stackdir = "center")
x, y, alpha, color, fill, group

f + **geom_violin**(scale = "area")
x, y, alpha, color, fill, group, linetype, size, weight

Discrete X, Discrete Y

g <- ggplot(diamonds, aes(cut, color))

g + **geom_count()**
x, y, alpha, color, fill, shape, size, stroke

Continuous Bivariate Distribution

h <- ggplot(diamonds, aes(carat, price))

h + **geom_bin2d**(binwidth = c(0.25, 500))
x, y, alpha, color, fill, linetype, size, weight

h + **geom_density2d()**
x, y, alpha, colour, group, linetype, size

h + **geom_hex()**
x, y, alpha, colour, fill, size

Continuous Function

i <- ggplot(economics, aes(date, unemploy))

i + **geom_area()**
x, y, alpha, color, fill, linetype, size

i + **geom_line()**
x, y, alpha, color, group, linetype, size

i + **geom_step**(direction = "hv")
x, y, alpha, color, group, linetype, size

Visualizing error

df <- data.frame(grp = c("A", "B"), fit = 4:5, se = 1:2)
j <- ggplot(df, aes(grp, fit, ymin = fit-se, ymax = fit+se))

j + **geom_crossbar**(fatten = 2)
x, y, ymax, ymin, alpha, color, fill, group, linetype, size

j + **geom_errorbar()**
x, ymax, ymin, alpha, color, group, linetype, size, width (also **geom_errorbarh()**)

j + **geom_linerange()**
x, ymin, ymax, alpha, color, group, linetype, size

j + **geom_pointrange()**
x, y, ymin, ymax, alpha, color, fill, group, linetype, shape, size

Maps

data <- data.frame(murder = USArrests$Murder, state = tolower(rownames(USArrests)))
map <- map_data("state")
k <- ggplot(data, aes(fill = murder))

k + **geom_map**(aes(map_id = state), map = map) + **expand_limits**(x = map$long, y = map$lat)
map_id, alpha, color, fill, linetype, size

Three Variables

seals$z <- with(seals, sqrt(delta_long^2 + delta_lat^2))
l <- ggplot(seals, aes(long, lat))

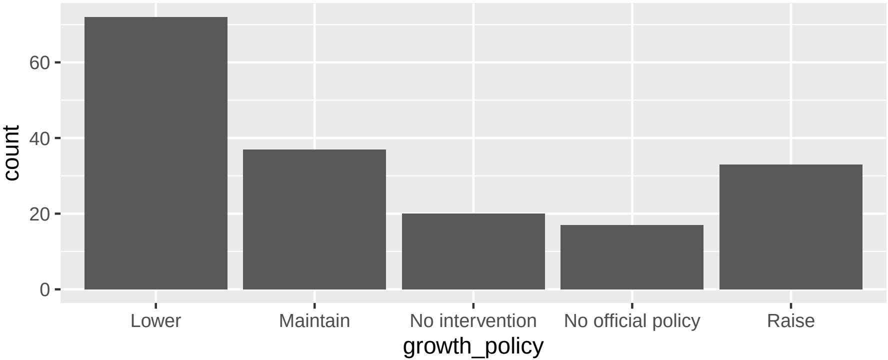
l + **geom_contour**(aes(z = z))
x, y, z, alpha, colour, group, linetype, size, weight

l + **geom_raster**(aes(fill = z), hjust=0.5, vjust=0.5, interpolate=FALSE)
x, y, alpha, fill

l + **geom_tile**(aes(fill = z))
x, y, alpha, color, fill, linetype, size, width

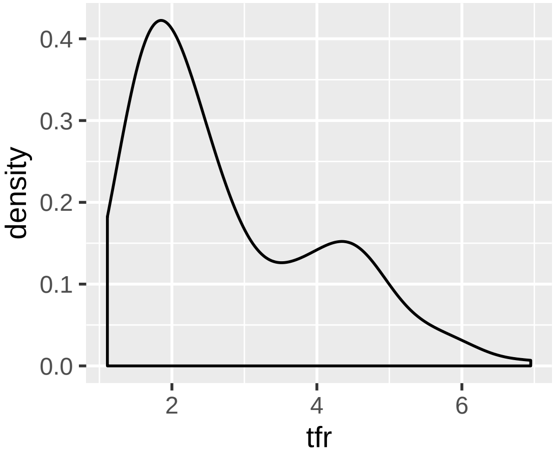
One Variable: Discrete - geom_bar()

```
> ggplot(data = df0, mapping = aes(x = growth_policy)) +
+   geom_bar()
```



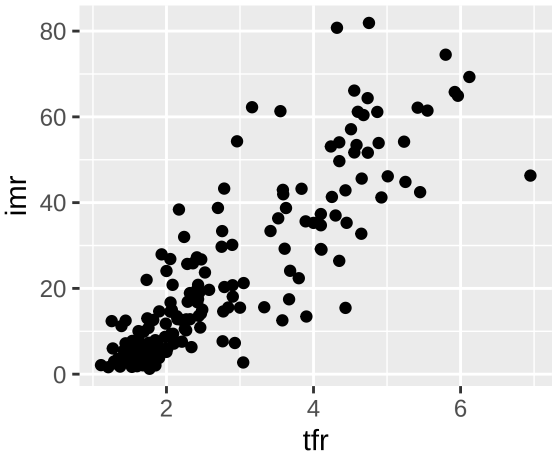
One Variable: Continuous - geom_density()

```
> ggplot(data = df0, mapping = aes(x = tfr)) +
+   geom_density()
```



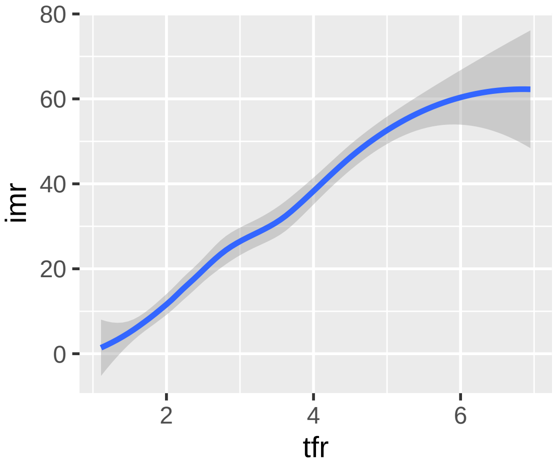
Two Variables: Both Continuous - geom_point()

```
> ggplot(data = df0, mapping = aes(x = tfr, y = imr)) +
+   geom_point()
```



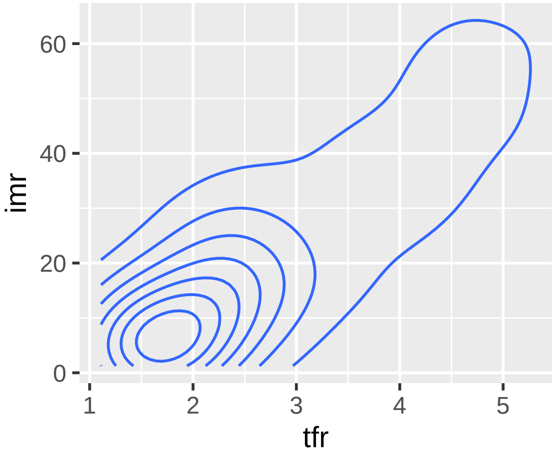
Two Variables: Both Continuous - geom_smooth()

```
> ggplot(data = df0, mapping = aes(x = tfr, y = imr)) +
+   geom_smooth()
```



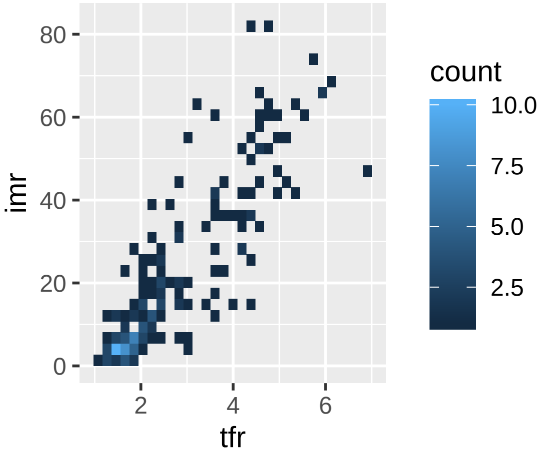
Two Variables: Both Continuous - geom_density2d()

```
> ggplot(data = df0, mapping = aes(x = tfr, y = imr)) +
+   geom_density2d()
```



Two Variables: Both Continuous - geom_bin2d()

```
> ggplot(data = df0, mapping = aes(x = tfr, y = imr)) +
+   geom_bin2d()
```

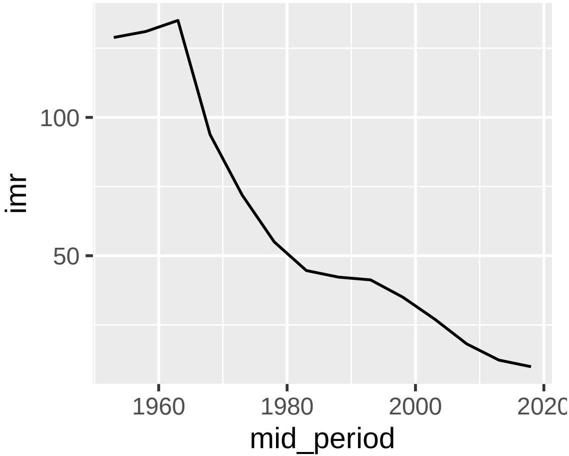


Two Variables: Continuous and Time

```
> df1
# A tibble: 14 x 5
   name  period    mid_period   imr   tfr
   <chr> <chr>          <dbl> <dbl> <dbl>
 1 China 1950-1955       1953 129.   6.11
 2 China 1955-1960       1958 131.   5.48
 3 China 1960-1965       1963 135.   6.15
 4 China 1965-1970       1968  93.8  6.3
 5 China 1970-1975       1973  71.9  4.85
 6 China 1975-1980       1978  55.0  3.01
 7 China 1980-1985       1983  44.6  2.52
 8 China 1985-1990       1988  42.3  2.73
 9 China 1990-1995       1993  41.3  1.83
10 China 1995-2000       1998  35.1  1.62
11 China 2000-2005       2003  27.1  1.61
12 China 2005-2010       2008  18.1  1.62
13 China 2010-2015       2013  12.3  1.64
14 China 2015-2020       2018   9.89 1.69
```

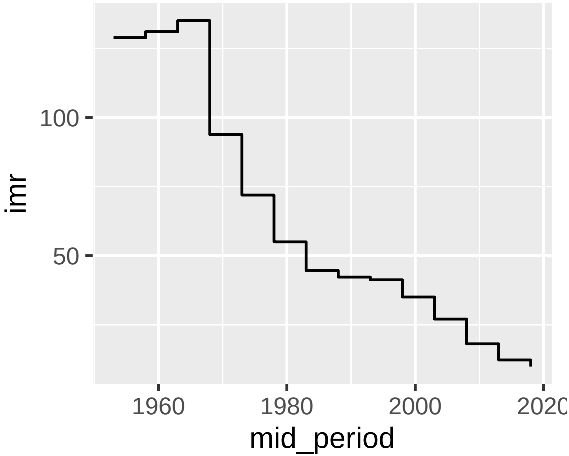
Two Variables: Continuous and Time - geom_line()

```
> ggplot(data = df1, mapping = aes(x = mid_period, y = imr)) +
+   geom_line()
```



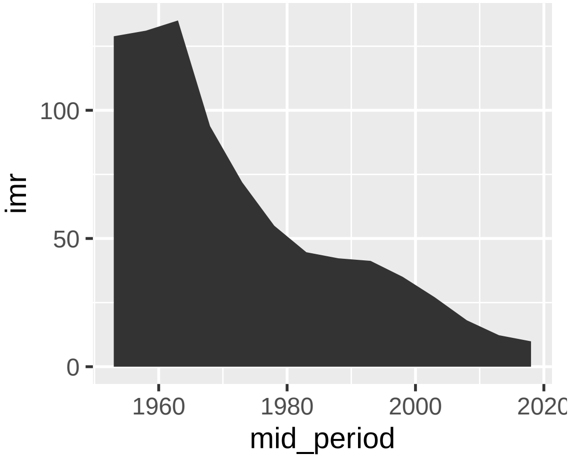
Two Variables: Continuous and Time - geom_step()

```
> ggplot(data = df1, mapping = aes(x = mid_period, y = imr)) +
+   geom_step()
```



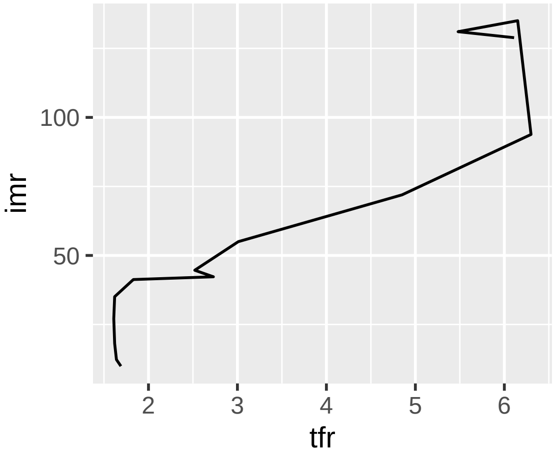
Two Variables: Continuous and Time - geom_bar()

```
> ggplot(data = df1, mapping = aes(x = mid_period, y = imr)) +
+   geom_area()
```



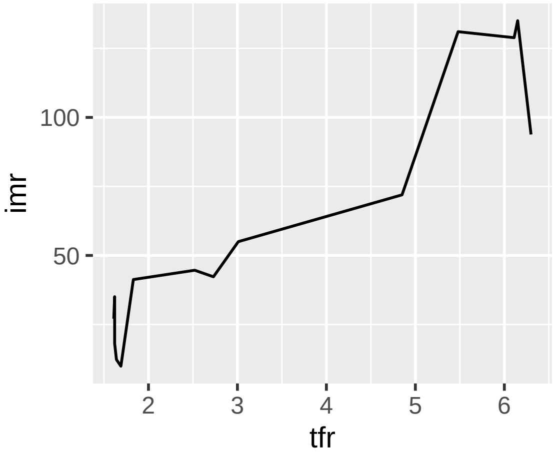
Two Variables: Continuous - geom_path()

```
> # geom_path() follows order in data
> ggplot(data = df1, mapping = aes(x = tfr, y = imr)) +
+   geom_path()
```



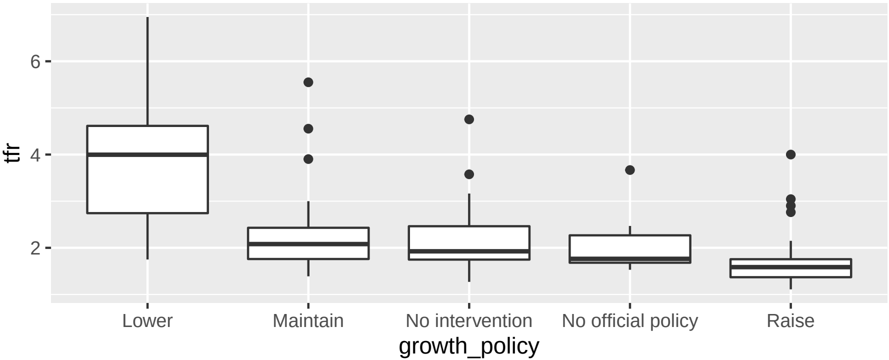
Two Variables: Continuous - geom_line()

```
> # geom_line() follows order on x-axis (fine if time, if not need geom_path())
> ggplot(data = df1, mapping = aes(x = tfr, y = imr)) +
+   geom_line()
```



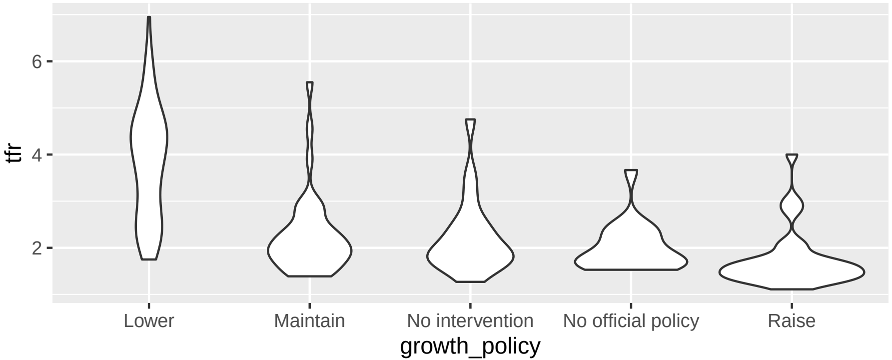
Two Variables: Continuous and Discrete - geom_boxplot()

```
> ggplot(data = df0, mapping = aes(x = growth_policy, y = tfr)) +
+   geom_boxplot()
```



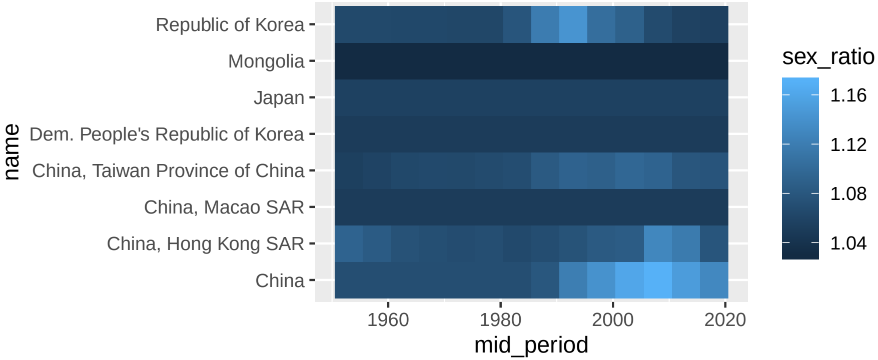
Two Variables: Continuous and Discrete - geom_violin()

```
> ggplot(data = df0, mapping = aes(x = growth_policy, y = tfr)) +
+   geom_violin()
```



Three Variables: Continuous/Discrete Mix - geom_tile()

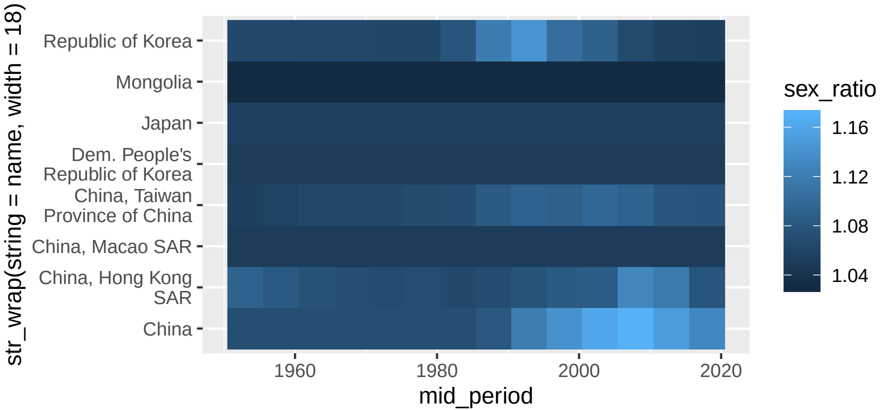
```
> head(df2, n = 2)
# A tibble: 2 x 7
  name                   period    mid_period   imr   tfr sex_ratio     pop
  <chr>                  <chr>          <dbl> <dbl> <dbl>     <dbl>   <dbl>
1 China                  1950-1955       1953 129.   6.11      1.07 593366.
2 China, Hong Kong SAR 1950-1955       1953  61.9  4.44      1.09   2251.
> ggplot(data = df2,
+        mapping = aes(x = mid_period, y = name, fill = sex_ratio)) +
+   geom_tile()
```



Side Step: Dealing with long category names

- The `str_wrap()` function in the `stringr` package (loaded with the `tidyverse`) can be used to put long strings over multiple lines.

```
> ggplot(data = df2,
+        mapping = aes(x = mid_period, y = str_wrap(string = name, width = 18),
+                      fill = sex_ratio)) +
+   geom_tile()
```

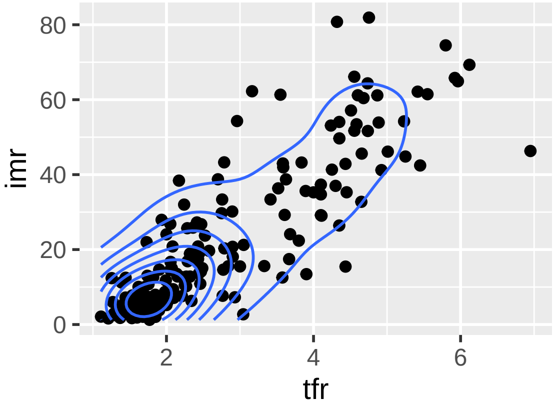


Layers

- Geoms can be added in layers
  - Adds more detail the plots
- The `data` and `mapping` aesthetics in the `ggplot` function are shared by all the geom functions
- To overwrite for a individual geom you can place `mappings` or `data` arguments in the geom function
  - This will treat mappings or data local to the layer only.

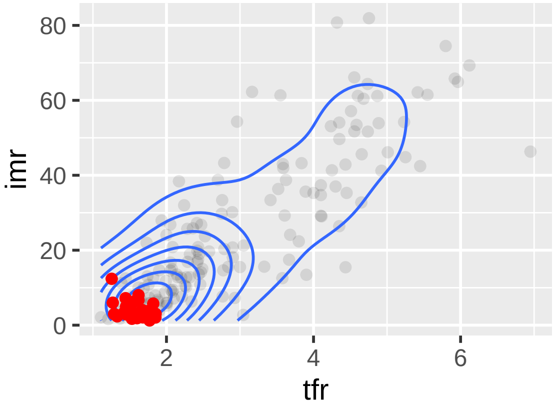
Layers

```
> ggplot(data = df0, mapping = aes(x = tfr, y = imr)) +
+   geom_point() +
+   geom_density2d()
```



Layers

```
> # faded points for on all countries (df0), red for European data
> # more on aesthetics and filter later!
> ggplot(data = df0, mapping = aes(x = tfr, y = imr)) +
+   geom_point(alpha = 0.1) +
+   geom_density2d() +
+   geom_point(data = filter(df0, area_name == "Europe"), colour = "red")
```

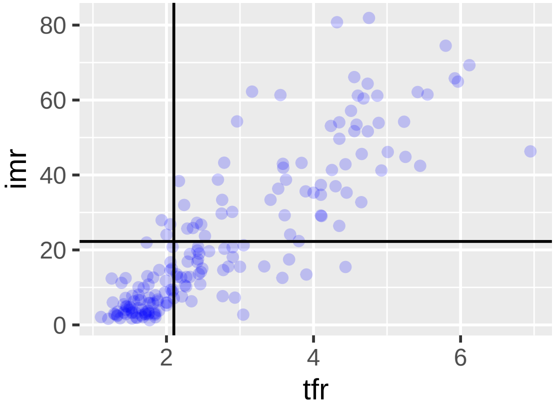


Layers

- Line geoms can help indicate important thresholds
  - The `geom_hline()` function for horizontal line with `yintercept` arguments.
  - The `geom_vline()` function for vertical line with `xintercept` arguments.
  - The `geom_abline()` function for a line with `intercept` and `slope` arguments.

Layers

```
> ggplot(data = df0, mapping = aes(x = tfr, y = imr)) +
+   geom_point(alpha = 0.2, colour = "blue") +
+   geom_vline(xintercept = 2.1) +
+   # use mapping when using a column in the data
+   geom_hline(mapping = aes(yintercept = mean(imr)))
```



Exercise 1 (ex21.R)

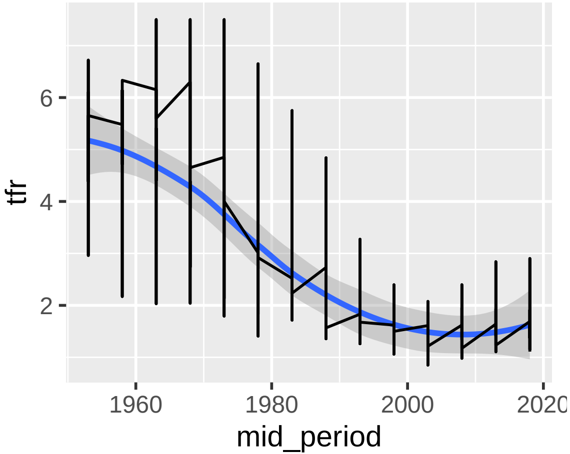
```
# 0.  a) Set the working directory to the course folder on your computor by loading
#     b) Check the working directory
getwd()
#     c) Load the tidyverse package (which loads the ggplot2 package amongst others)
library(#####)
#     d) Run the code in ex21_prelim.R to import the UN data for this exercise
source("./exercise./ex21_prelim.R")
#     e) Get familiar with the data by printing to console...
# all countries, 2010-2015 only
d1
# UK data, all periods
d2
# South Eastern Asia data, all periods
d3
##
##
##
# 1. Create a scatter plot of infant mortalitiy rates (x) against total fertility ra
#    in all countries in the 2010-2015 period
#    (Hint: a) see above to help select the correct data b) use imr and tfr columns)



# 2. Create a bar plot of the immigration policies in different countries from d1
#    (Hint: policiy data in the immigration_policy variable)
```

Groups

- Many `geoms_` functions use a single object to describe all of the data.
- You can set the `group` aesthetic in the `mappings` to a **discrete** variable to draw multiple objects.
  - This will tell ggplot2 to draw separate object for each unique value of the grouping variable.
- Will not add a legend or distinguishing features to the plot.
  - These are added when we have some more aesthetics for the `mappings`, e.g. `colour` or `linetype` (will get to these soon).

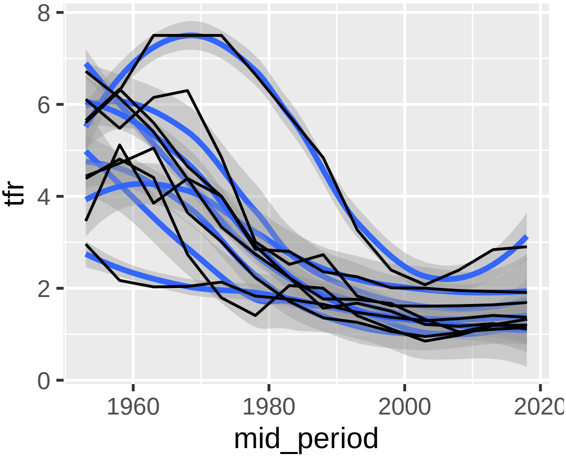
Groups

```
> # eastern asia: one smooth line and one data line through all points
> ggplot(data = df2, mapping = aes(x = mid_period, y = tfr)) +
+   geom_smooth() +
+   geom_line()
```



Groups

```
> # eastern asia: smooth line and data line for each country (identified by name)
> ggplot(data = df2, mapping = aes(x = mid_period, y = tfr, group = name)) +
+   geom_smooth() +
+   geom_line()
```



Optional Aesthetics

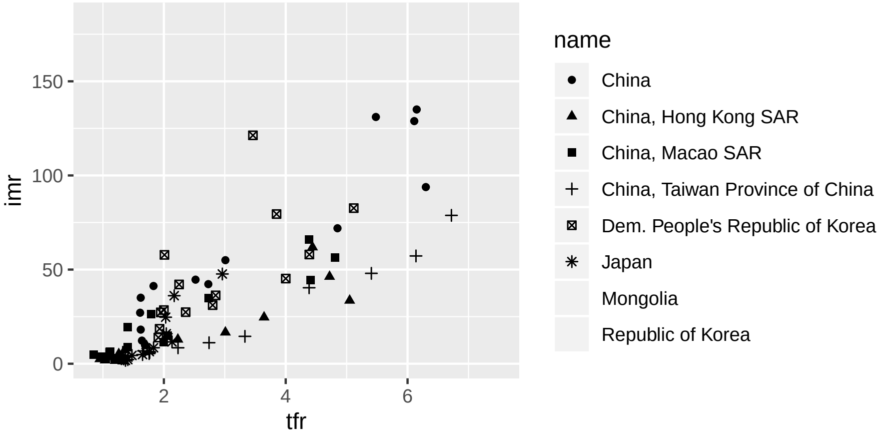
- Beyond `group`, there are other aesthetics (`aes`) that can be used depending on the geom, for example:
  - `shape`: shape of point
  - `linetype`: type of line used
  - `colour`: border colour
  - `size`: size of object
  - `fill`: internal colour
  - `alpha`: transparency (between 0 and 1)
  - and many more . . .
- Not all aesthetics work with all geom.
  - For example `geom_point()` has no `linetype` option.
  - Check the cheatsheet to see what is available.

Optional Aesthetics

- You can set the aesthetic to a
  - Single value to change the appearance for all plotted objects
    - Use outside of `mapping = aes()`
  - Variables (columns) in the data
    - Use inside of `mapping = aes()`
- When set to variable names in the data
  - If discrete will operate by each group (category) of the variable.
  - If continuous will operate along the scale of the variable.
- Not all aesthetics can be set to continuous variables
  - For example, `linetype = mid_period`
- Can set different aesthetics to different variables, allowing you to show more many dimensions of your data.

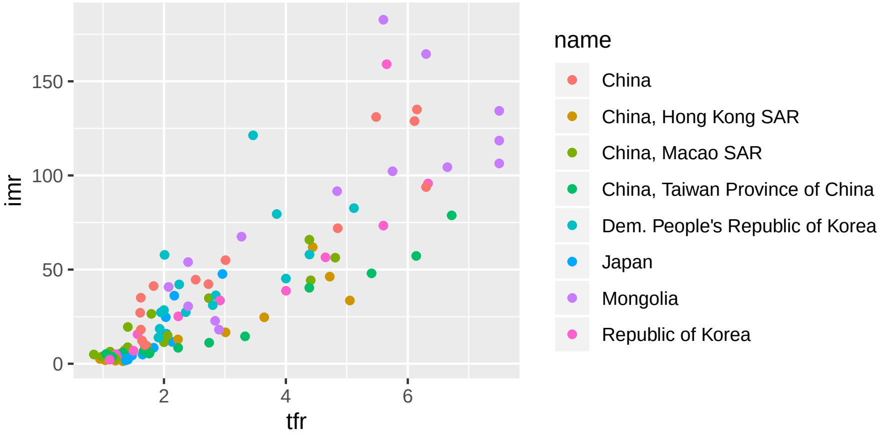
Optional Aesthetics

```
> # eastern asia: set shape from discrete variable
> ggplot(data = df2, mapping = aes(x = tfr, y = imr, shape = name)) +
+   geom_point()
```



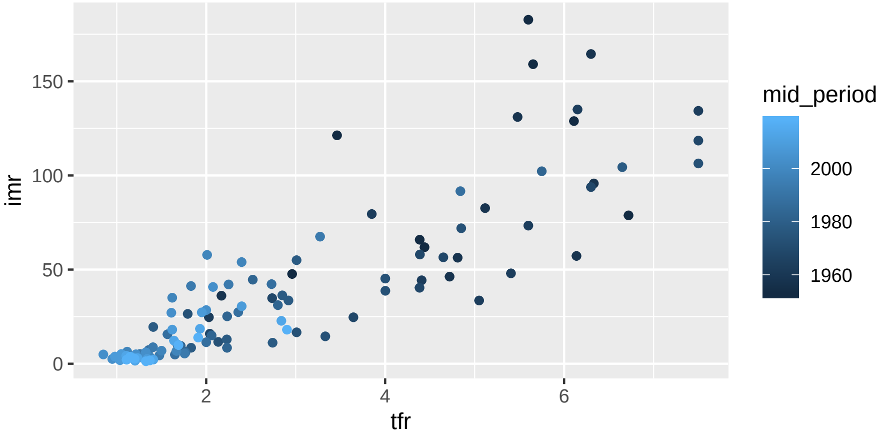
Optional Aesthetics

```
> # eastern asia: set colour from continuous variable
> ggplot(data = df2, mapping = aes(x = tfr, y = imr, colour = name)) +
+   geom_point()
```



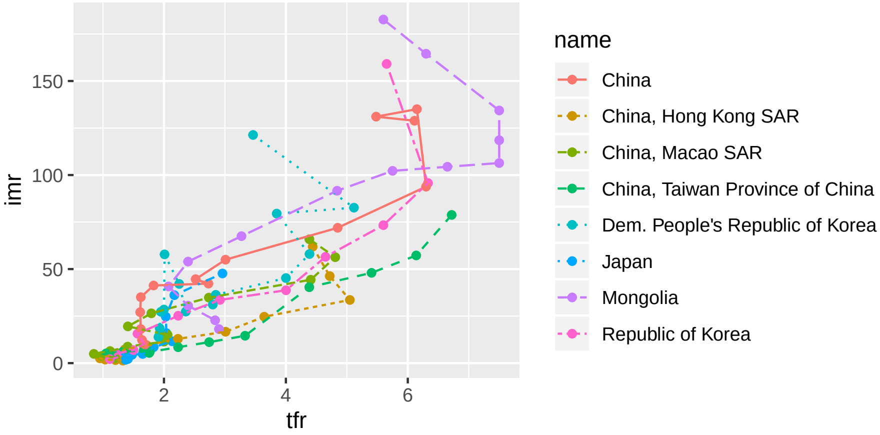
Optional Aesthetics

```
> # eastern asia: set colour from continuous variable
> ggplot(data = df2, mapping = aes(x = tfr, y = imr, colour = mid_period)) +
+   geom_point()
```



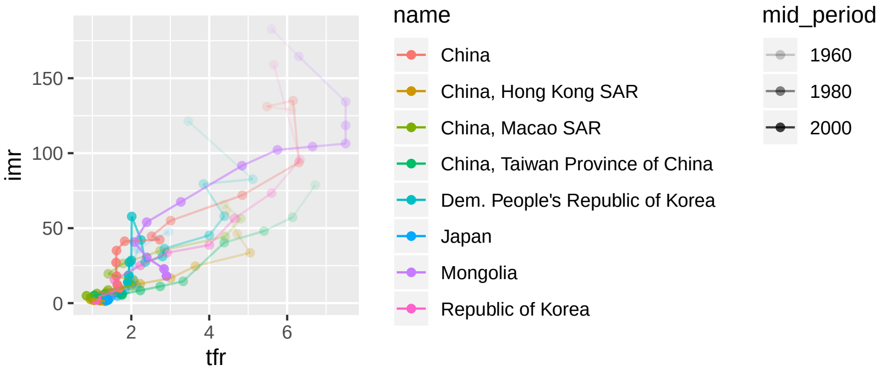
Optional Aesthetics

```
> # eastern asia: set colour and linetype from discrete variable
> ggplot(data = df2,
+        mapping = aes(x = tfr, y = imr, colour = name, linetype = name)) +
+   geom_point() +
+   geom_path()
```



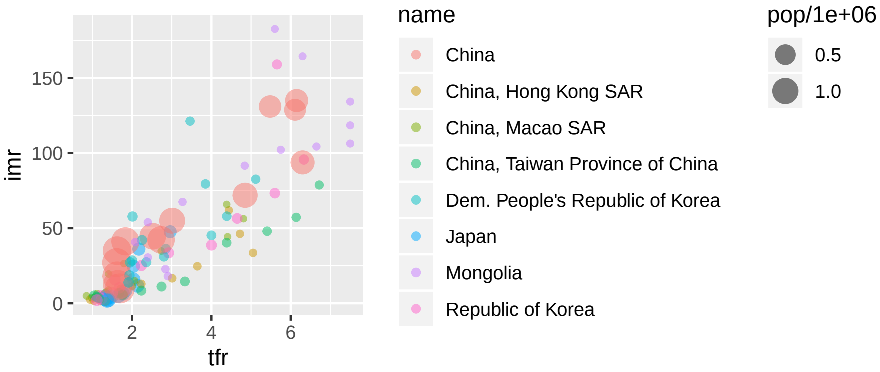
Optional Aesthetics

```
> # eastern asia: set colour from discrete and alpah from continuous variable
> ggplot(data = df2,
+        mapping = aes(x = tfr, y = imr, colour = name, alpha = mid_period)) +
+   geom_point() +
+   geom_path() +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```



Optional Aesthetics

```
> # eastern asia: set colour and size from data, set alpha to 0.5 for all.
> ggplot(data = df2,
+        mapping = aes(x = tfr, y = imr, colour = name, size = pop/1e6)) +
+   # all points with same transparency
+   geom_point(alpha = 0.5) +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```

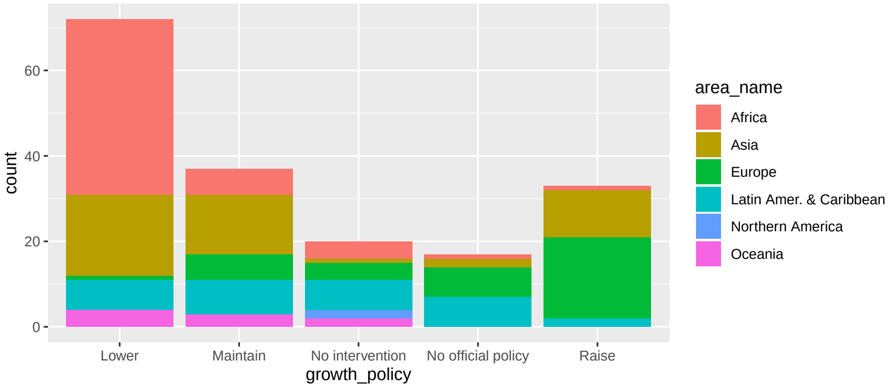


Position

- Each geoms has three main arguments (`mapping`, `position`, `stat`)
- The `position` adjustments determine how to arrange geoms that would otherwise occupy the same space.
- For most geoms you are unlikely to want to change from the default.
- However, for `geom_bar()` it is useful to know
  - `stack`: stacks elements on top of one another
  - `dodge`: arrange elements side by side
  - `fill`: stack elements on top of one another, normalize height
- For other geoms there are other position adjustment possibilities
  - `jitter`: adds random noise to `x` and `y` position of each element to avoid over plotting
  - `nudge`: nudge labels (in `geom_label()`) away from points

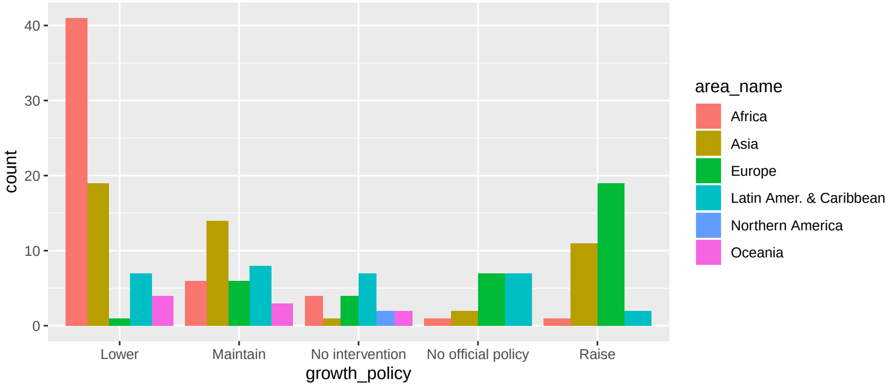
Position

```
> # stack position (default for geom_bar())
> ggplot(data = df0, mapping = aes(x = growth_policy, fill = area_name)) +
+   geom_bar()
```



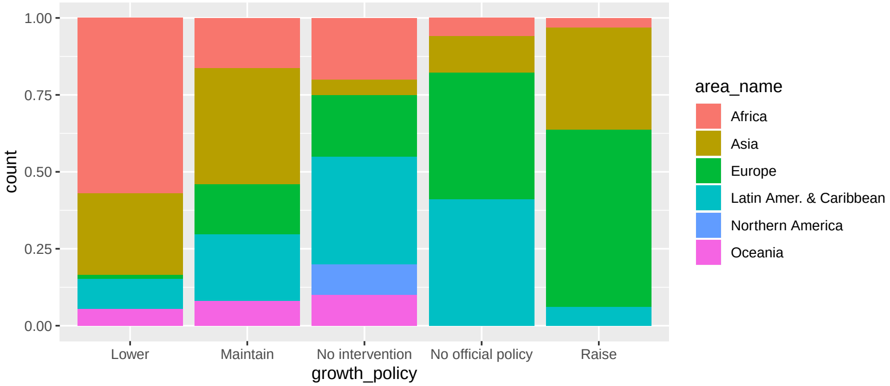
Position

```
> # dodge position
> ggplot(data = df0, mapping = aes(x = growth_policy, fill = area_name)) +
+   geom_bar(position = "dodge")
```



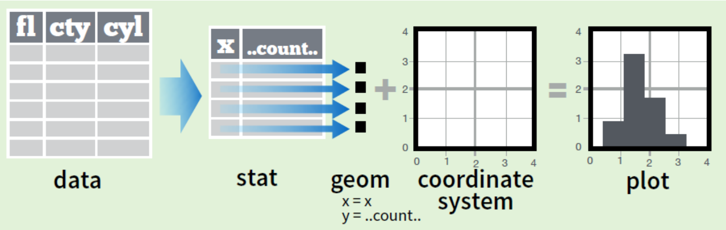
Position

```
> # fill position
> ggplot(data = df0, mapping = aes(x = growth_policy, fill = area_name)) +
+   geom_bar(position = "fill")
```



Stats

- Each geoms has three main arguments (`mapping`, `position`, `stat`)
- The `stat` argument builds new variables to plot (e.g., count, prop).
  - Short for statistical transformation.
- Each geom is associated with a default stat that it uses to calculate values to plot.
  - Applied the transformation and stores the results behind the scenes.
  - Uses and intuitive set of defaults.
  - Rarely need to adjust a geom `stat`.



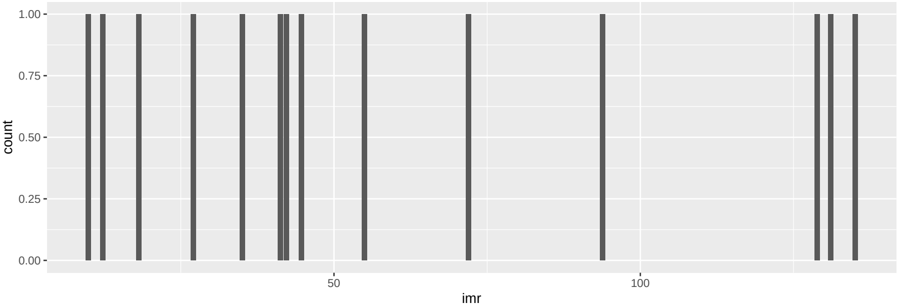
Stats

- Some stats we have already seen in action:
  - `identity`: use raw values, e.g. `geom_point()`
  - `count`: computes two new variables, count and proportion, e.g. `geom_bar()`
  - `bin`: arrange data into bins and counts, e.g. `geom_histogram()`
  - `density`: computes kernel density estimates, e.g. `geom_density()`
  - `smooth`: fit a model to your data and then plot the model line, e.g. `geom_smooth()`
  - `boxplot`: computes box plots statistics (min, max, IQR, median), e.g. `geom_boxplot()`
- For most geoms you are unlikely to want to change from the default.
  - For `geom_bar()` it is useful to know

Stats

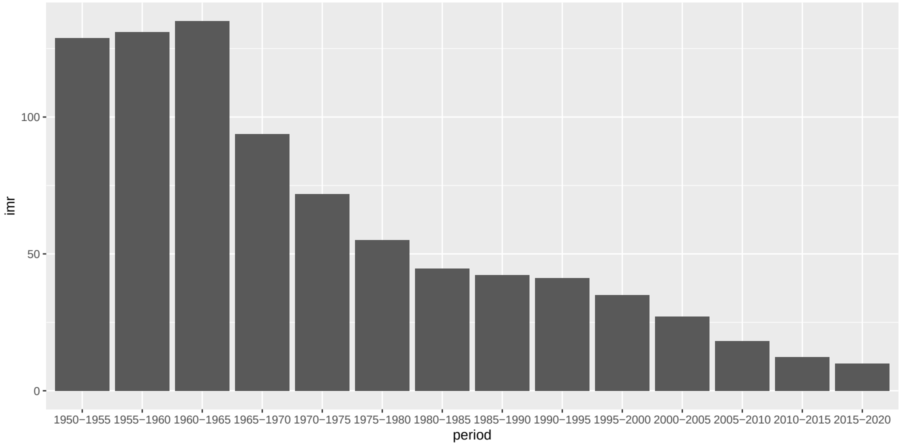
```
> # how can we plot a bar for imr in every period?... this gives an error...
> ggplot(data = df1, mapping = aes(x = period, y = imr)) +
+   geom_bar()
Error: stat_count() must not be used with a y aesthetic.
```

```
> # this is not what we want...
> ggplot(data = df1, mapping = aes(x = imr)) +
+   geom_bar()
```



Stats

```
> # china: identity stat
> ggplot(data = df1, mapping = aes(x = period, y = imr)) +
+   geom_bar(stat = "identity")
```

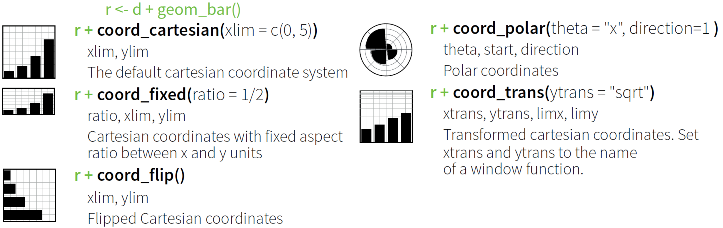


Exercise 2 (ex22.R)

```
# 0.  a) Check your working directory is in the course folder. Load .Rproj file if n
getwd()
#     b) Load the tidyverse package (which loads the ggplot2 package amongst others)
library(tidyverse)
#     c) Run the code in ex22_prelim.R to import the UN data for this exercise
source(#####)
##
##
##
# 1. Create a scatter plot of infant mortalitiy rates (x) against total fertility ra
#    a) point colours matching area names
#    b) point sizes matching the population size in millions (divide pop by 1000)


# 2. Adapt the plot above to add
#    a) horizontal line where tfr is 2.1
#    b) all points to have a transparency of 0.5




# 3. Create a plot of paths for the infant mortalitiy rate (x) against total fertili
#    relationship for Southeast Asian countries in d3 using
#    a) seperate paths for each country
#    b) transparency to change by the years in the mid_period column
```

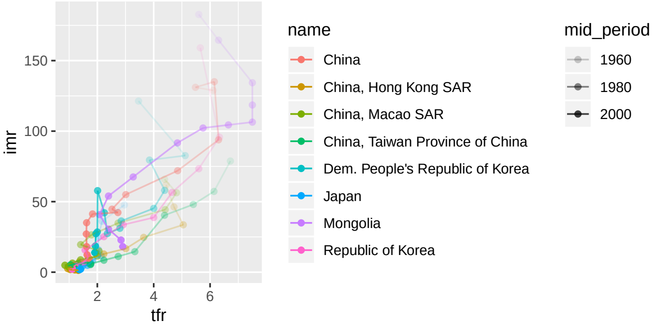
Coordinates

- Plots are based on a coordinate system.
  - The `ggplot()`, like most software, uses the Cartesian coordinate system by default
- Can change the coordinates system of easily using a `coord_` function with `ggplot()`



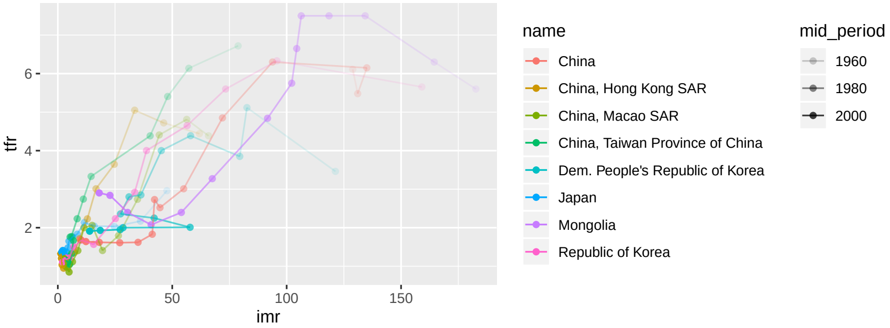
Coordinates

```
> # eastern asia: fix coordinates: 1 coord unit of imr (y) same as 0.05 tfr (x)
> ggplot(data = df2,
+        mapping = aes(x = tfr, y = imr, colour = name, alpha = mid_period)) +
+   geom_point() +
+   geom_path() +
+   coord_fixed(ratio = 0.05) +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```



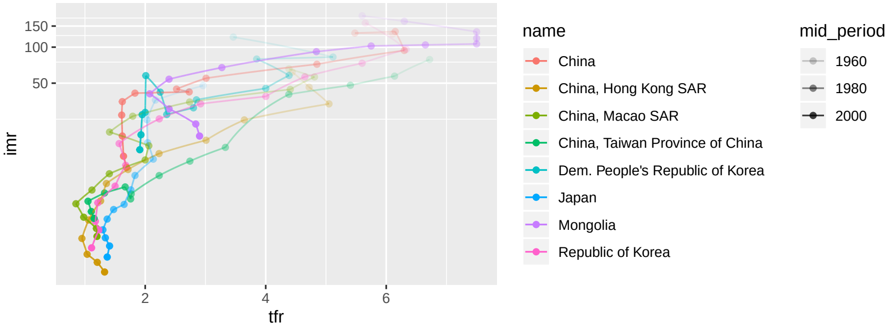
Coordinates

```
> # eastern asia flip coordinates: x is y, y is x
> ggplot(data = df2,
+        mapping = aes(x = tfr, y = imr, colour = name, alpha = mid_period)) +
+   geom_point() +
+   geom_path() +
+   coord_flip() +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```



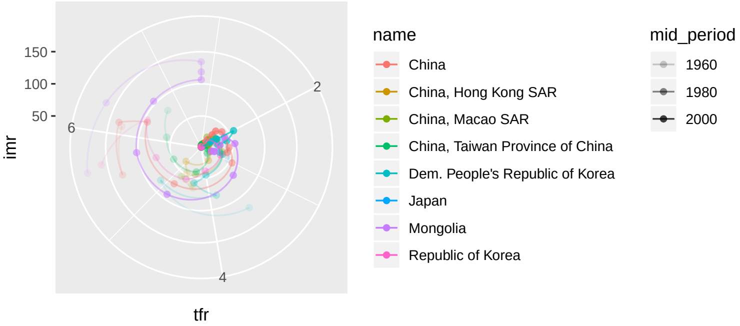
Coordinates

```
> # log y axes
> ggplot(data = df2,
+        mapping = aes(x = tfr, y = imr, colour = name, alpha = mid_period)) +
+   geom_point() +
+   geom_path() +
+   coord_trans(y = "log") +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```



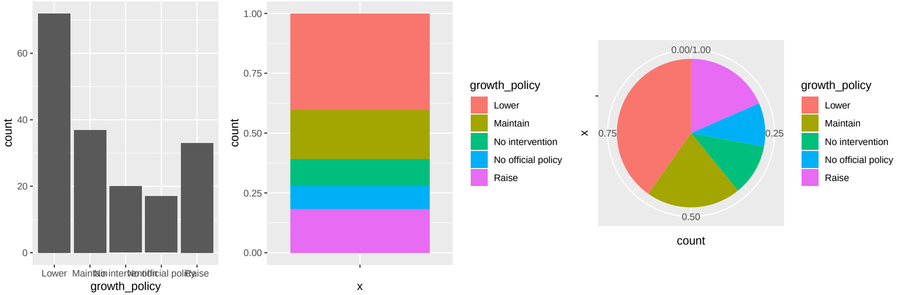
Coordinates

```
> # polar coordinates: x is now the angle in circle and y is distance from centre
> ggplot(data = df2,
+         mapping = aes(x = tfr, y = imr, colour = name, alpha = mid_period)) +
+   geom_point() +
+   geom_path() +
+   coord_polar() +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```



Pie Charts

```
> ggplot(data = df0, mapping = aes(x = growth_policy)) +
+   geom_bar()
>
> ggplot(data = df0, mapping = aes(x = "", fill = growth_policy)) +
+   geom_bar(position = "fill")
>
> ggplot(data = df0, mapping = aes(x = "", fill = growth_policy)) +
+   geom_bar(position = "fill") +
+   coord_polar(theta = "y")
```



Facets

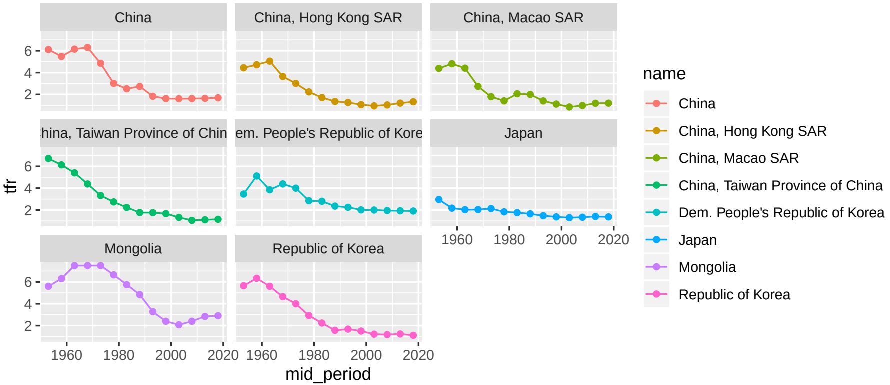
- Facets divide a plot into subplots based on the values of one or more discrete variables
  - Subplots can be a very effective way to compare across discrete (categorical) values
- Two functions:
  - `facet_wrap()` wraps a sequence of panels defined by a discrete variable(s) onto a page in roughly rectangular form.
  - `facet_grid()` forms a matrix of panels defined by row and column faceting variables. It is most useful when you have two discrete variables, and all combinations of the variables exist in the data.

Facets

- Define facet layouts using arguments depending on function
  - `facet_wrap()` use `facet = "a"` or `facet = vars(a)`
  - `facet_grid()` use `row = vars(a)`, `col = vars(b)`
- Other arguments are similar
  - `nrow, ncol`: Number of rows and columns.
  - `scales`: fixes or frees scales in facets
    - `"fixed"`: both scales fixed (default)
    - `"free"`: both scales free
    - `"free_x"` or `"free_y"`: scales free in one dimension.
  - `labeller`: adjust facet strip labels,
    - for example `labeller = label_wrap_gen(10)` to make sure each facet strip label is only a maximum 10 characters wide.

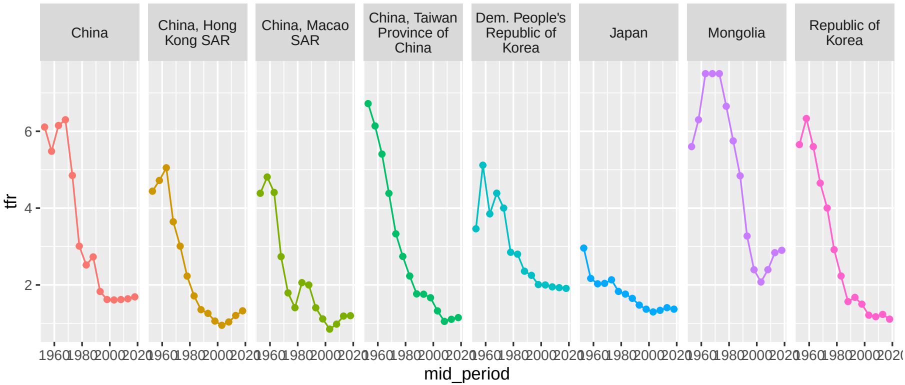
Facets

```
> # eastern asia: facet_wrap() function for each country (name)
> ggplot(data = df2, mapping = aes(x = mid_period, y = tfr, colour = name)) +
+   geom_point() +
+   geom_line() +
+   facet_wrap(facets = "name") +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```



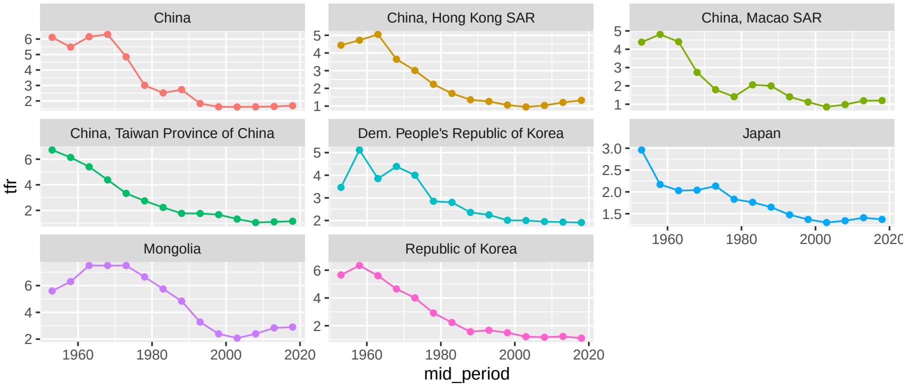
Facets

```
> # facet_wrap() function using one row and restrict label width
> ggplot(data = df2, mapping = aes(x = mid_period, y = tfr, colour = name)) +
+   geom_point() +
+   geom_line() +
+   facet_wrap(facets = vars(name), nrow = 1, labeller = label_wrap_gen(15)) +
+   # drop country name guide
+   guides(colour = FALSE)
```



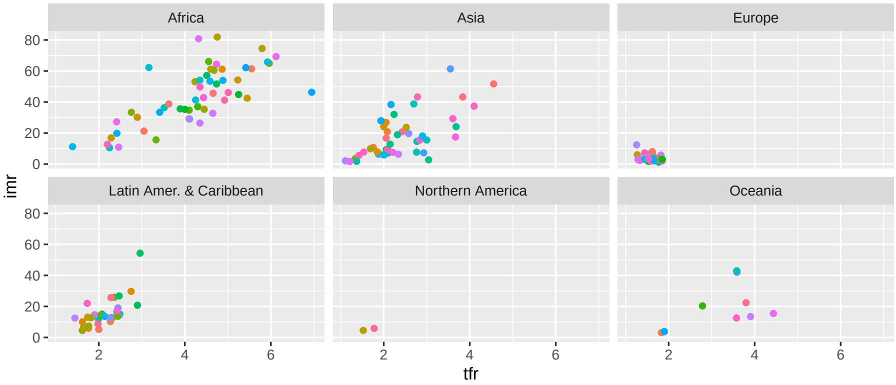
Facets

```
> # facet_wrap() function with different y axis limits
> ggplot(data = df2, mapping = aes(x = mid_period, y = tfr, colour = name)) +
+   geom_point() +
+   geom_line() +
+   facet_wrap(facets = vars(name), scales = "free_y") +
+   guides(colour = FALSE)
```



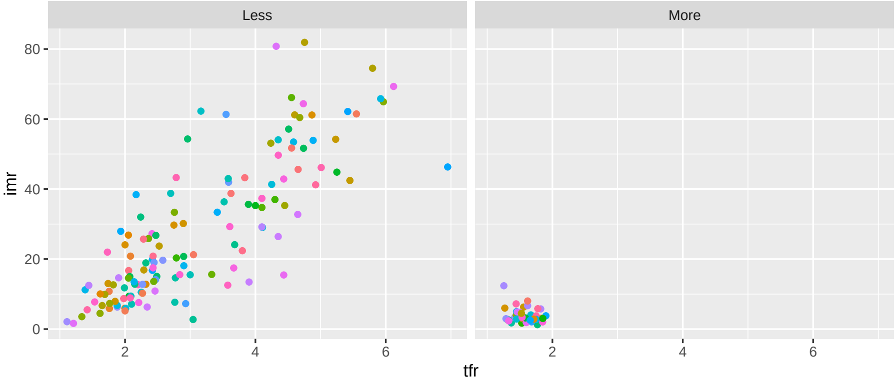
Facets

```
> # facet_wrap() function scatter plot
> ggplot(data = df0,
+        mapping = aes(x = tfr, y = imr, colour = name)) +
+   geom_point() +
+   facet_wrap(facets = vars(area_name)) +
+   guides(colour = FALSE)
```



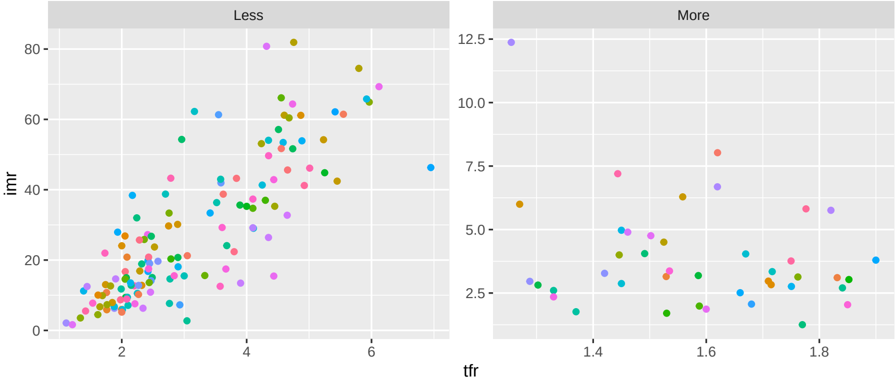
Facets

```
> # facet_wrap() function scatter plot using development level
> ggplot(data = df0,
+         mapping = aes(x = tfr, y = imr, colour = name)) +
+   geom_point() +
+   facet_wrap(facets = vars(developed)) +
+   guides(colour = FALSE)
```



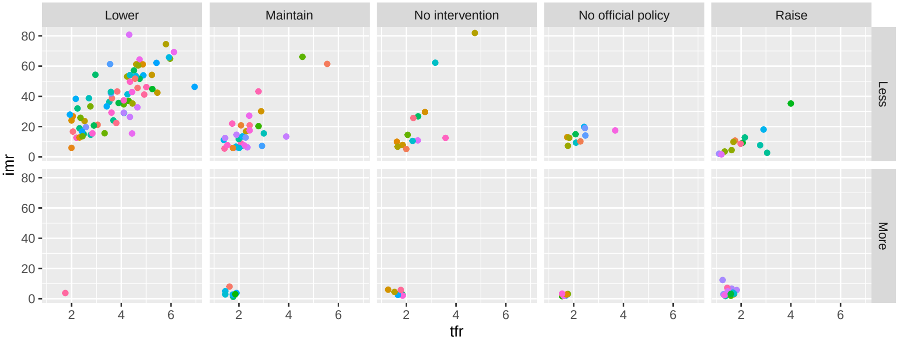
Facets

```
> # all data: facet_wrap() function scatter plot with x and y scales free
> ggplot(data = df0,
+        mapping = aes(x = tfr, y = imr, colour = name)) +
+   geom_point() +
+   facet_wrap(facets = "developed", scales = "free") +
+   guides(colour = FALSE)
```



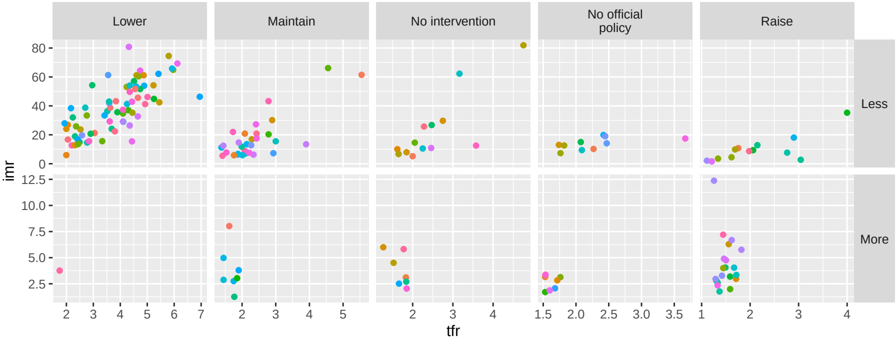
Facets

```
> # facet_grid() function scatter plot using development status and population growt
> ggplot(data = df0,
+        mapping = aes(x = tfr, y = imr, colour = name)) +
+   geom_point() +
+   facet_grid(row = vars(developed), col = vars(growth_policy)) +
+   guides(colour = FALSE)
```



Facets

```
> # ... alter labels and free grid scales
> ggplot(data = df0,
+        mapping = aes(x = tfr, y = imr, colour = name)) +
+   geom_point() +
+   # rotate growth policy labels to fit legend on my slides
+   facet_grid(row = vars(developed), col = vars(growth_policy),
+              scales = "free", labeller = label_wrap_gen(18)) +
+   guides(colour = FALSE) +
+   # rotate growth policy labels to fit legend on my slides
+   theme(strip.text.y = element_text(angle = 0))
```

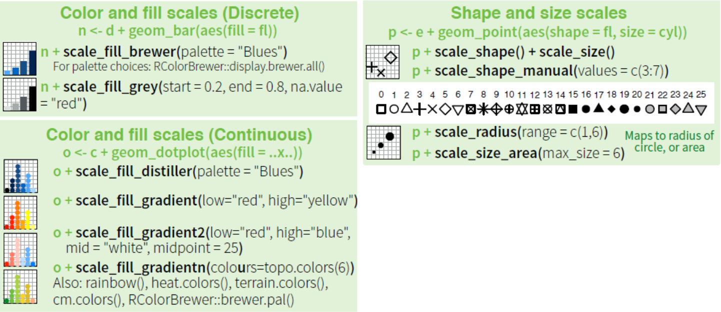


Exercise 3 (ex23.R)

```
# 0.  a) Check your working directory is in the course folder. Load .Rproj file if n
getwd()
#     b) Load the tidyverse package (which loads the ggplot2 package amongst others)

#     c) Run the code in ex23_prelim.R to import the UN data for this exercise
source("./exercise/ex23_prelim.R")
##
##
##
# 1. Create a pie chart of the immigration policies in different countries from d1



# 2. Adapt the code from the question above to create pie charts for the growth_poli
#    a. seperate facets for each area
#    b. no axis
#    (Hint: use theme_void() to drop axis)




# 3. Uncomment the solution to Question 1 of ex22 and then adapt so that the infant
#    transformed to the log10 scale
# ggplot(data = d1, mapping = aes(x = imr, y = tfr, colour = area_name, size = pop/1
```

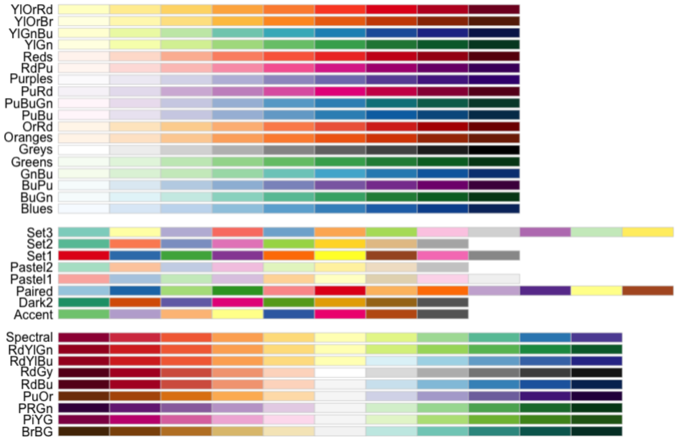
Scales

- The `scale` functions change aesthetics from their default.
- Each aesthetic has its own functions. Take a general form:
  - `scale_*_continuous()`: alter aesthetics based on continuous variables
  - `scale_*_discrete()`: alter aesthetics based on discrete variables
  - `scale_*_manual(values = c())`: map discrete values to manually chosen visual ones



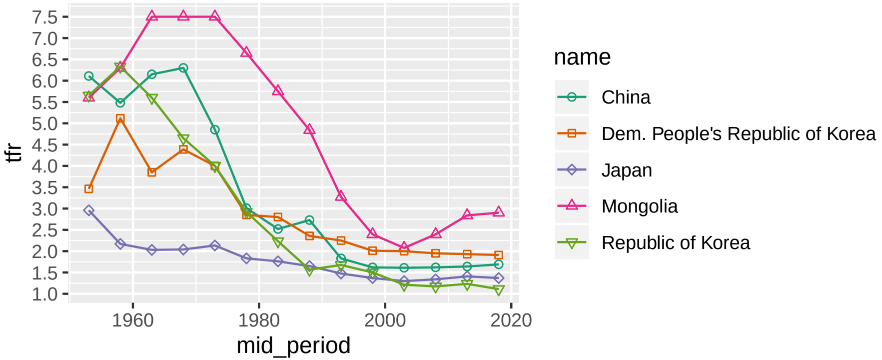
Scales

- Colour schemes from ColorBrewer that are loaded with `ggplot2`
  - `http://colorbrewer2.org`



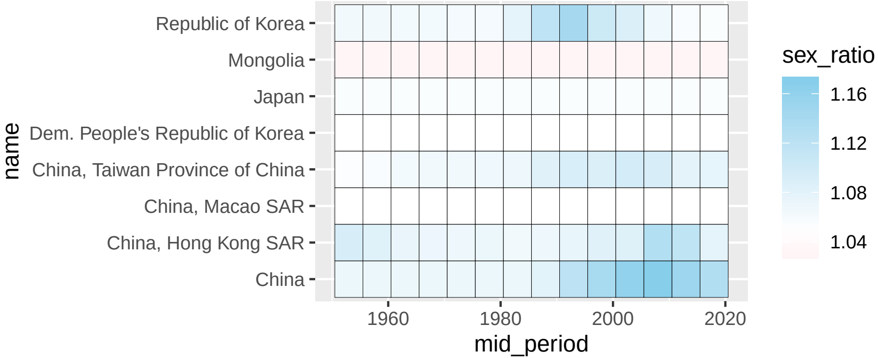
Scales

```
> # eastern asia without Hong Kong, Macau and Taiwan
> ggplot(data = df2 %>%
+          filter(!str_detect(string = name, pattern = ",")),
+        mapping = aes(x = mid_period, y = tfr, colour = name, shape = name)) +
+   geom_point() +
+   geom_line() +
+   scale_color_brewer(palette = "Dark2") +
+   scale_shape_manual(values = 21:25) +
+   scale_y_continuous(breaks = seq(from = 1, to= 8, by = 0.5))
```



Scales

```
> ggplot(data = df2, mapping = aes(x = mid_period, y = name, fill = sex_ratio)) +
+   geom_tile(colour = "black") +
+   scale_fill_gradient2(low="pink", high="skyblue", mid="white", midpoint=1.05)
```

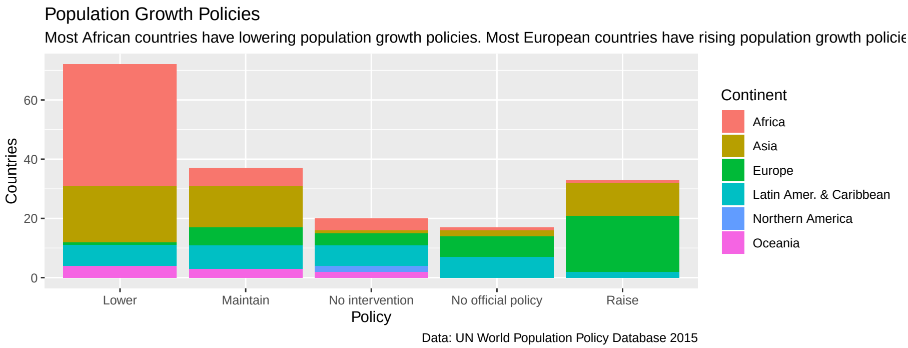


Labels

- Good labels are critical for making your plots accessible to a wider audience.
- The `labs()` function can add
  - `title`: main title
  - `subtitle`: highlight main message
  - `caption`: data source information
  - `x`, `y`, `fill`, `colour`, `alpha`, `...` : full variable names for aesthetics

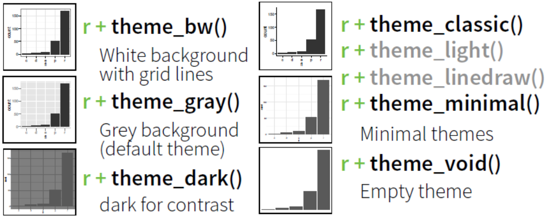
Labels

```
> # all countries 2010-15 data
> ggplot(data = df0, mapping = aes(x = growth_policy, fill = area_name)) +
+   geom_bar() +
+   labs(title = "Population Growth Policies",
+        subtitle = "Most African countries have lowering population growth policie
+        caption = "Data: UN World Population Policy Database 2015",
+        x = "Policy", y = "Countries", fill = "Continent")
```



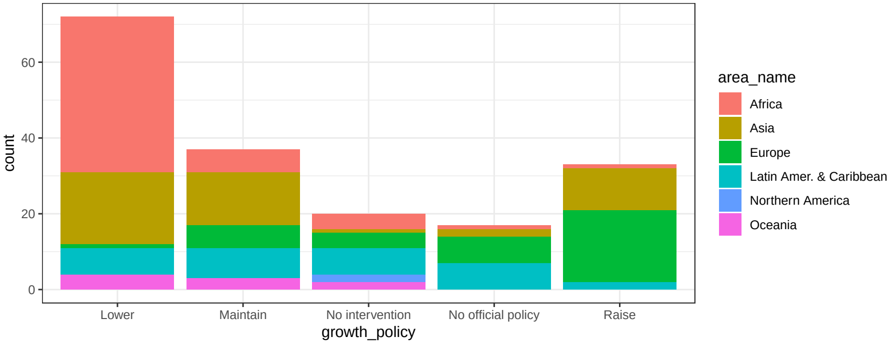
Themes

- The `theme` functions customize the "look" of plots
  - Changes how the plot looks without changing the information that the plot displays.
- There are eight theme functions in `ggplot2`
- The `ggthemes` package has many themes to match publication styles e.g. Economist or FiveThirtyEight



Themes

```
> # change theme
> ggplot(data = df0, mapping = aes(x = growth_policy, fill = area_name)) +
+   geom_bar() +
+   theme_bw()
```



Saving

- Can assign a plot to an R object
  - Can then keep adding to the plot with the +

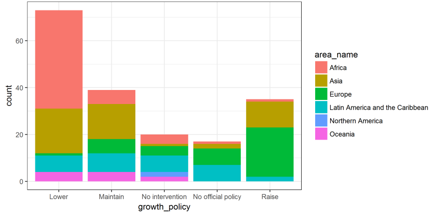
```
> # save a plot to an object
> g <- ggplot(data = df0, mapping = aes(x = growth_policy, fill = area_name)) +
+   geom_bar()
> # plot g with the black and white theme
> g + theme_bw()
```

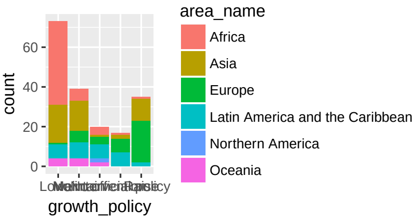
- The `ggsave()` function to save plot from
  - `filename`: matches file type to file extension, e.g. `filename = myplot.pdf` will create a PDF. If no path is given in the file name, the file will appear in the current working directory (`getwd()`).
  - `width`, `height`, `units`: plot size, uses RStudio window size by default
  - `scale`: scales the size of the plots objects

```
> # saves the last plot from RStudio as a PNG
> ggsave(filename = "myplot.png", width = 10, height = 5, unit = "cm", scale = 2)
> # saves the plot from object g as a PDF
> ggsave(filename = "myplot.pdf", width = 10, height = 5, unit = "cm", plot = g)
```

Scale

- Scale alters the point size:
  - Left: PNG with scale = 2
  - Right: PDF with scale = 1 (default)





RStudio Cheatsheet

Data Visualization with ggplot2 : : CHEAT SHEET

Basics

ggplot2 is based on the **grammar of graphics**, the idea that you can build every graph from the same components: a **data** set, a **coordinate system**, and geoms—visual marks that represent data points.

data + **geom** x = F · y = A + **coordinate system** = **plot**

To display values, map variables in the data to visual properties of the geom (**aesthetics**) like **size**, **color**, and **x** and **y** locations.

data + **geom** x = F · y = A color = F size = A + **coordinate system** = **plot**

Complete the template below to build a graph.

ggplot (data = <DATA>) + — required
<GEOM_FUNCTION> (mapping = aes(<MAPPINGS>),
stat = <STAT> , position = <POSITION>) +
<COORDINATE_FUNCTION> +
<FACET_FUNCTION> +
<SCALE_FUNCTION> +
<THEME_FUNCTION>

Not required, sensible defaults supplied

ggplot(data = mpg, **aes**(x = cty, y = hwy)) Begins a plot that you finish by adding layers to. Add one geom function per layer.

aesthetic mappings · data · geom

qplot(x = cty, y = hwy, data = mpg, geom = "point") Creates a complete plot with given data, geom, and mappings. Supplies many useful defaults.

last_plot() Returns the last plot

ggsave("plot.png", width = 5, height = 5) Saves last plot as 5' x 5' file named "plot.png" in working directory. Matches file type to file extension.

Geoms

Use a geom function to represent data points, use the geom's aesthetic properties to represent variables. Each function returns a layer.

GRAPHICAL PRIMITIVES

a <- ggplot(economics, aes(date, unemploy))
b <- ggplot(seals, aes(x = long, y = lat))

a + geom_blank()
(Useful for expanding limits)

b + geom_curve(aes(yend = lat + 1, xend=long+1,curvature=z)) - x, xend, y, yend, alpha, angle, color, curvature, linetype, size

a + geom_path(lineend="butt", linejoin="round", linemitre=1)
x, y, alpha, color, group, linetype, size

a + geom_polygon(aes(group = group))
x, y, alpha, color, fill, group, linetype, size

b + geom_rect(aes(xmin = long, ymin=lat, xmax= long + 1, ymax = lat + 1)) - xmax, xmin, ymax, ymin, alpha, color, fill, linetype, size

a + geom_ribbon(aes(ymin=unemploy - 900, ymax=unemploy + 900)) - x, ymax, ymin, alpha, color, fill, group, linetype, size

LINE SEGMENTS

common aesthetics: x, y, alpha, color, linetype, size

b + geom_abline(aes(intercept=0, slope=1))
b + geom_hline(aes(yintercept = lat))
b + geom_vline(aes(xintercept = long))

b + geom_segment(aes(yend=lat+1, xend=long+1))
b + geom_spoke(aes(angle = 1:1155, radius = 1))

ONE VARIABLE continuous

c <- ggplot(mpg, aes(hwy)); c2 <- ggplot(mpg)

c + geom_area(stat = "bin")
x, y, alpha, color, fill, linetype, size

c + geom_density(kernel = "gaussian")
x, y, alpha, color, fill, group, linetype, size, weight

c + geom_dotplot()
x, y, alpha, color, fill

c + geom_freqpoly() x, y, alpha, color, group, linetype, size

c + geom_histogram(binwidth = 5) x, y, alpha, color, fill, linetype, size, weight

c2 + geom_qq(aes(sample = hwy)) x, y, alpha, color, fill, linetype, size, weight

discrete

d <- ggplot(mpg, aes(fl))

d + geom_bar()
x, alpha, color, fill, linetype, size, weight

TWO VARIABLES

continuous x , continuous y

e <- ggplot(mpg, aes(cty, hwy))

e + geom_label(aes(label = cty), nudge_x = 1, nudge_y = 1, check_overlap = TRUE) x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

e + geom_jitter(height = 2, width = 2)
x, y, alpha, color, fill, shape, size

e + geom_point(), x, y, alpha, color, fill, shape, size, stroke

e + geom_quantile(), x, y, alpha, color, group, linetype, size, weight

e + geom_rug(sides = "bl"), x, y, alpha, color, linetype, size

e + geom_smooth(method = lm), x, y, alpha, color, fill, group, linetype, size, weight

e + geom_text(aes(label = cty), nudge_x = 1, nudge_y = 1, check_overlap = TRUE), x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

discrete x , continuous y

f <- ggplot(mpg, aes(class, hwy))

f + geom_col(), x, y, alpha, color, fill, group, linetype, size

f + geom_boxplot(), x, y, lower, middle, upper, ymax, ymin, alpha, color, fill, group, linetype, shape, size, weight

f + geom_dotplot(binaxis = "y", stackdir = "center"), x, y, alpha, color, fill, group

f + geom_violin(scale = "area"), x, y, alpha, color, fill, group, linetype, size, weight

discrete x , discrete y

g <- ggplot(diamonds, aes(cut, color))

g + geom_count(), x, y, alpha, color, fill, shape, size, stroke

continuous bivariate distribution

h <- ggplot(diamonds, aes(carat, price))

h + geom_bin2d(binwidth = c(0.25, 500))
x, y, alpha, color, fill, linetype, size, weight

h + geom_density2d()
x, y, alpha, colour, group, linetype, size

h + geom_hex()
x, y, alpha, colour, fill, size

continuous function

i <- ggplot(economics, aes(date, unemploy))

i + geom_area()
x, y, alpha, color, fill, linetype, size

i + geom_line()
x, y, alpha, color, group, linetype, size

i + geom_step(direction = "hv")
x, y, alpha, color, group, linetype, size

visualizing error

df <- data.frame(grp = c("A", "B"), fit = 4:5, se = 1:2)
j <- ggplot(df, aes(grp, fit, ymin = fit-se, ymax = fit+se))

j + geom_crossbar(fatten = 2)
x, y, ymax, ymin, alpha, color, fill, group, linetype, size

j + geom_errorbar(), x, ymax, ymin, alpha, color, group, linetype, size, width (also **geom_errorbarh()**)

j + geom_linerange()
x, ymin, ymax, alpha, color, group, linetype, size

j + geom_pointrange()
x, y, ymin, ymax, alpha, color, fill, group, linetype, shape, size

maps

data <- data.frame(murder = USArrests$Murder,
state = tolower(rownames(USArrests)))
map <- map_data("state")
k <- ggplot(data, aes(fill = murder))

k + geom_map(aes(map_id = state), map = map)
+ **expand_limits**(x = map$long, y = map$lat),
map_id, alpha, color, fill, linetype, size

THREE VARIABLES

seals$z <- with(seals, sqrt(delta_long^2 + delta_lat^2)); l <- ggplot(seals, aes(long, lat))

l + geom_contour(aes(z = z))
x, y, z, alpha, colour, group, linetype, size, weight

l + geom_raster(aes(fill = z), hjust=0.5, vjust=0.5, interpolate=FALSE)
x, y, alpha, fill

l + geom_tile(aes(fill = z)), x, y, alpha, color, fill, linetype, size, width

RStudio

RStudio Cheatsheet

Stats An alternative way to build a layer

A stat builds new variables to plot (e.g., count, prop).

data stat geom coordinate system plot
x = x
y = ..count..

Visualize a stat by changing the default stat of a geom function, **geom_bar(stat="count")** or by using a stat function, **stat_count(geom="bar")**, which calls a default geom to make a layer (equivalent to a geom function). Use **..name..** syntax to map stat variables to aesthetics.

geom to use | stat function | geommappings
i + stat_density2d(aes(fill = ..level..), geom = "polygon"**)**
variable created by stat

c + stat_bin(binwidth = 1, origin = 10**)**
x, y | ..count.., ..ncount.., ..density.., ..ndensity..

c + stat_count(width = 1**) x, y,** | ..count.., ..prop..

c + stat_density(adjust = 1, kernel = "gaussian"**)**
x, y, | ..count.., ..density.., ..scaled..

e + stat_bin_2d(bins = 30, drop = T**)**
x, y, fill | ..count.., ..density..

e + stat_bin_hex(bins=30**) x, y, fill** | ..count.., ..density..

e + stat_density_2d(contour = TRUE, n = 100**)**
x, y, color, size | ..level..

e + stat_ellipse(level = 0.95, segments = 51, type = "t"**)**

l + stat_contour(aes(z = z)**) x, y, z, order** | ..level..

l + stat_summary_hex(aes(z = z), bins = 30, fun = max**)**
x, y, z, fill | ..value..

l + stat_summary_2d(aes(z = z), bins = 30, fun = mean**)**
x, y, z, fill | ..value..

f + stat_boxplot(coef = 1.5**) x, y** | ..lower.., ..middle.., ..upper.., ..width.. , ..ymin.., ..ymax..

f + stat_ydensity(kernel = "gaussian", scale = "area"**) x, y** | ..density.., ..scaled.., ..count.., ..n.., ..violinwidth.., ..width..

e + stat_ecdf(n = 40**) x, y** | ..x.., ..y..

e + stat_quantile(quantiles = c(0.1, 0.9), formula = y ~ log(x), method = "rq"**) x, y** | ..quantile..

e + stat_smooth(method = "lm", formula = y ~ x, se=T, level=0.95**) x, y** | ..se.., ..x.., ..y.., ..ymin.., ..ymax..

ggplot() + stat_function(aes(x = -3:3), n = 99, fun = dnorm, args = list(sd=0.5)**) x** | ..x.., ..y..

e + stat_identity(na.rm = TRUE**)**

ggplot() + stat_qq(aes(sample=1:100), dist = qt, dparam=list(df=5)**) sample, x, y** | ..sample.., ..theoretical..

e + stat_sum() x, y, size | ..n.., ..prop..

e + stat_summary(fun.data = "mean_cl_boot"**)**

h + stat_summary_bin(fun.y = "mean", geom = "bar"**)**

e + stat_unique()

Scales

Scales map data values to the visual values of an aesthetic. To change a mapping, add a new scale.

(n <- d + geom_bar(aes(fill = fl)))

scale_ | aesthetic to adjust | prepackaged scale to use | scale-specific arguments

n + scale_fill_manual(
values = c("skyblue", "royalblue", "blue", "navy"),
limits = c("d", "e", "p", "r"), **breaks** =c("d", "e", "p", "r"),
name = "fuel", **labels** = c("D", "E", "P", "R"))

range of values to include in mapping | title to use in legend/axis | labels to use in legend/axis | breaks to use in legend/axis

GENERAL PURPOSE SCALES

Use with most aesthetics

scale_*_continuous() - map cont' values to visual ones
scale_*_discrete() - map discrete values to visual ones
scale_*_identity() - use data values **as** visual ones
scale_*_manual(values = c()**)** - map discrete values to manually chosen visual ones
scale_*_date(date_labels = "%m/%d"), date_breaks = "2 weeks"**)** - treat data values as dates.
scale_*_datetime() - treat data x values as date times. Use same arguments as scale_x_date(). See ?strptime for label formats.

X & Y LOCATION SCALES

Use with x or y aesthetics (x shown here)

scale_x_log10() - Plot x on log10 scale
scale_x_reverse() - Reverse direction of x axis
scale_x_sqrt() - Plot x on square root scale

COLOR AND FILL SCALES (DISCRETE)

n <- d + geom_bar(aes(fill = fl)**)**

n + scale_fill_brewer(palette = "Blues"**)**
For palette choices:
RColorBrewer::display.brewer.all()

n + scale_fill_grey(start = 0.2, end = 0.8, na.value = "red"**)**

COLOR AND FILL SCALES (CONTINUOUS)

o <- c + geom_dotplot(aes(fill = ..x..))

o + scale_fill_distiller(palette = "Blues"**)**

o + scale_fill_gradient(low="red", high="yellow"**)**

o + scale_fill_gradient2(low="red", high="blue", mid = "white", midpoint = 25**)**

o + scale_fill_gradientn(colours=topo.colors(6)**)**
Also: rainbow(), heat.colors(), terrain.colors(), cm.colors(), RColorBrewer::brewer.pal()

SHAPE AND SIZE SCALES

p <- e + geom_point(aes(shape = fl, size = cyl))
p + scale_shape() + scale_size()
p + scale_shape_manual(values = c(3:7)**)**

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

p + scale_radius(range = c(1,6)**)**
p + scale_size_area(max_size = 6**)**

Coordinate Systems

r <- d + geom_bar()

r + coord_cartesian(xlim = c(0, 5)**)**
xlim, ylim
The default cartesian coordinate system

r + coord_fixed(ratio = 1/2**)**
ratio, xlim, ylim
Cartesian coordinates with fixed aspect ratio between x and y units

r + coord_flip()
xlim, ylim
Flipped Cartesian coordinates

r + coord_polar(theta = "x", direction=1 **)**
theta, start, direction
Polar coordinates

r + coord_trans(ytrans = "sqrt"**)**
xtrans, ytrans, limx, limy
Transformed cartesian coordinates. Set xtrans and ytrans to the name of a window function.

π + coord_quickmap()
π + coord_map(projection = "ortho", orientation=c(41, -74, 0))projection, orienztation, xlim, ylim
Map projections from the mapproj package (mercator (default), azequalarea, lagrange, etc.)

Position Adjustments

Position adjustments determine how to arrange geoms that would otherwise occupy the same space.

s <- ggplot(mpg, aes(fl, fill = drv))

s + geom_bar(position = "dodge")
Arrange elements side by side

s + geom_bar(position = "fill")
Stack elements on top of one another, normalize height

e + geom_point(position = "jitter")
Add random noise to X and Y position of each element to avoid overplotting

e + geom_label(position = "nudge")
Nudge labels away from points

s + geom_bar(position = "stack")
Stack elements on top of one another

Each position adjustment can be recast as a function with manual **width** and **height** arguments
s + geom_bar(position = position_dodge(width = 1))

Themes

r + theme_bw()
White background with grid lines

r + theme_gray()
Grey background (default theme)

r + theme_dark()
dark for contrast

r + theme_classic()

r + theme_light()

r + theme_linedraw()

r + theme_minimal()
Minimal themes

r + theme_void()
Empty theme

Faceting

Facets divide a plot into subplots based on the values of one or more discrete variables.

t <- ggplot(mpg, aes(cty, hwy)) + geom_point()

t + facet_grid(cols = vars(fl))
facet into columns based on fl

t + facet_grid(rows = vars(year))
facet into rows based on year

t + facet_grid(rows = vars(year), cols = vars(fl))
facet into both rows and columns

t + facet_wrap(vars(fl))
wrap facets into a rectangular layout

Set **scales** to let axis limits vary across facets

t + facet_grid(rows = vars(drv), cols = vars(fl), scales = "free")
x and y axis limits adjust to individual facets
"free_x" - x axis limits adjust
"free_y" - y axis limits adjust

Set **labeller** to adjust facet labels

t + facet_grid(cols = vars(fl), labeller = label_both)

fl: c | fl: d | fl: e | fl: p | fl: r

t + facet_grid(rows = vars(fl), labeller = label_bquote(alpha ^ .(fl)**))**

α^c α^d α^e α^p α^r

Labels

t + labs(x = "New x axis label", **y** = "New y axis label",
title ="Add a title above the plot",
subtitle = "Add a subtitle below title",
caption = "Add a caption below plot",
<AES> = "New <AES> legend title")

Use scale functions to update legend labels

t + annotate(geom = "text", x = 8, y = 9, label = "A"**)**

geom to place | manual values for geom's aesthetics

Legends

n + theme(legend.position = "bottom"**)**
Place legend at "bottom", "top", "left", or "right"

n + guides(fill = "none"**)**
Set legend type for each aesthetic: colorbar, legend, or none (no legend)

n + scale_fill_discrete(name = "Title", labels = c("A", "B", "C", "D", "E")**)**
Set legend title and labels with a scale function.

Zooming

Without clipping (preferred)

t + coord_cartesian(
xlim = c(0, 100), ylim = c(10, 20)**)**

With clipping (removes unseen data points)

t + xlim(0, 100**) + ylim(**10, 20**)**

t + scale_x_continuous(limits = c(0, 100)**) + scale_y_continuous(**limits = c(0, 100)**)**

RStudio

Exercise 4 (ex24.R)

```
# 0.  a) Check your working directory is in the course folder. Load the .Rproj file
getwd()
#     b) Load the tidyverse package (which loads the ggplot2 package amongst others)
library(#####)
#     c) Run the code in ex24_prelim.R to import the UN data for this exercise
source("./exercise/ex24_prelim.R")
##
##
##
# 1. Uncomment the code below (from ex23.R) and adapt to
#    a. change the colour of the points to come from the "Set1" palette
#    b. add more breaks in the size legend
#    (Hint: use scale_size_continuous() with breaks argument set to a vector of
#    typical population values such as c(50, 250, 500, 1000) )
#    c. x-axis label: "Infant Mortality Rate"
#    d. y-axis label: "Total Fertility Rate"
#    e. colour label: "Continent"
#    f. size label: "Population (m)"
# ggplot(data = d1, mapping = aes(x = imr, y = tfr, colour = area_name, size = pop/1
#   geom_point() +
#   coord_trans(x = "log10")
```