Data Visualization and Maps II

HES 505 Fall 2023: Session 30

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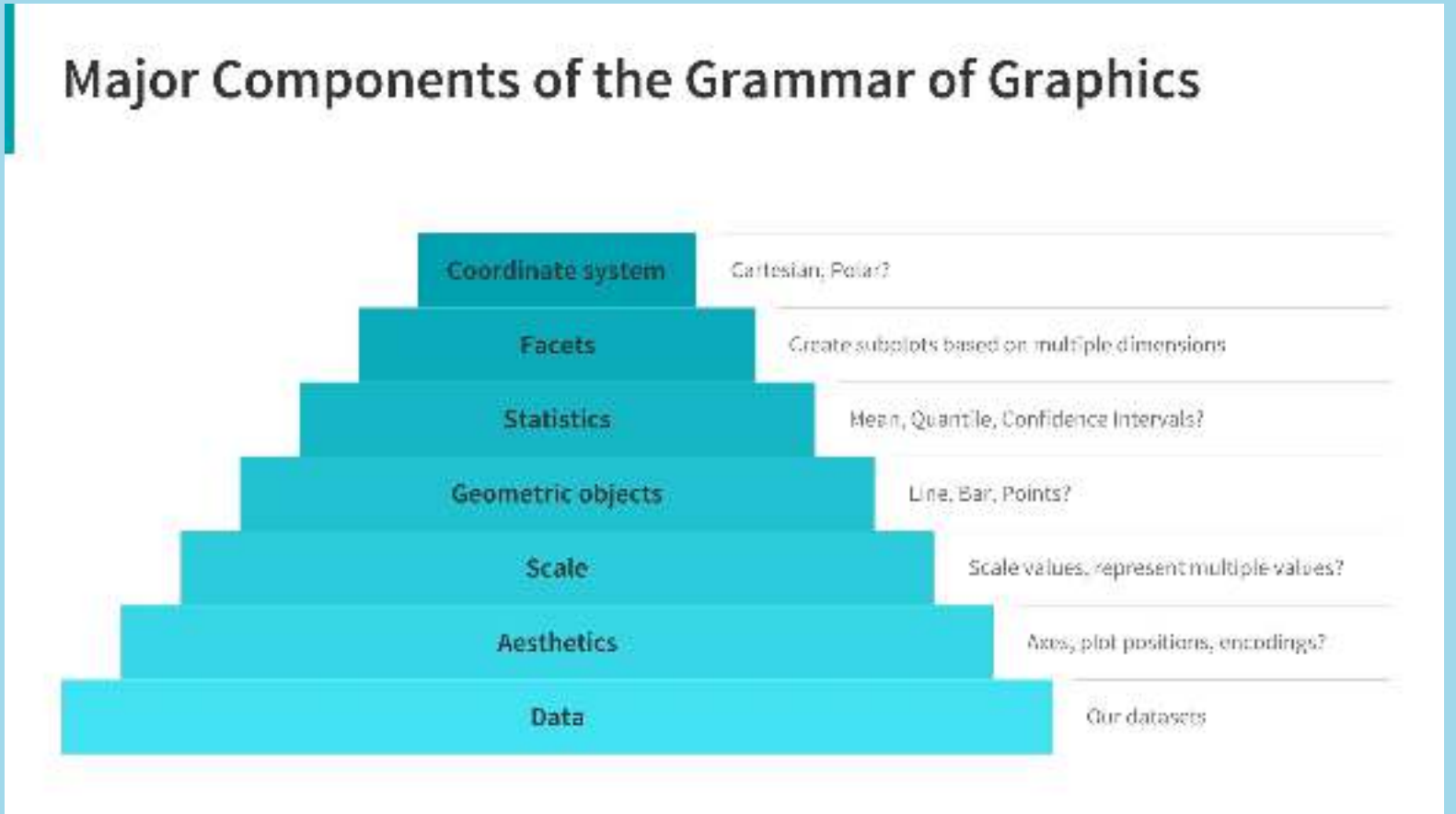
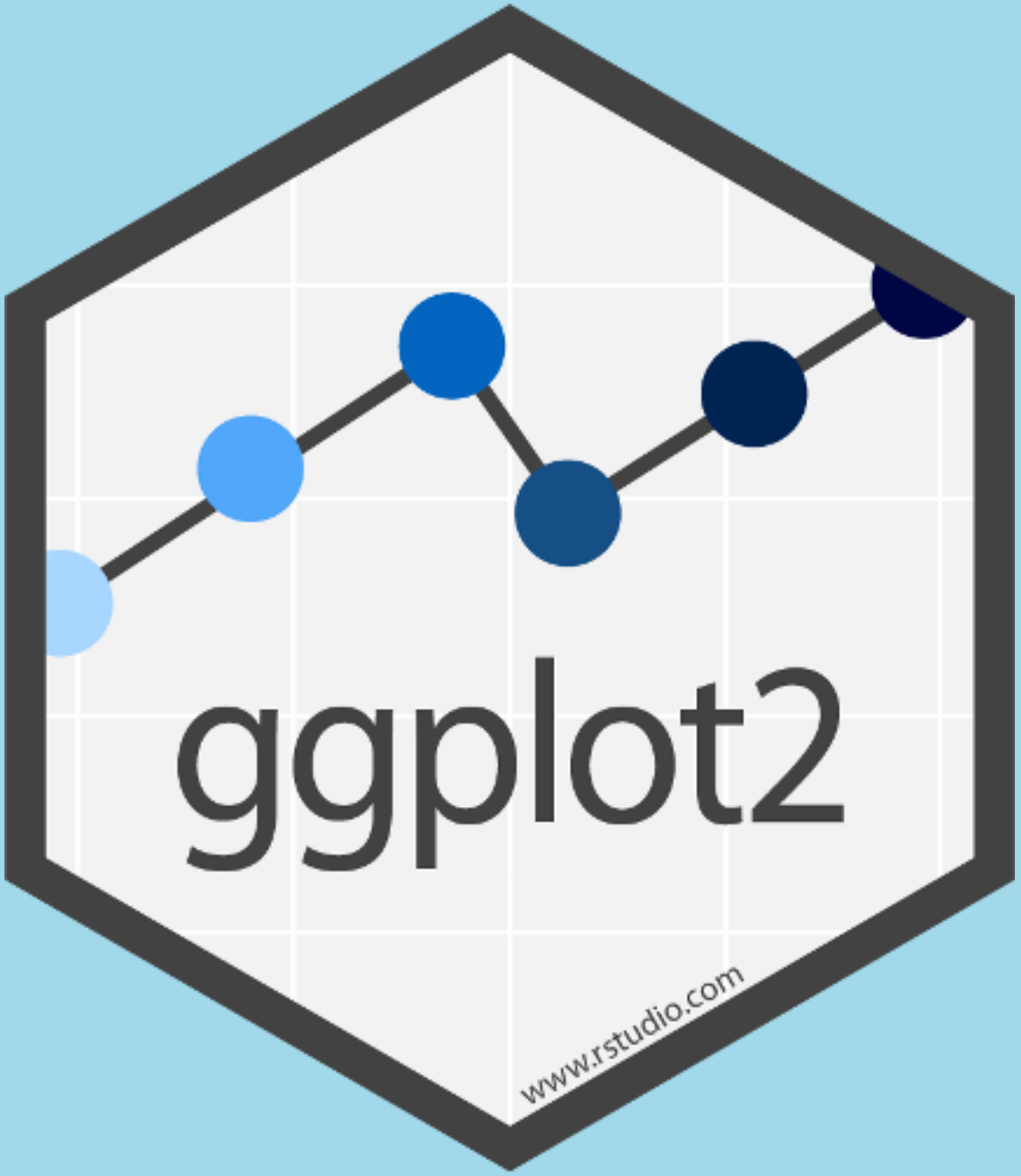
Objectives

By the end of today you should be able to: * Understand the relationship between the Grammar of Graphics and `ggplot` syntax

- Describe the various options for customizing `ggplots` and their syntactic conventions
- Generate complicated plot layouts without additional pre-processing
- Construct a map using `ggplot2` and `tmap`
- Combine vector and raster data in the same map


Major Components of the Grammar of Graphics
Coordinate system
Cartesian, Polar?
Facets
Create subplots based on multiple dimensions
Statistics
Mean, Quantile, Confidence Intervals?
Geometric objects
Line, Bar, Points?
Scale
Scale values, represent multiple values?
Aesthetics
Axes, plot positions, encodings?
Data
Our datasets

##


ggplot2
www.rstudio.com

`{ggplot2}` is a system for declaratively creating graphics,
based on "The Grammar of Graphics" (Wilkinson, 2005).

You provide the data, tell `ggplot2` how to map variables to aesthetics, what graphical primitives to use, and it takes care of the details.

Advantages of {ggplot2}

- consistent underlying “grammar of graphics” (Wilkinson 2005)
- very flexible, layered plot specification
- theme system for polishing plot appearance
- lots of additional functionality thanks to extensions
- active and helpful community

The Grammar of {ggplot2}

Component	Function	Explanation
Data	`ggplot(data)`	*The raw data that you want to visualise.*
Aesthetics	`aes()`	*Aesthetic mappings between variables and visual properties.*
Geometries	`geom_*()`	*The geometric shapes representing the data.*

The Grammar of {ggplot2}

Component	Function	Explanation
Data	`ggplot(data)`	*The raw data that you want to visualise.*
Aesthetics	`aes()`	*Aesthetic mappings between variables and visual properties.*
Geometries	`geom_*()`	*The geometric shapes representing the data.*
Statistics	`stat_*()`	*The statistical transformations applied to the data.*
Scales	`scale_*()`	*Maps between the data and the aesthetic dimensions.*
Coordinate System	`coord_*()`	*Maps data into the plane of the data rectangle.*
Facets	`facet_*()`	*The arrangement of the data into a grid of plots.*
Visual Themes	`theme()` and `theme_*()`	*The overall visual defaults of a plot.*

A Basic ggplot Example

The Data

Bike sharing counts in London, UK, powered by TfL Open Data

- covers the years 2015 and 2016
- incl. weather data acquired from freemeteo.com
- prepared by Hristo Mavrodiev for Kaggle
- further modification by myself

Variable	Description	Class
date	Date encoded as `YYYY-MM-DD`	date
day_night	`day` (6:00am–5:59pm) or `night` (6:00pm–5:59am)	character
year	`2015` or `2016`	factor
month	`1` (January) to `12` (December)	factor
season	`winter`, `spring`, `summer`, or `autumn`	factor
count	Sum of reported bikes rented	integer
is_workday	`TRUE` being Monday to Friday and no bank holiday	logical
is_weekend	`TRUE` being Saturday or Sunday	logical
is_holiday	`TRUE` being a bank holiday in the UK	logical
temp	Average air temperature (°C)	double
temp_feel	Average feels like temperature (°C)	double
humidity	Average air humidity (%)	double
wind_speed	Average wind speed (km/h)	double
weather_type	Most common weather type	character

ggplot2::ggplot()

ggplot: Create a new ggplot

Description

`ggplot()` initializes a ggplot object. It can be used to declare the input data frame for a graphic and to specify the set of plot aesthetics intended to be common throughout all subsequent layers unless specifically overridden.

Usage

```
ggplot(data = NULL, mapping = aes(), ..., environment = parent.frame())
```

Arguments

data	Default dataset to use for plot. If not already a data.frame, will be converted to one by `fortify()`. If not specified, must be supplied in each layer added to the plot.
mapping	Default list of aesthetic mappings to use for plot. If not specified, must be supplied in each layer added to the plot.
...	Other arguments passed on to methods. Not currently used.
environment	DEPRECATED. Used prior to tidy evaluation.

Details

`ggplot()` is used to construct the initial plot object, and is almost always followed by `+` to add component to the plot. There are two common ways to invoke `ggplot()`:

- `ggplot(df, aes(x, y, <other aesthetics>))`
- `ggplot(df)`
- `ggplot()`

Data

```
1  ggplot(data = bikes)
```

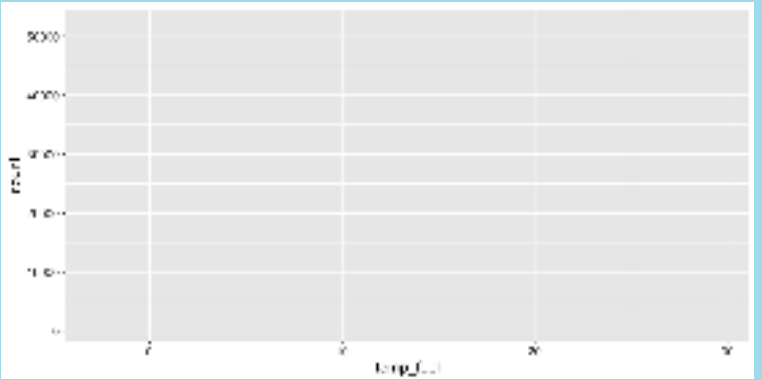
Aesthetic Mapping

= link variables to graphical properties

- positions (`x`, `y`)
- colors (`color`, `fill`)
- shapes (`shape`, `linetype`)
- size (`size`)
- transparency (`alpha`)
- groupings (`group`)

Aesthetic Mapping

```
1 ggplot(data = bikes) +
2   aes(x = temp_feel, y = count)
```



aesthetics

`aes()` outside as component

```
ggplot(data = bikes) +
  aes(x = temp_feel, y = count)
```

`aes()` inside, explicit matching

```
ggplot(data = bikes, mapping = aes(x = temp_feel, y = count))
```

`aes()` inside, implicit matching

```
ggplot(bikes, aes(temp_feel, count))
```

`aes()` inside, mixed matching

```
ggplot(bikes, aes(x = temp_feel, y = count))
```

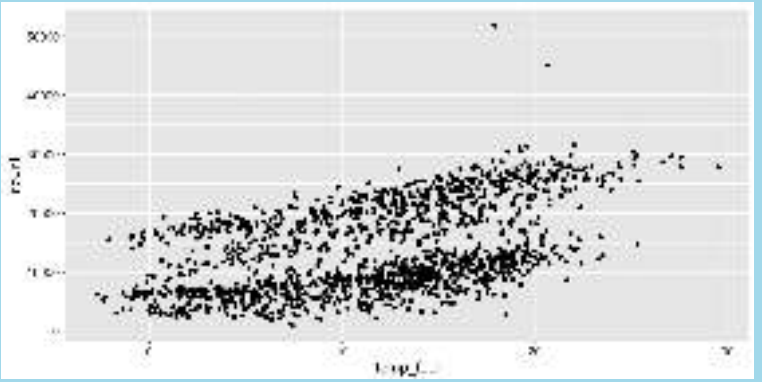
Geometries

= interpret aesthetics as graphical representations

- points
- lines
- polygons
- text labels
- …

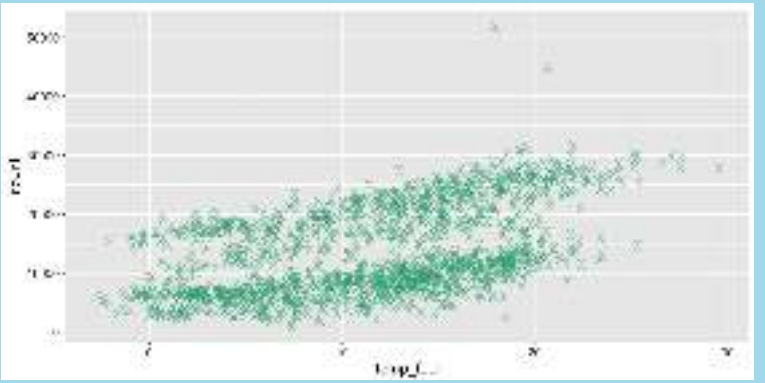
Geometries

```
ggplot(
    bikes,
    aes(x = temp_feel, y = count)
  ) +
  geom_point()
```



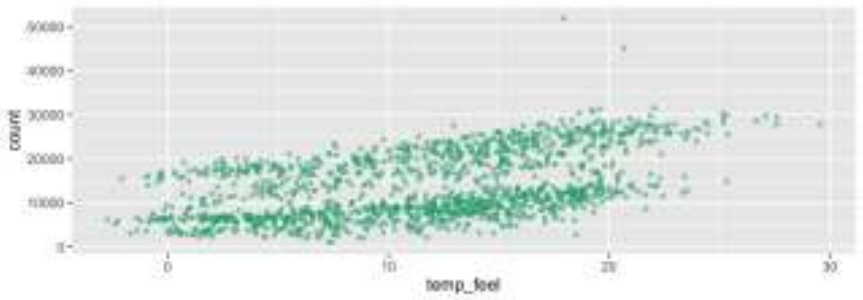
Visual Properties of Layers

```
ggplot(
    bikes,
    aes(x = temp_feel, y = count)
  ) +
  geom_point(
    color = "#28a87d",
    alpha = .5,
    shape = "X",
    stroke = 1,
    size = 4
  )
```

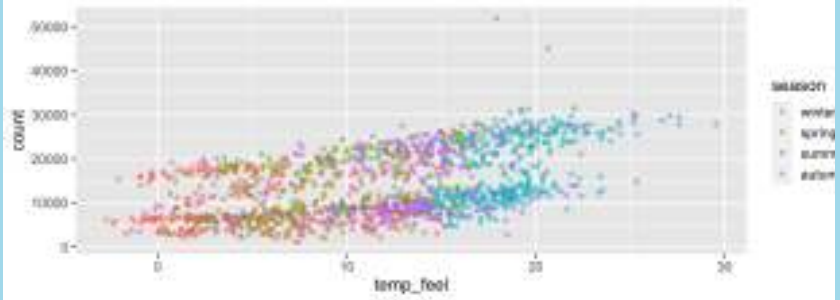


Setting vs Mapping of Visual Properties

```
ggplot(
    bikes,
    aes(x = temp_feel, y = count)
  ) +
  geom_point(
    color = "#28a87d",
    alpha = .5
  )
```

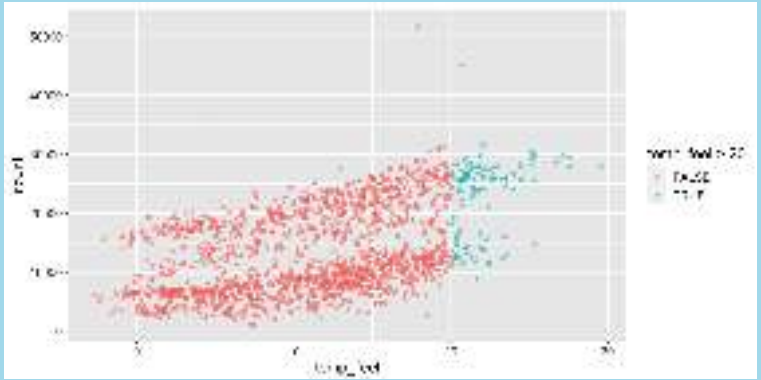



```
ggplot(
    bikes,
    aes(x = temp_feel, y = count)
  ) +
  geom_point(
    aes(color = season),
    alpha = .5
  )
```



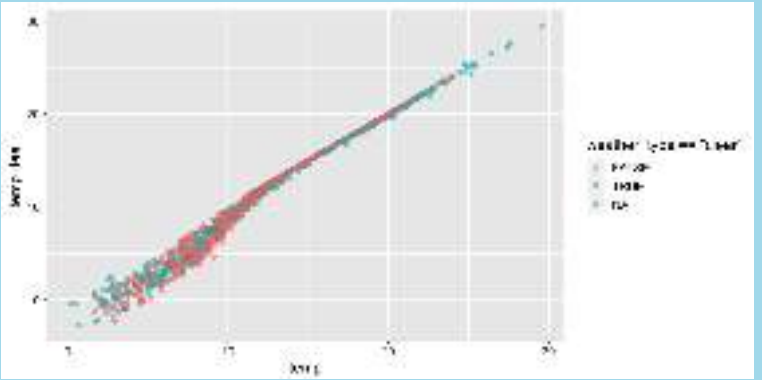
Mapping Expressions

```
ggplot(
    bikes,
    aes(x = temp_feel, y = count)
  ) +
  geom_point(
    aes(color = temp_feel > 20),
    alpha = .5
  )
```



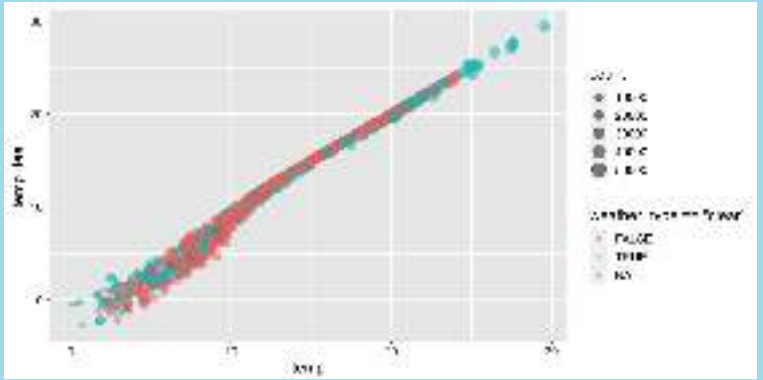
Mapping Expressions

```
ggplot(
    bikes,
    aes(x = temp, y = temp_feel)
  ) +
  geom_point(
    aes(color = weather_type == "c
    alpha = .5,
    size = 2
  )
```



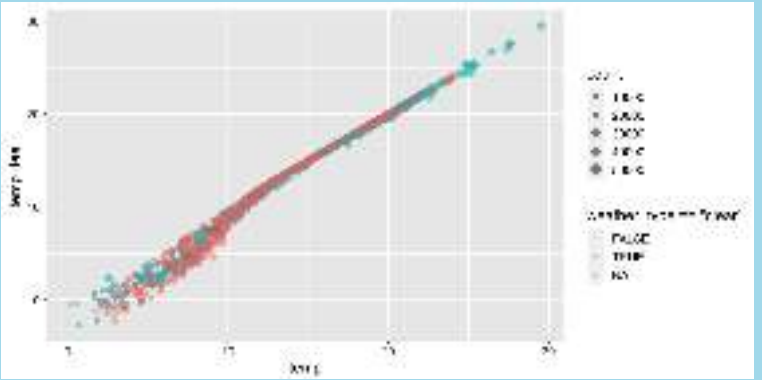
Mapping to Size

```
ggplot(
    bikes,
    aes(x = temp, y = temp_feel)
  ) +
  geom_point(
    aes(color = weather_type == "c
        size = count),
    alpha = .5
  )
```



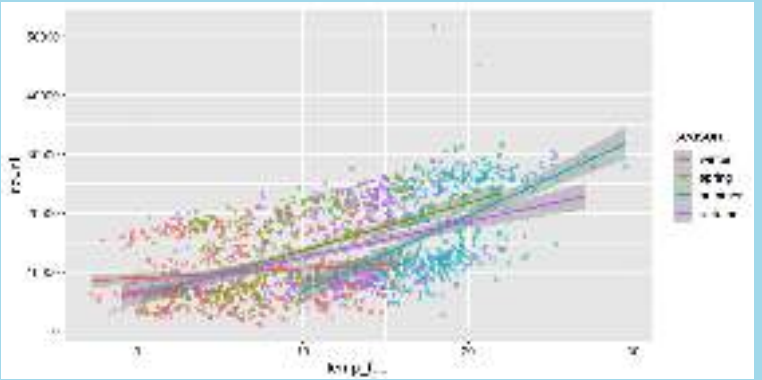
Setting a Constant Property

```
ggplot(
    bikes,
    aes(x = temp, y = temp_feel)
  ) +
  geom_point(
    aes(color = weather_type == "c
        size = count),
    shape = 18,
    alpha = .5
  )
```



Adding More Layers

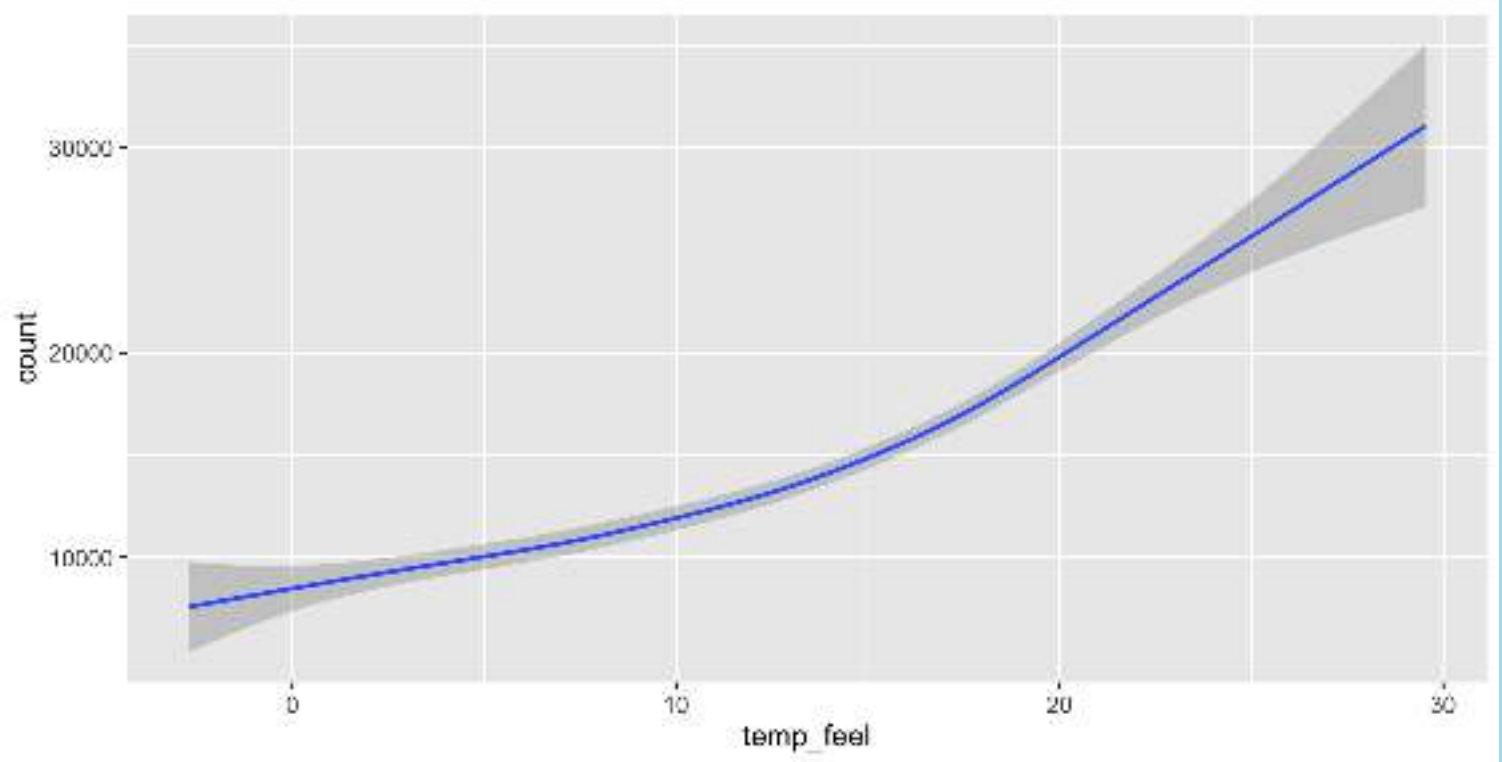
```
ggplot(
    bikes,
    aes(x = temp_feel, y = count,
        color = season)
  ) +
  geom_point(
    alpha = .5
  ) +
  geom_smooth(
    method = "lm"
  )
```



Statistical Layers

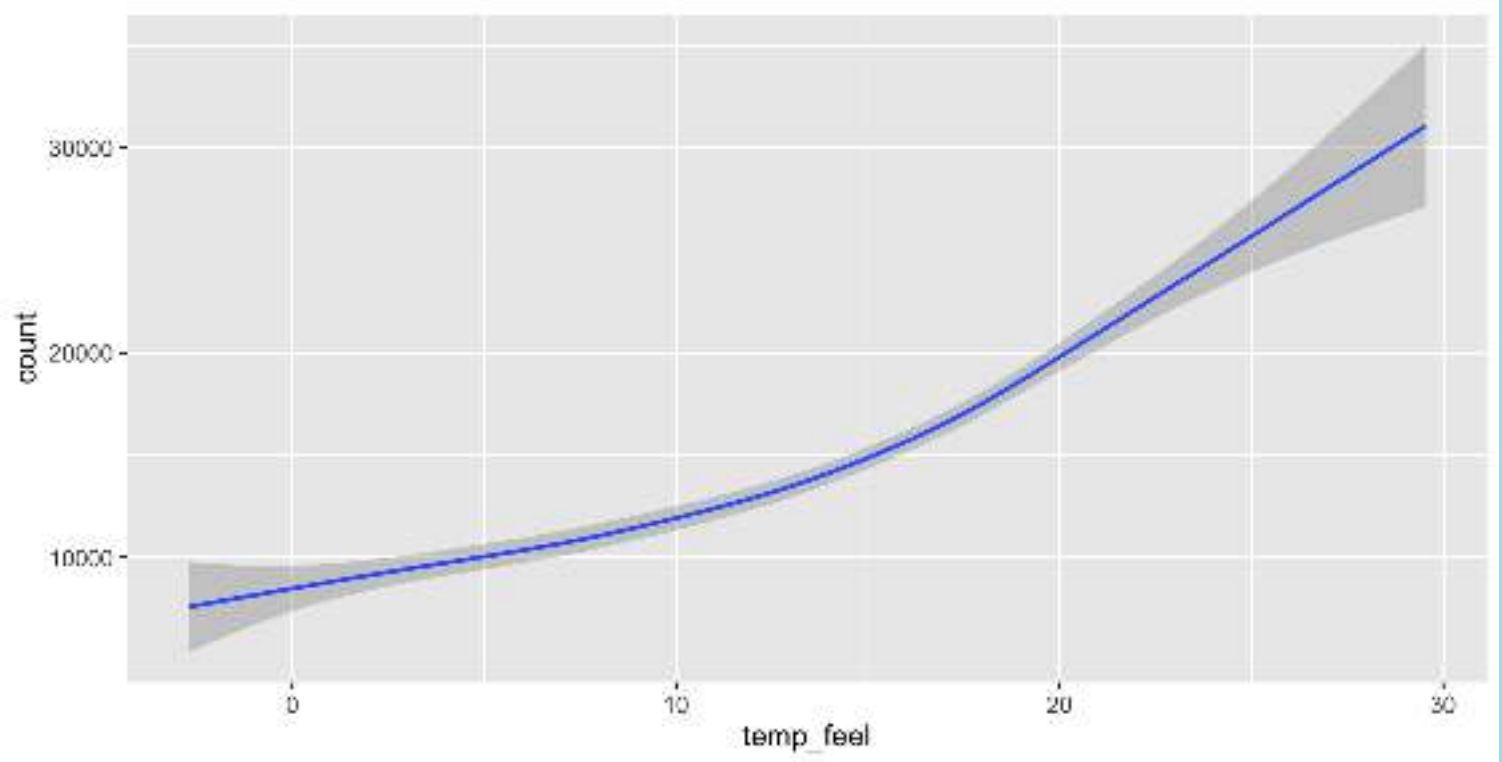
`stat_*()` and `geom_*()`

```
1  ggplot(bikes, aes(x = temp_feel, y = count)) +
2    stat_smooth(geom = "smooth")
```



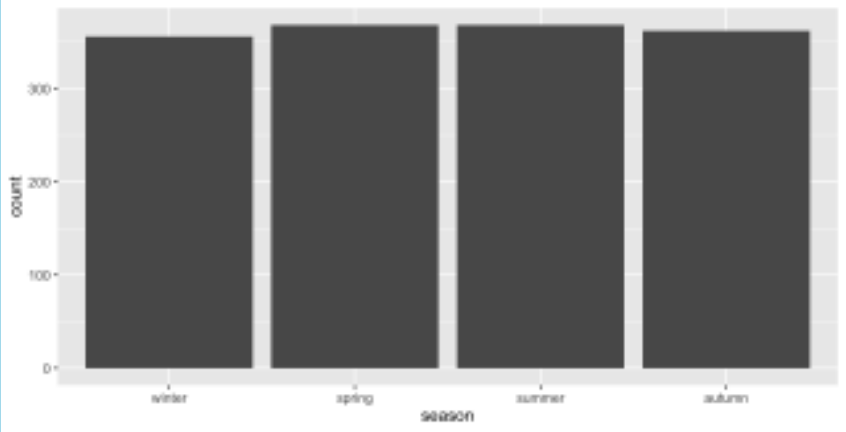
`stat_*()` and `geom_*()`

```
1  ggplot(bikes, aes(x = temp_feel, y = count)) +
2    geom_smooth(stat = "smooth")
```

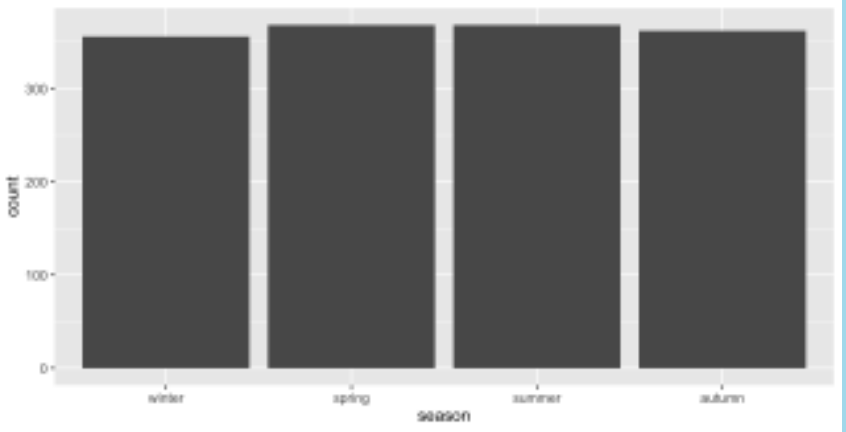


`stat_*()` and `geom_*()`

```
1 ggplot(bikes, aes(x = season)) +
2   stat_count(geom = "bar")
```

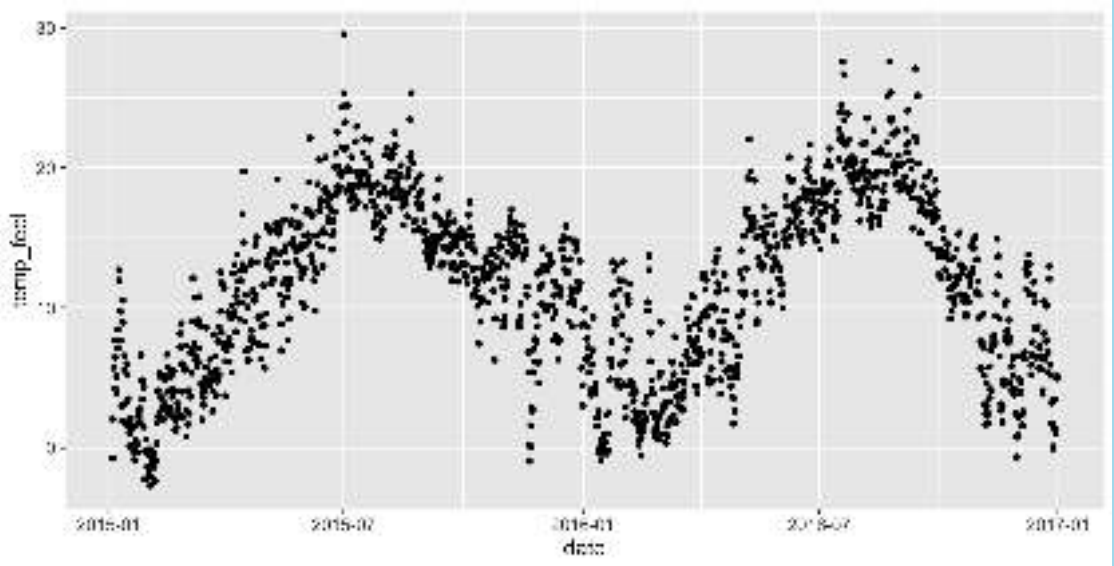



```
1 ggplot(bikes, aes(x = season)) +
2   geom_bar(stat = "count")
```

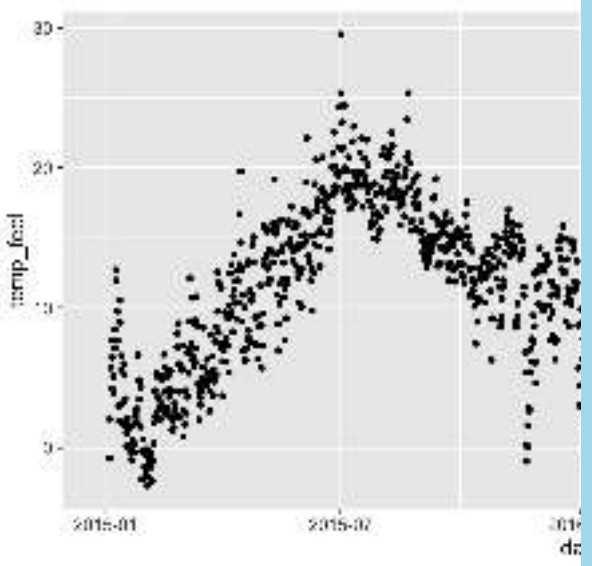


`stat_*()` and `geom_*()`

```
1  ggplot(bikes, aes(x = date, y = temp_feel)) +
2    stat_identity(geom = "point")
```




```
1  ggplot(bikes, aes(x = da
2    geom_point(stat = "ide
```



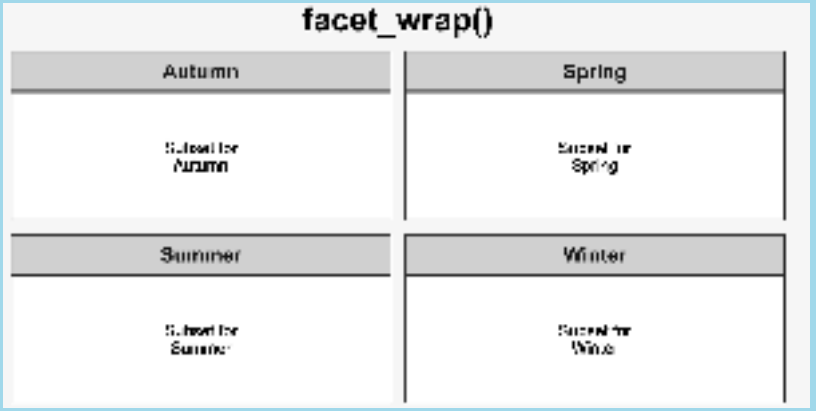
Facets

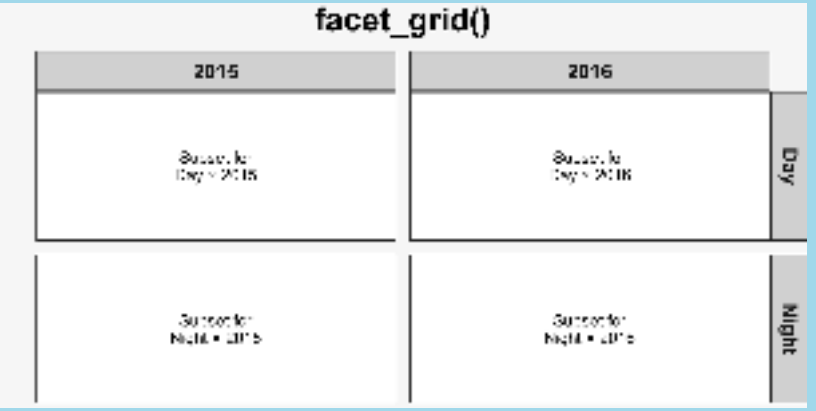
Facets

= split variables to multiple panels

Facets are also known as:

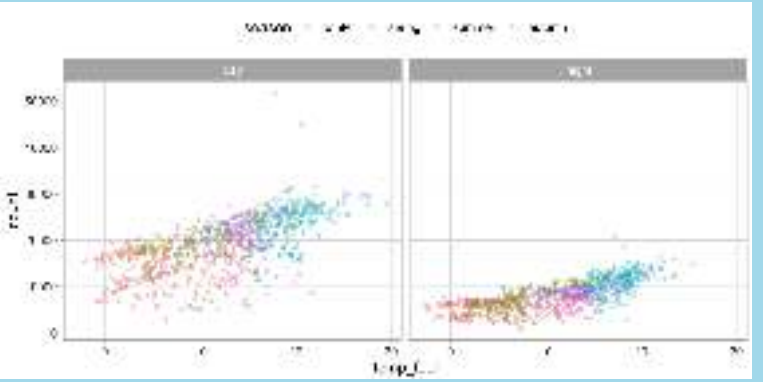
- small multiples
- trellis graphs
- lattice plots
- conditioning


facet_wrap()
Autumn
Spring
Summer
Winter


facet_grid()
2015
2016
Day
Night

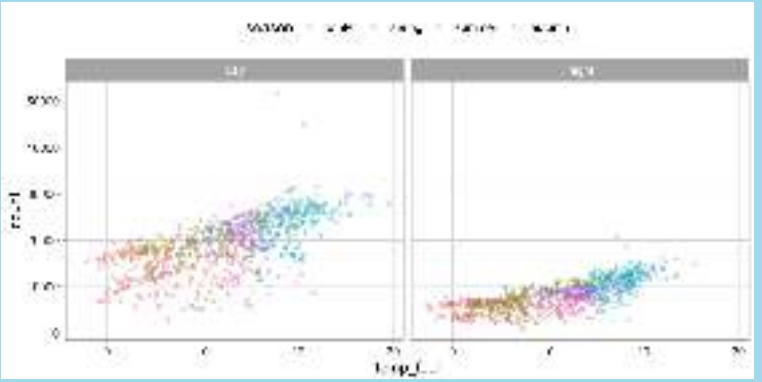
Wrapped Facets

```
g <-
  ggplot(
    bikes,
    aes(x = temp_feel, y = count,
        color = season)
  ) +
  geom_point(
    alpha = .3,
    guide = "none"
  )
g +
  facet_wrap(
    vars(day_night)
  )
```



Wrapped Facets

```
g +
  facet_wrap(
    ~ day_night
  )
```



Scales

Scales

= translate between variable ranges and property ranges

- feels-like temperature $\rightleftarrows$ x
- reported bike shares $\rightleftarrows$ y
- season $\rightleftarrows$ color
- year $\rightleftarrows$ shape
- …

Scales

The `scale_*()` components control the properties of all the
aesthetic dimensions mapped to the data.

Consequently, there are `scale_*()` functions for all aesthetics such as:

- **positions** via `scale_x_*()` and `scale_y_*()`
- **colors** via `scale_color_*()` and `scale_fill_*()`
- **sizes** via `scale_size_*()` and `scale_radius_*()`
- **shapes** via `scale_shape_*()` and
  `scale_linetype_*()`

Scales

The `scale_*()` components control the properties of all the
aesthetic dimensions mapped to the data.

The extensions (*) can be filled by e.g.:

- `continuous()`, `discrete()`, `reverse()`, `log10()`, `sqrt()`, `date()` for positions
- `continuous()`, `discrete()`, `manual()`, `gradient()`, `gradient2()`, `brewer()` for colors
- `continuous()`, `discrete()`, `manual()`, `ordinal()`, `area()`, `date()` for sizes
- `continuous()`, `discrete()`, `manual()`, `ordinal()` for shapes
- `continuous()`, `discrete()`, `manual()`, `ordinal()`,

Continuous vs. Discrete in {ggplot2}

Continuous:
quantitative or numerical data

- height
- weight
- age
- counts

Discrete:
qualitative or categorical data

- species
- sex
- study sites
- age group

Continuous vs. Discrete in {ggplot2}

Continuous:
quantitative or numerical data

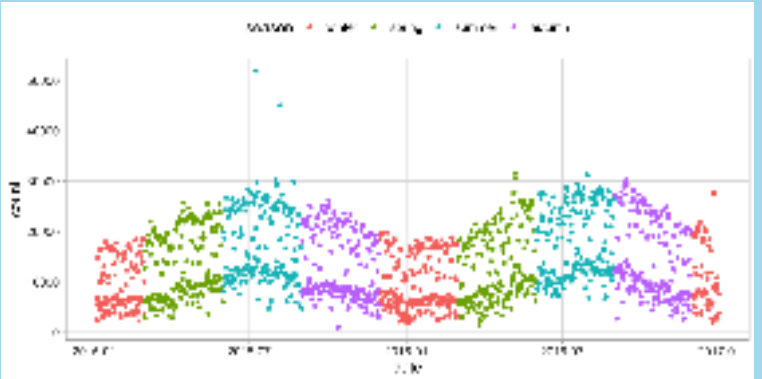
- height (continuous)
- weight (continuous)
- age (continuous or discrete)
- counts (discrete)

Discrete:
qualitative or categorical data

- species (nominal)
- sex (nominal)
- study site (nominal or ordinal)
- age group (ordinal)

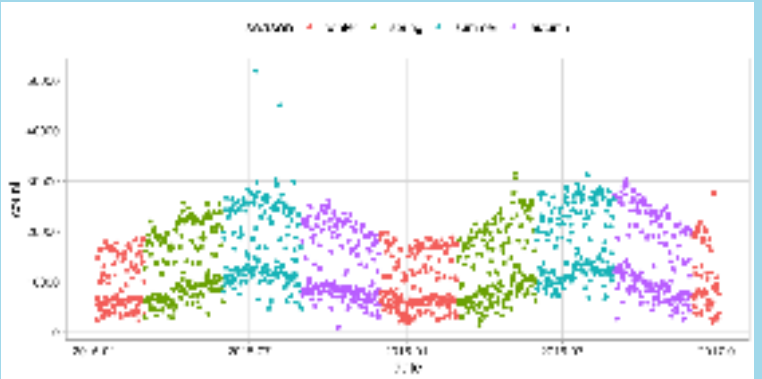
Aesthetics + Scales

```
ggplot(
    bikes,
    aes(x = date, y = count,
        color = season)
  ) +
  geom_point()
```



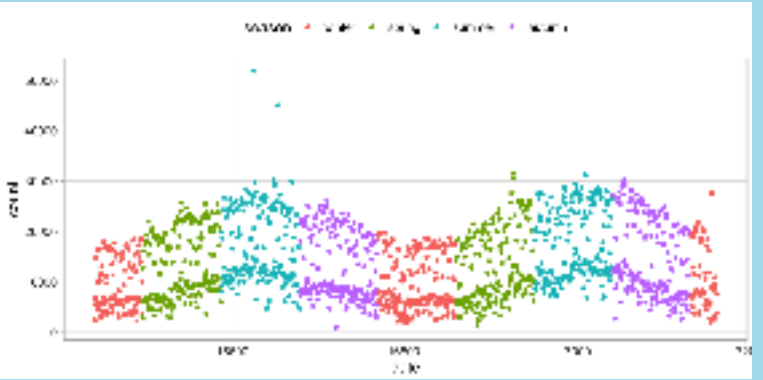
Aesthetics + Scales

```
ggplot(
    bikes,
    aes(x = date, y = count,
        color = season)
  ) +
  geom_point() +
  scale_x_date() +
  scale_y_continuous() +
  scale_color_discrete()
```



Scales

```
ggplot(
    bikes,
    aes(x = date, y = count,
        color = season)
  ) +
  geom_point() +
  scale_x_continuous() +
  scale_y_continuous() +
  scale_color_discrete()
```



Coordinate Systems

= interpret the position aesthetics

- **linear coordinate systems:** preserve the geometrical shapes
  - `coord_cartesian()`
  - `coord_fixed()`
  - `coord_flip()`
- **non-linear coordinate systems:** likely change the geometrical shapes
  - `coord_polar()`

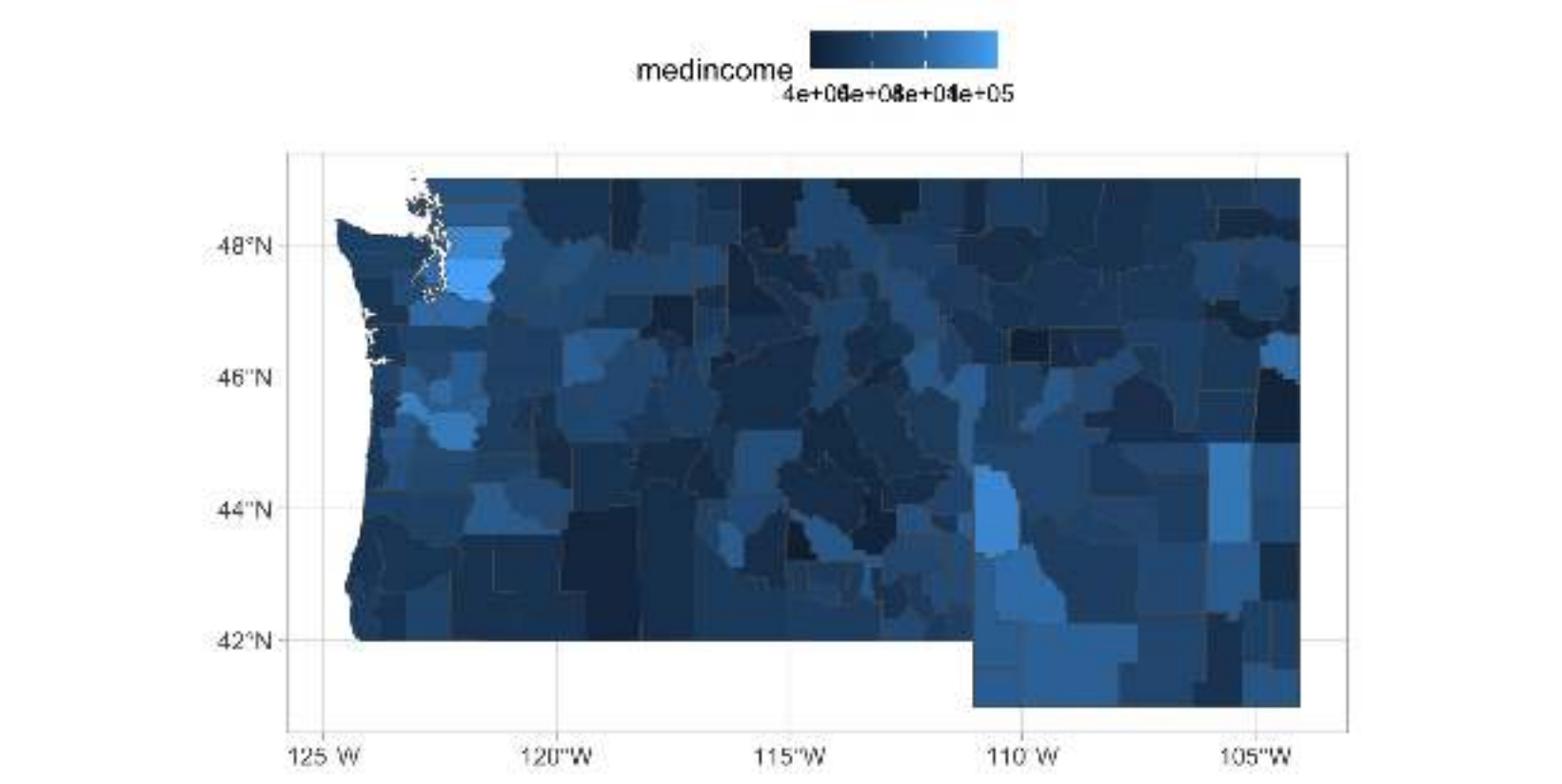
Building Choropleth Maps

Using ggplot2

```
cty.info <- get_acs(geography = "county",
                        variables = c(pop="B01003_001",
                                      medincome = "B19013_001"),
                        survey="acs5",
                        state = c("WA", "OR", "ID", "MT", "WY"),
                        geometry = TRUE, key = censkey, progress_bar=FALSE) %
  select(., -moe) %>%
  pivot_wider(
    names_from = "variable",
    values_from = "estimate"
  )

p <- ggplot(data=cty.info) +
  geom_sf(mapping=aes(fill=medincome))
```

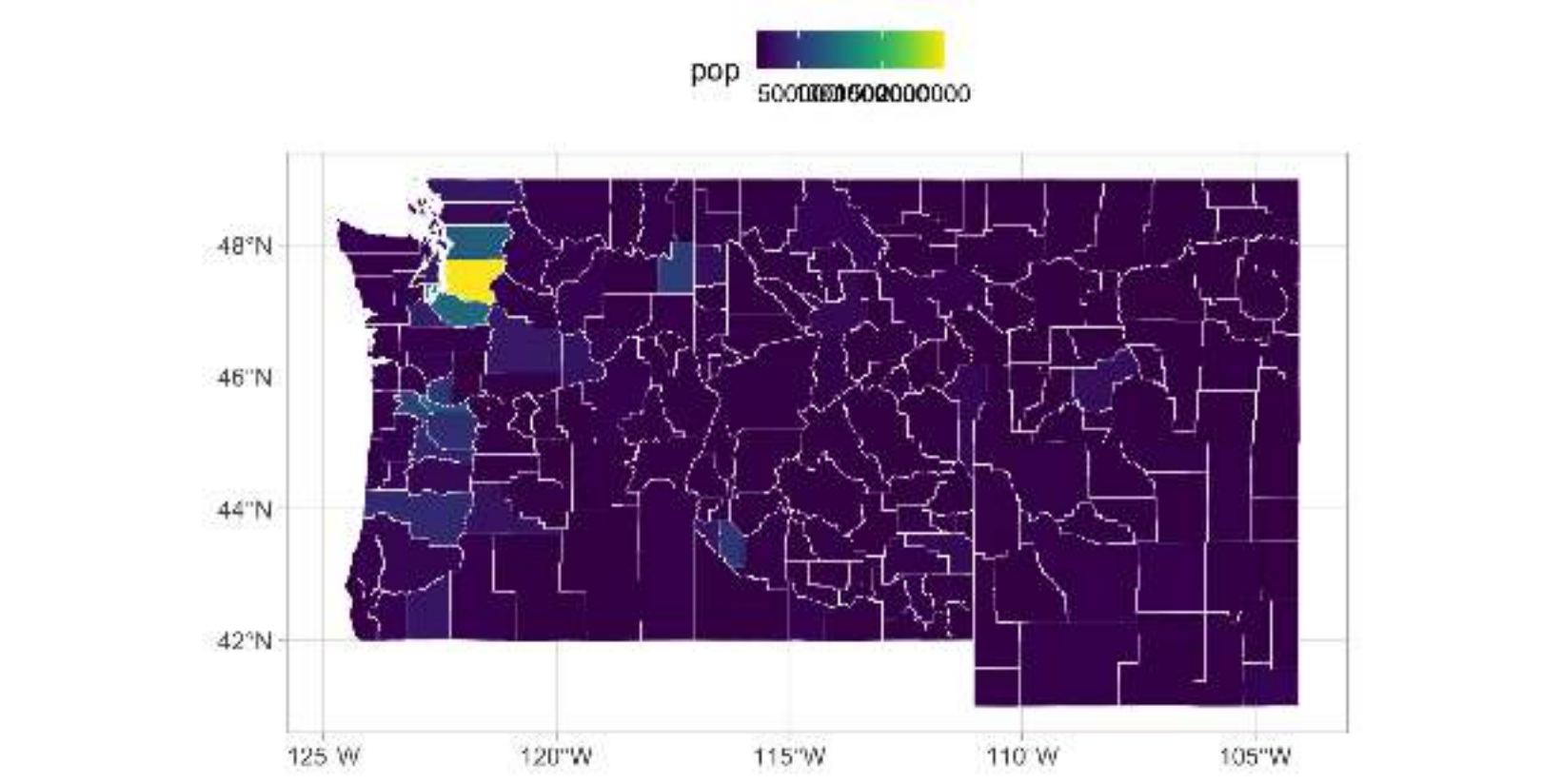
Static Maps with ggplot2



Changing aesthetics

```
p <- ggplot(data=cty.info) +
  geom_sf(mapping=aes(fill=pop), color="white") +
  scale_fill_viridis()
```

Changing aesthetics

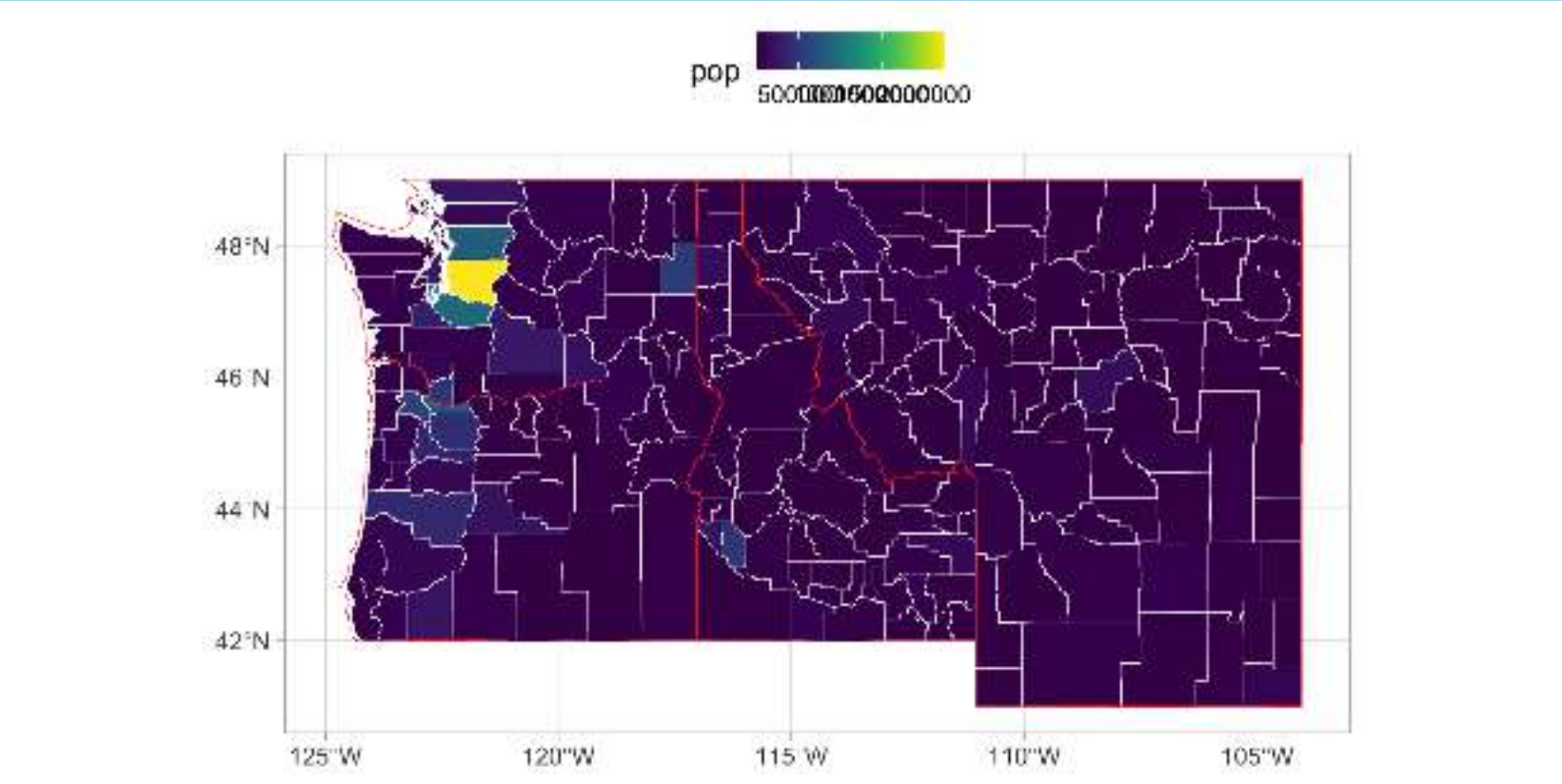


Adding layers

```
st <- tigris::states(progress_bar=FALSE) %>%
  filter(., STUSPS %in% c("WA", "OR", "ID", "MT", "WY"))

p <- ggplot(data=cty.info) +
  geom_sf(mapping=aes(fill=pop), color="white") +
  geom_sf(data=st, fill=NA, color="red") +
  scale_fill_viridis()
```

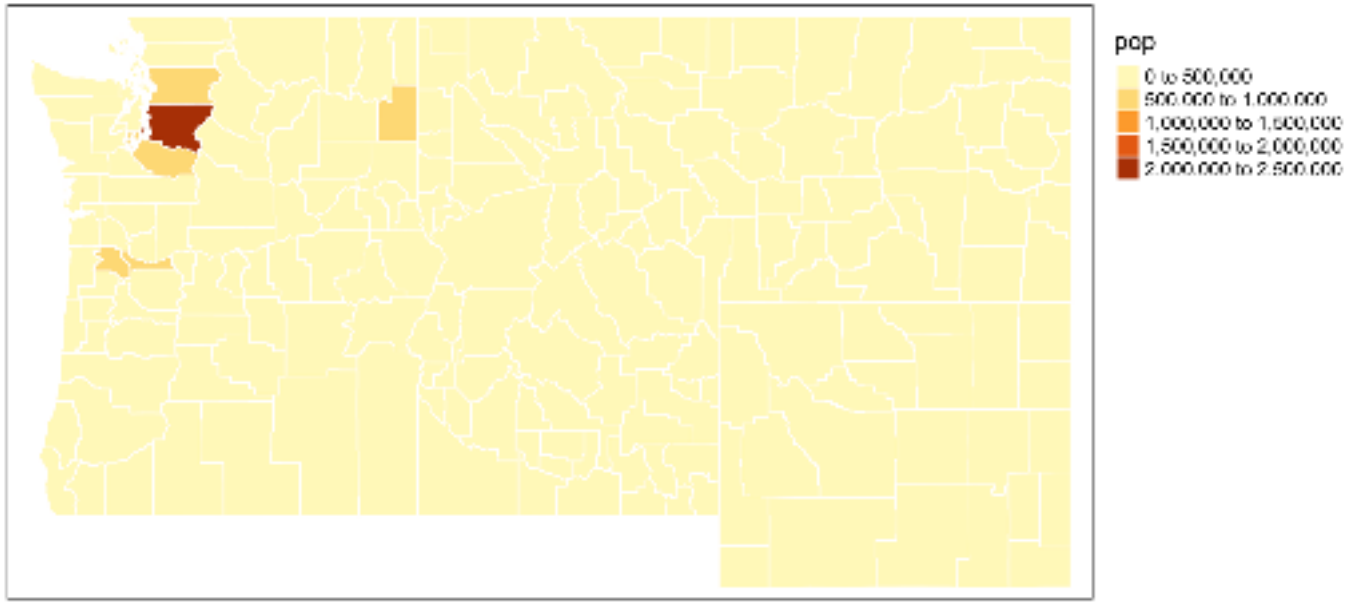
Adding layers



Using tmap

```
pt <- tm_shape(cty.info) +
  tm_polygons(col = "pop",
              border.col = "white") +
  tm_legend(outside = TRUE)
```

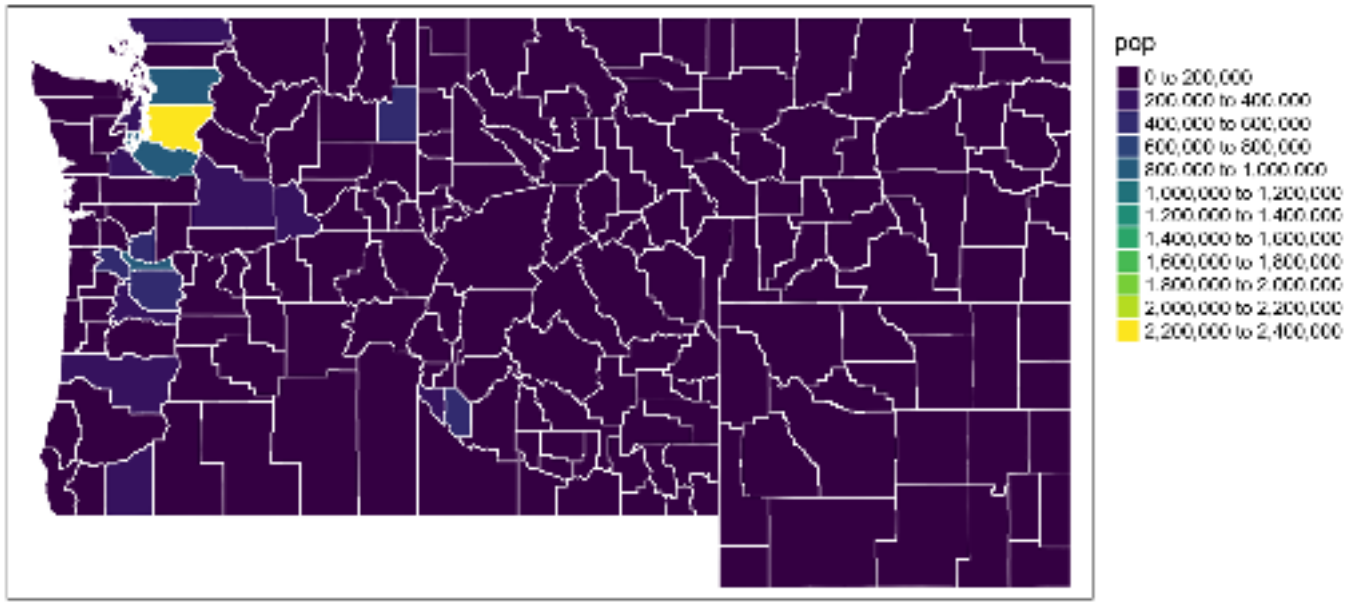
Using tmap


pop
0 to 500,000
500,000 to 1,000,000
1,000,000 to 1,500,000
1,500,000 to 2,000,000
2,000,000 to 2,500,000

Changing aesthetics

```
pt <- tm_shape(cty.info) +
  tm_polygons(col = "pop", n=10,palette=viridis(10),
              border.col = "white") +
  tm_legend(outside = TRUE)
```

Changing aesthetics



Adding layers

```
pt <- tm_shape(cty.info) +
  tm_polygons(col = "pop", n=10,palette=viridis(10),
              border.col = "white") +
  tm_shape(st) +
  tm_borders("red") +
  tm_legend(outside = TRUE)
```

Adding layers