DS 116 - Data Visualization

Visualizing Uncertainty

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Visualizing uncertainty

There are many sources of uncertainty

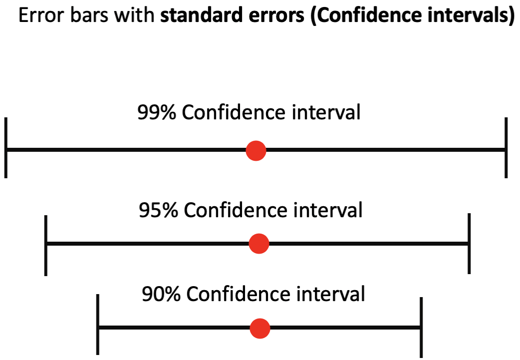
- Uncertainty of point estimates
- Uncertainty of distributions
- Uncertainty of predictions (curve fit) etc..

Section 1

Uncertainty of point estimates

Error bars

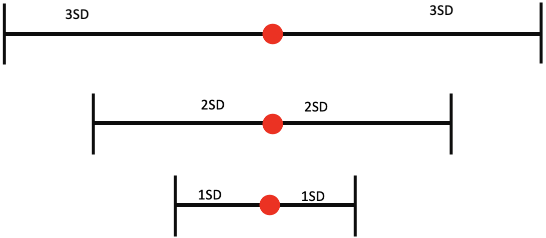
Uncertainty of point estimates



Error bars

Uncertainty with standard deviations

Error bars with **standard deviations**

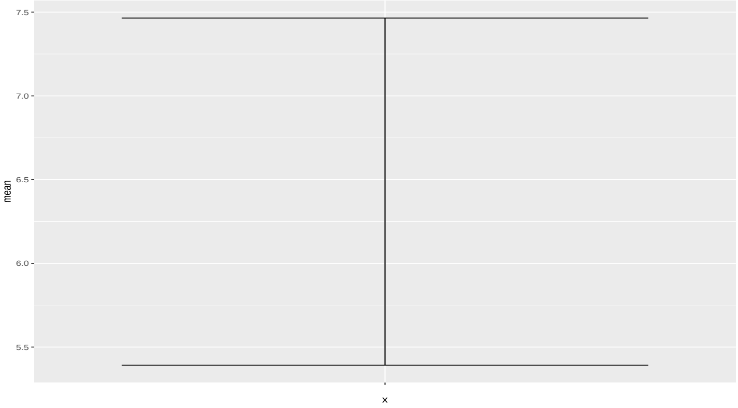


Error bars

```
movies_small <- read.csv('Data/movies_small.csv')
summarised <-  movies_small %>% summarise(mean = mean(imdbRating),
                                    sd = sd(imdbRating))
summarised
##       mean       sd
## 1 6.428149 1.036453
```

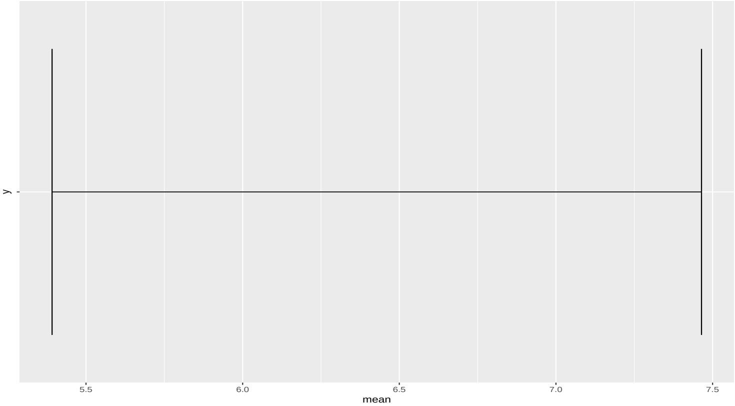
Error bars

```
ggplot(summarised, mapping = aes(x = "", y = mean, ymax = mean+sd,
                                  ymin = mean-sd)) + geom_errorbar()
```



Error bars

```
ggplot(summarised, mapping = aes(x = mean, y = "",  xmax = mean+sd,
                                 xmin = mean-sd)) + geom_errorbarh()
```



Error bars

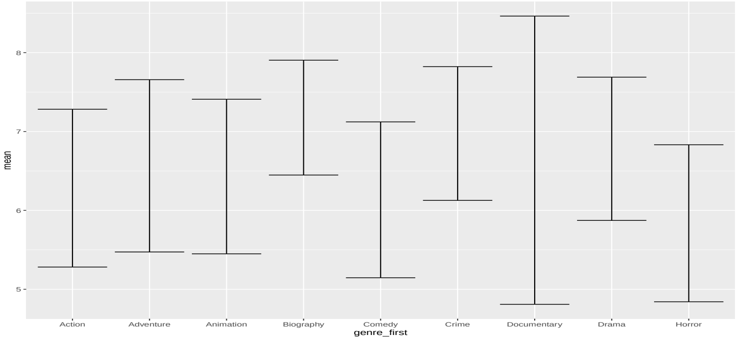
If you want to look at the error bars by groups - summarise by groups using dplyr

```
summarised <-  movies_small  %>% group_by(genre_first) %>%
  summarise(mean = mean(imdbRating), sd = sd(imdbRating))
summarised
## # A tibble: 9 x 3
##   genre_first  mean    sd
##   <chr>       <dbl> <dbl>
## 1 Action       6.28 1.00
## 2 Adventure    6.56 1.09
## 3 Animation    6.43 0.980
## 4 Biography    7.18 0.728
## 5 Comedy       6.13 0.988
## 6 Crime        6.97 0.848
## 7 Documentary  6.64 1.83
## 8 Drama        6.78 0.908
## 9 Horror       5.84 0.995
```

Error bars

- use the grouping variable as x aesthetics

```
ggplot(summarised, aes(x = genre_first, y = mean, ymin=mean-sd,
                       ymax = mean+sd)) + geom_errorbar()
```



Error bars

There are few functions in R that can be used for generating the data for error bars

- +- 1 SD

```
smean.sdl(movies_small$imdbRating, mult = 1)
##      Mean    Lower    Upper
## 6.428149 5.391696 7.464602
```

- +- 2sd

```
smean.sdl(movies_small$imdbRating, mult = 2)
##      Mean    Lower    Upper
## 6.428149 4.355243 8.501055
```

Error bars

Hmisc also has functions to construct Confidence Intervals

- 95%

```
smean.cl.normal(movies_small$imdbRating, conf.int = 0.95)
##      Mean    Lower    Upper
## 6.428149 6.384806 6.471493
```

- 99% confidence interval

```
smean.cl.normal(movies_small$imdbRating, conf.int = 0.99)
##      Mean    Lower    Upper
## 6.428149 6.371168 6.485130
```

Error bars

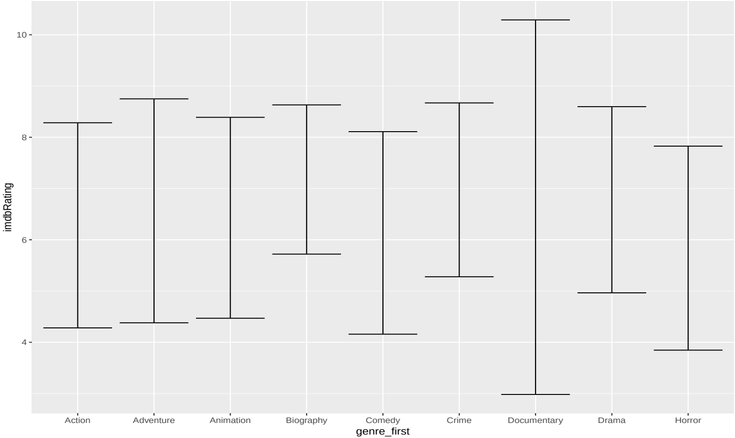
- ggplot2 has a wrapper for Hmisc functions: mean_cl_normal, mean_sdl, mean_se
- To construct the error bars with the functions we will use stat_summary() layer

stat_summary() applies defined function on y by the given values of x. No need to summarise with dplyr and create new dataframe

Error bars

Error bars for imdbRating by genre (+- 2 SD)

```
ggplot(movies_small, aes(x = genre_first, y = imdbRating)) +
  stat_summary(fun.data = mean_sdl, geom = "errorbar")
```

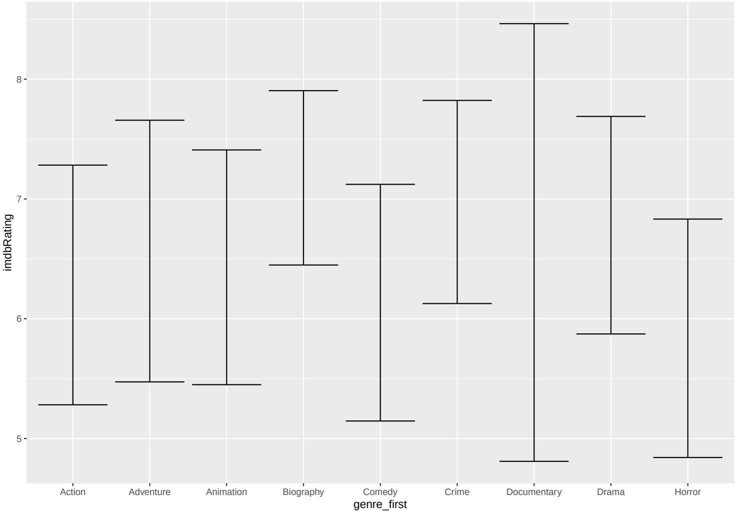


Error bars

- By default, mult = 2.
- If you want to change this, use fun.args in stat_summary()

```
ggplot(movies_small, aes(x = genre_first, y = imdbRating)) +
  stat_summary(fun.data = mean_sdl, geom = "errorbar",
               fun.args = list(mult = 1))
```

Error bars

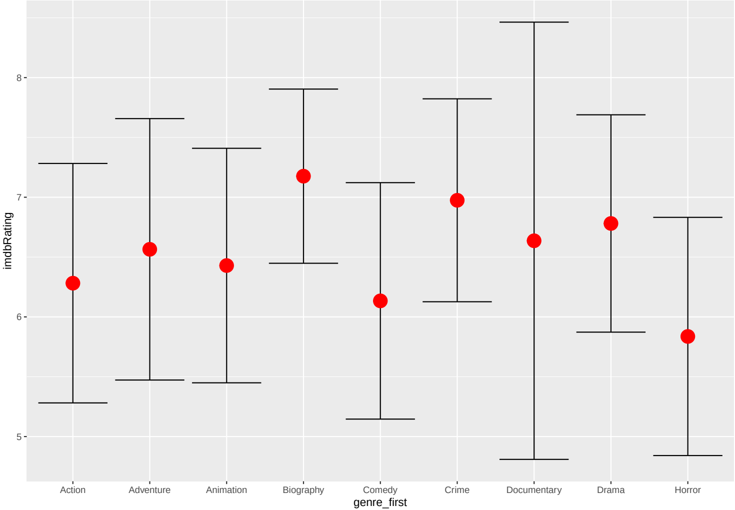

imdbRating
8
7
6
5
Action
Adventure
Animation
Biography
Comedy
Crime
Documentary
Drama
Horror
genre_first

Error bars

use stat_summary() again to add the mean as a red point to the error bar

```
ggplot(movies_small, aes(x = genre_first, y = imdbRating)) +
  stat_summary(fun.data = mean_sdl, geom = "errorbar",
               fun.args = list(mult = 1)) +
  stat_summary(fun = mean, geom = 'point', color = 'red', size = 6)
```

Error bars


8
7
6
5
imdbRating
Action
Adventure
Animation
Biography
Comedy
Crime
Documentary
Drama
Horror
genre_first

Section 2

Confidence intervals

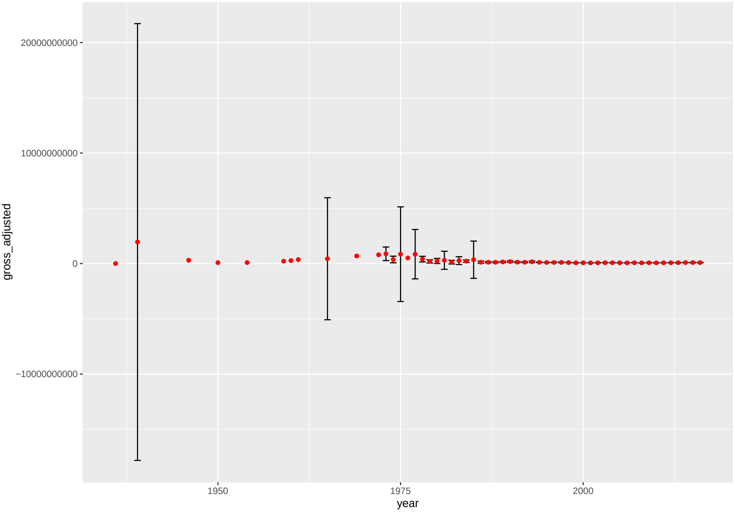
Confidence intervals

We can visualize confidence intervals with error bars as well

- mean_cl_normal will create 95% CI by default

```
ggplot(movies_small, aes(x = year, y = gross_adjusted)) +
  stat_summary(fun.data = mean_cl_normal, geom = "errorbar") +
  stat_summary(fun = mean, geom='point', color = 'red')
```

Confidence Intervals

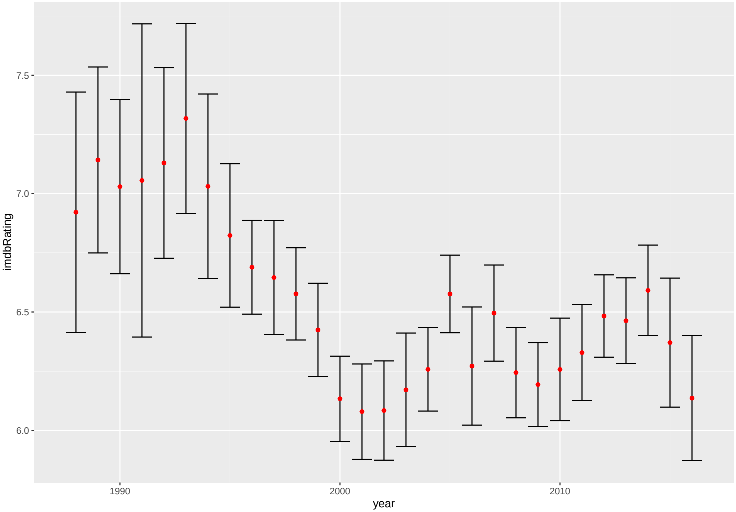


Confidence Intervals

Subset the data with the years starting from 1987

```
movies_small %>% filter(year > 1987) %>%
ggplot(aes(x = year, y = imdbRating)) +
  stat_summary(fun.data = mean_cl_normal, geom = "errorbar") +
  stat_summary(fun = mean, geom='point', color = 'red')
```

Confidence Intervals



Confidence Intervals

Error bars with confidence intervals can help us to do initial hypothesis testing

$$H_0 : \mu_0 = \mu_1$$

$$H_1 : \mu_0 \neq \mu_1$$

We can look at the error bars

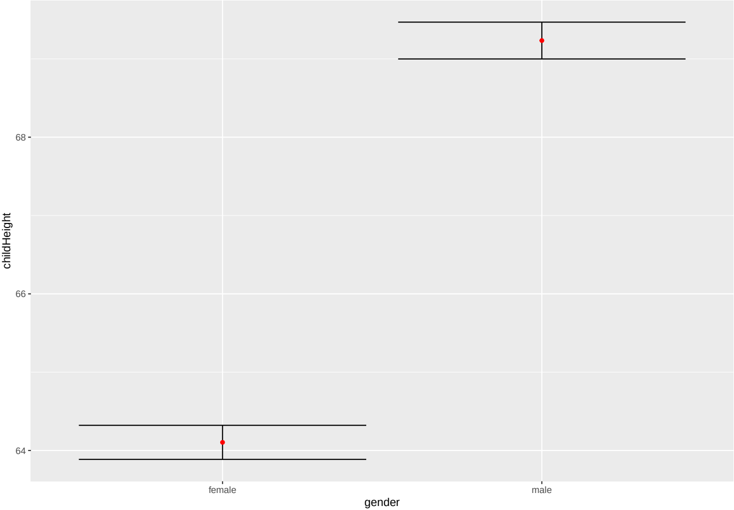
- No intersection of the bars is an indicator of rejecting the null hypothesis
- Larger is the gap between error bars, more likely you will reject H_0

Confidence intervals

Confidence intervals for Height by gender

```
ggplot(GaltonFamilies, aes(x = gender, y = childHeight)) +
  stat_summary(fun.data = mean_cl_normal, geom = "errorbar") +
  stat_summary(fun = mean, geom='point', color = 'red')
```

Confidence Intervals



Confidence Intervals

Testing the hypothesis

$$H_0 : \mu_{male} = \mu_{female}$$

$$H_1 : \mu_{male} \neq \mu_{female}$$

```
t.test(GaltonFamilies$childHeight~GaltonFamilies$gender)
##
##  Welch Two Sample t-test
##
## data:  GaltonFamilies$childHeight by GaltonFamilies$gender
## t = -31.476, df = 929.89, p-value < 0.00000000000000022
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -5.449979 -4.810266
## sample estimates:
## mean in group female   mean in group male
##             64.10397             69.23410
```

Confidence Intervals

Look at the mtcars data

- hp Horsepower
- am transmission automatics vs manual

First - t.test

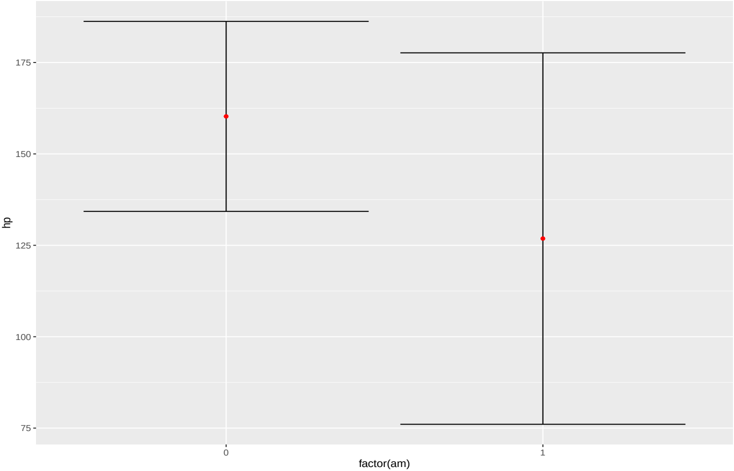
```
t.test(mtcars$hp~mtcars$am)
##
##  Welch Two Sample t-test
##
## data:  mtcars$hp by mtcars$am
## t = 1.2662, df = 18.715, p-value = 0.221
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -21.87858  88.71259
## sample estimates:
## mean in group 0 mean in group 1
##        160.2632        126.8462
```

Confidence Intervals

Confidence interval

```
ggplot(mtcars, aes(x = factor(am), y = hp)) +
  stat_summary(fun.data = mean_cl_normal, geom = "errorbar") +
  stat_summary(fun = mean, geom='point', color = 'red')
```

Confidence Intervals



Section 3

Uncertainty in curve fit

Uncertainty in curve fit

When we fit a model into the data, we sometimes look for answers to the following questions:

- What is the mean response for a particular value of x?
- In which interval will these value lie

Uncertainty in curve fit

To answer these questions, we can construct confidence interval around the regression line, using the following formula:

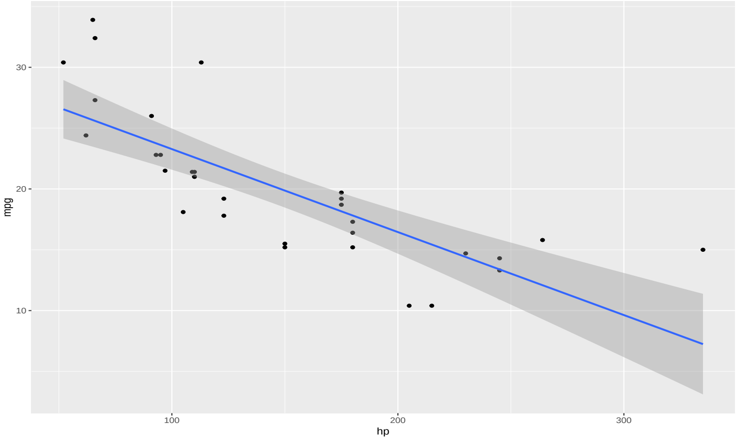
$$\hat{y}_h \pm t_{\alpha/2,n-2}\sqrt{MSE\left(\frac{1}{n}+\frac{(x_k-\bar{x})^2}{\sum(x_i-\bar{x}^2)}\right)}$$

Wider is the confidence interval, more uncertainty we would have for that specific x value.

Uncertainty in curve fit

To get the confidence interval on the graph, specify se=TRUE (the default option) either in stat_smooth or geom_smooth

```
ggplot(mtcars, aes(x = hp, y = mpg)) + geom_point() +
  geom_smooth(method = 'lm')
```



Uncertainty in curve fit

As you can see from the formula, further away you go from the mean, larger becomes the confidence interval

```
ggplot(mtcars, aes(x = hp, y = mpg)) + geom_point() +
  geom_smooth(method = 'lm') +
  geom_vline(xintercept = mean(mtcars$hp), color = 'red')
```