Probability and Statistics B
Project
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Contents

1 Hypothesis

The task given was to investigate the difference in runtimes of Hollywood and Bollywood films, based on a criticism by a reviewer that Bollywood films are sometimes too long.
Hypotheses are set out as:
$H_0 : \mu_H = \mu_B$
$H_1 : \mu_H < \mu_B$
As such, an investigation is set up to see if it is fair to say that films from both categories, in general, are of the same length. If this is rejected, it is then asserted that Bollywood films are indeed longer than Hollywood films.

2 Data

To ensure the investigation was fair, care was taken to ensure the samples were fair and accurate reflections of the categories.

2.1 Choice

For the samples, 50 films from each category were selected based on the same criteria, that being:

- they had a release date in 2015, 2016, 2017, 2018, or 2019
- they were in the top 10 highest grossing films of that category for their release year

The reasoning behind this decison was that revenue generated from a film is a direct measure of interest by the general public. We posture that reasons for interest in films is the same worldwide, and that the attitudes towards runtime do not change between Hollywood and Bollywood films.

2.2 Source

To ensure the accuracy of data, the top 10 grossing films were obtained from Wikipedia, and cross checked these with other sources. These were added to online lists in the TMDb (The Movie Database) website. TMDb is used by over 200,000 web developers to obtain information about digital media, including films, television programmes and shorts. This information includes the runtime of films, and it was these runtimes that were used in the project.
All sources can be found in References.

2.3 Storage

To avoid the monotonous task of manually entering the details of 100 films, the names of the films were inserted into the online list on TMDb. TMDb has an API (Application Programming Interface) that allows information to be fetched in JSON (JavaScript Object Notation) format, which can be used in R with the `jsonlite` library. An R script was, therefore, written to use the API to fetch the lists from the internet. These lists were stored in variables named `hollywood` and `bollywood`. Then, writing another R script obtained the runtimes of each film, and stored these in vectors `hollywood_runtime` and `bollywood_runtime`. These were then convered to `numeric` format (from `integer` format) to allow use with R functions.

3 Analysis

The analysis tests the hypothesis to the 95% and 99% confidence intervals. This suggests that the probability of a type I error, that is the chance a correct null hypothesis is rejected, is 0.05 and 0.01, respectively. We first discuss if H_0 is true, and then consider the alternative H_1.

3.1 Assumptions

The Central Limit Theorem can be used to assume the two samples of independent film runtimes are normally distributed. This allows the use of, as the sample is large, the normal assumption to derive confidence intervals. Discussion of the validity of this assumption for the samples leads to acceptance, as below.
It can be seen from the histogram and Q-Q plot of normal quantiles for Hollywood films that the sample approachs a normal distribution. There is a distinctive bell shape in the histogram, and the Q-Q plot approaches a linear curve (an indicator of a normally distributed sample). There is one outlier, which may increase the mean - noted for later.
The plots for Bollywood films also show that we approach a normal distrinution. The samples approach a bell curve, and the Q-Q plot is relatively linear. We note that the sample does tend to favour lower film runtimes - which is again noted for later.

3.2 Testing for H_0

The 95% and 99% confidence intervals were obtained to test if the means are equal. Using the assumption of normally distributed samples, the test statistic can be used, that is:

$$\frac{(\bar{X}_H - \bar{X}_B) - (\mu_H - \mu_B)}{\sqrt{\frac{\sigma_H^2}{n} + \frac{\sigma_B^2}{n}}} \sim N(0,1)$$

With large n, take $\sigma^2 = s^2$. As $s_H^2 = 366.1229$ and $s_B^2 = 214.8608$, this gives:

$$\frac{(125.5 - 150.42)}{\sqrt{\frac{366.1229}{50} + \frac{214.8608}{50}}} = -7.257169$$

From the $N(0,1)$ distribution, there is a 95% confidence interval of $(-1.959964, 1.959964)$. It is clear the test statistic is outwith this interval, so H_0 is rejected at 5% chance of type I error.
A 99% confidence interval from a $N(0,1)$ distribution is $(-2.575829, 2.575829)$. Again, it is clear the test statistic is outwith this interval, so, again, reject H_0, this iteration with 1% chance of type I error.

3.3 Accepting H_1

To test whether H_1 is acceptable as an alternative hypothesis, t-tests were ran in R at 95% and 99% confidence levels, on the basis of a one-sided test, that $\mu_H < \mu_B$.
Both tests gave a p-value of 6.327×10^{-11}, which suggests a very strong inclination to reject H_0, as it is well below the significance level, and to favour H_1 as an alternative hypothesis.

4 Conclusion

In conclusion, a fair and sufficiently large sample of Bollywood and Hollywood movies was selected. These were then applied to the hypothesis set by the film reviewer, and both confidence intervals and t-tests were used to discuss the validity of the hypothesis. The results gave, at over 99% confidence, that Bollywood films from the sample are longer than Hollywood films. This is including a skewness due to outliers that may see the samples converge to the same mean, stregthening the statistical test. Given the choice of sample and these results, it can be said that, statistically, Bollywood films are longer than Hollywood films.

5 References

Throughout the project, the course notes were referred to. Alongside this, the following websites were used for consultation and to obtain data:

Wikipedia	(https://en.wikipedia.org)
TMDb	(https://www.themoviedb.org)
Box Office Mojo	(https://www.boxofficemojo.com/)
Bollywood Hungama	(https://www.bollywoodhungama.com)
Khan Academy	(https://www.khanacademy.org)
Stack Overflow	(https://stackoverflow.com)
Stack Exchange	(https://stackexchange.com)

A Films

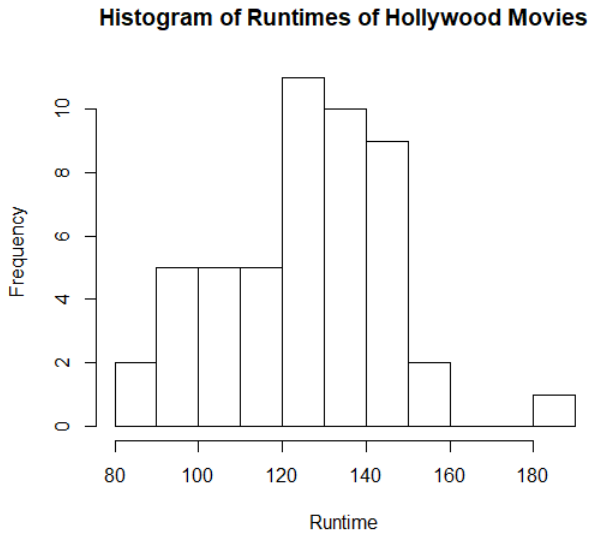
The data used in the two samples is given as follows.

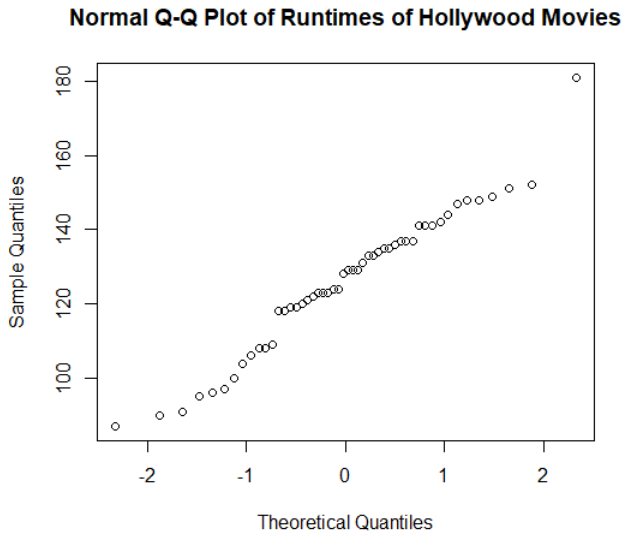
A.1 Hollywood

All the movies and corresponding data can be viewed at https://www.themoviedb.org/list/138881.
The runtimes of movies (in order), stored in the `hollywood_runtime` vector, are:

181	118	142	104	100	124	129	128	122	123
134	149	118	129	144	121	90	148	119	135
152	129	141	119	137	133	135	131	96	120
133	97	147	87	106	108	109	151	123	108
136	124	141	95	137	91	137	141	123	148

These data can be shown on a histogram:





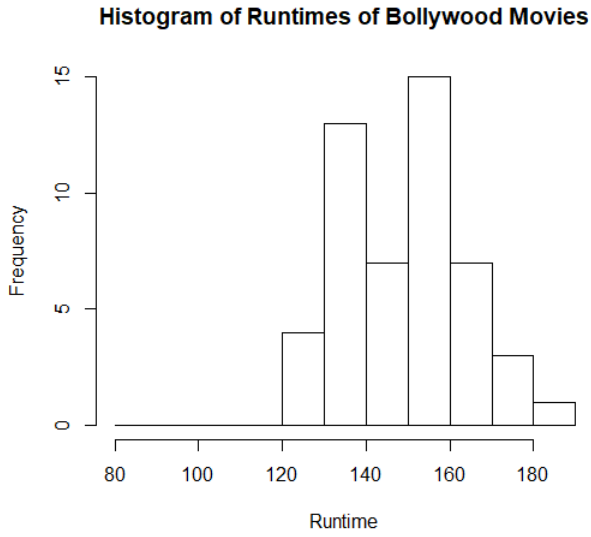
A.2 Bollywood

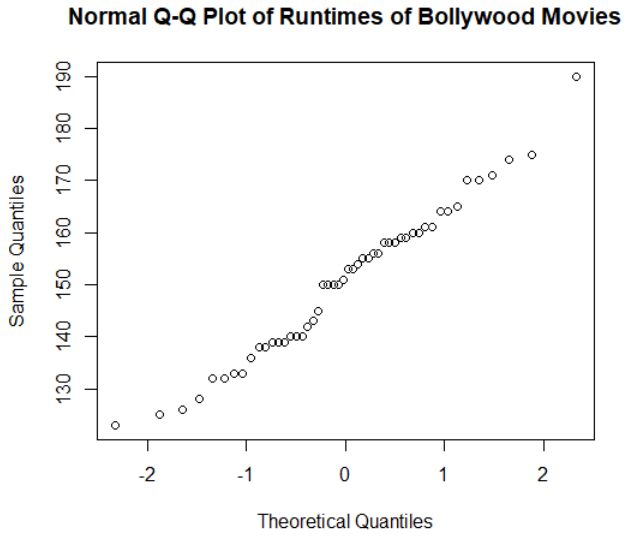
All the movies and corresponding data can be viewed at https://www.themoviedb.org/list/138884.
The runtimes of movies (in order), stored in the `bollywood_runtime` vector, are:

156	171	175	138	155	132	133	142	150	161
164	139	159	164	160	145	140	125	140	150
165	132	155	151	143	150	139	136	139	161
158	150	190	126	140	138	153	133	159	174
158	158	128	153	154	170	160	123	156	170

The movie **Sultan** was included in the sample, but was not in the database used. The runtime for this movie was sourced separately from Wikipedia (and cross checked) and is the final entry in the table.

These data can be shown on a histogram:





B R Scripts

These scripts are written as if querying for the Hollywood movies, they can and were simply adapted for Bollywood movies by changing references to `hollywood` to `bollywood`.

B.1 Films

```
hollywood_file="https://api.themoviedb.org/3/list/138881?api_key=
8e2981306aaa0d1218f9fbf7165f99d8&language=en-US"

#ensure the jsonlite library is loaded
hollywood <- fromJSON(hollywood_file,flatten=TRUE)
hollywood_list <- hollywood['items']
```

B.2 Runtime

```
#ensure the jsonlite library is loaded
for(i in 1:50){
id=hollywood_list[["items"]][["id"]][[i]]
json <- fromJSON(paste("https://api.themoviedb.org/3/movie/",id,"?api_key=
8e2981306aaa0d1218f9fbf7165f99d8&language=en-US"),flatten=TRUE)
hollywood_runtime[i]=json['runtime']
}
```

C t-tests

t-tests were run in R, and the outputs are given below.

C.1 95%

Running the command `t.test(hollywood_runtime,bollywood_runtime,alternative="l")` yielded:

```
Welch Two Sample t-test

data: hollywood_runtime and bollywood_runtime
t = -7.205, df = 91.779, p-value = 7.9e-11
alternative hypothesis: true difference in means is less than 0
95 percent confidence interval:
-Inf -18.89591
sample estimates:
mean of x mean of y
125.86 150.42
```

C.2 99%

Running the command `t.test(hollywood_runtime,bollywood_runtime,alternative="l"),conf.level=0.99)` yielded:

```
Welch Two Sample t-test

data: hollywood_runtime and bollywood_runtime
t = -7.205, df = 91.779, p-value = 7.9e-11
alternative hypothesis: true difference in means is less than 0
99 percent confidence interval:
-Inf -16.48918
sample estimates:
mean of x mean of y
125.86 150.42
```