Movie Popularity Prediction

Group 8

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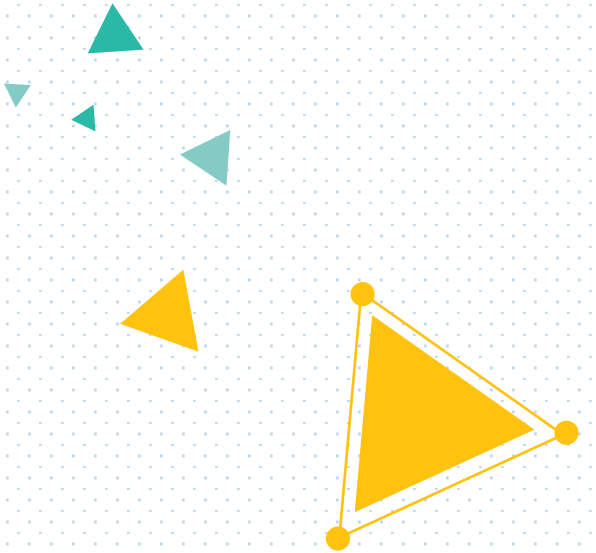
01 Part One *Overview*



Overview

- Purpose: Predict on movies' ratings.
- Model:
  - Linear Model
  - Nonlinear Model
  - Neural Network

Overview – Raw Data

- Over 4000 movies, 21 Variables

ID:

- id - The movie_id

Scalar Variable:

- budget - The budget in which the movie was made
- revenue - The worldwide revenue generated by the movie
- runtime - The running time of the movie in minutes
- vote_average - average ratings the movie received
- vote_count - the count of votes recieved

Other Variable:

- homepage - A link to the homepage of the movie
- keywords - The keywords or tags related to the movie
- overview - A brief description of the movie
- tagline - Movie's tagline
- title - Title of the movie

Categorical Variable

- genre - The genre of the movie, Action, Comedy, Thriller etc
- original_language - The language in which the movie was made
- original_title - The title of the movie before translation or adaptation
- spoken_language - The language in which the movie was released
- production_companies - The production house of the movie
- production_countries - The country in which it was produced
- release_date - The date on which it was released
- status - "Released" or "Rumored"
- cast – cast of the movie
- crew – crew of the movie

Overview – Raw Data

- 4802 movies, 21 Variables

ID:

- id - The movie_id

Scalar Variable:

- budget - The budget in which the movie was made
- revenue - The worldwide revenue generated by the movie
- **runtime - The running time of the movie in minutes**
- **vote_average - average ratings the movie received**
- **vote_count - the count of votes recieved**

Other Variable:

- homepage - A link to the homepage of the movie
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- status - "Released" or "Rumored"
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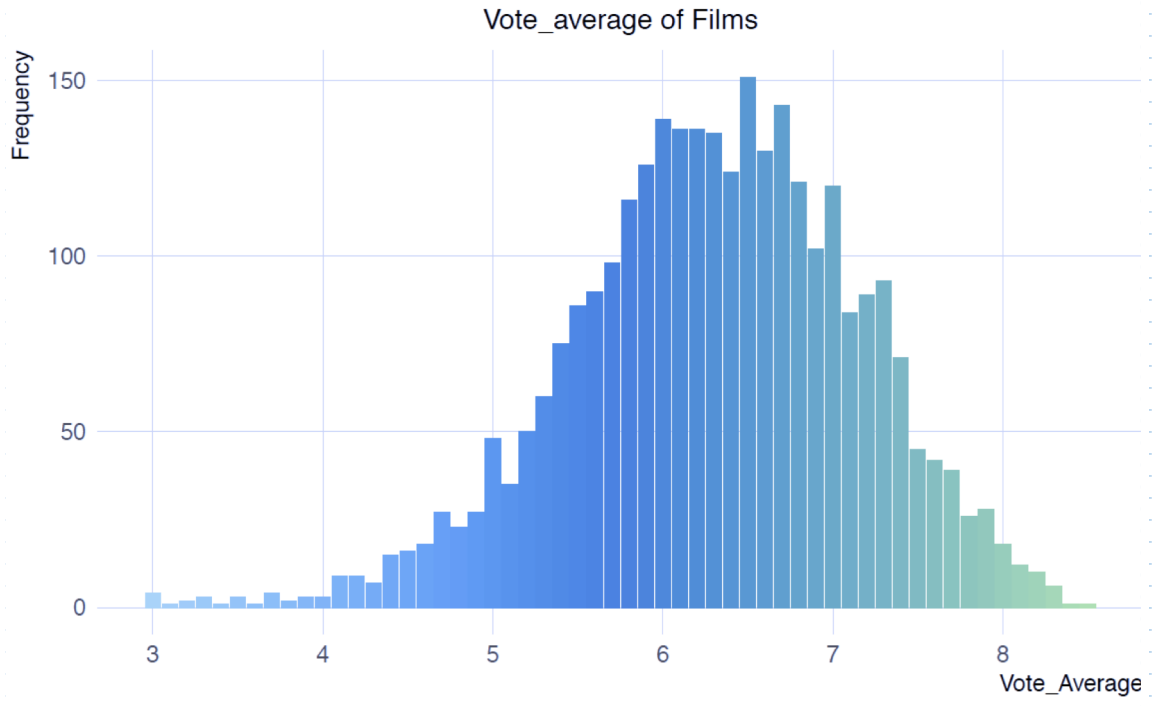
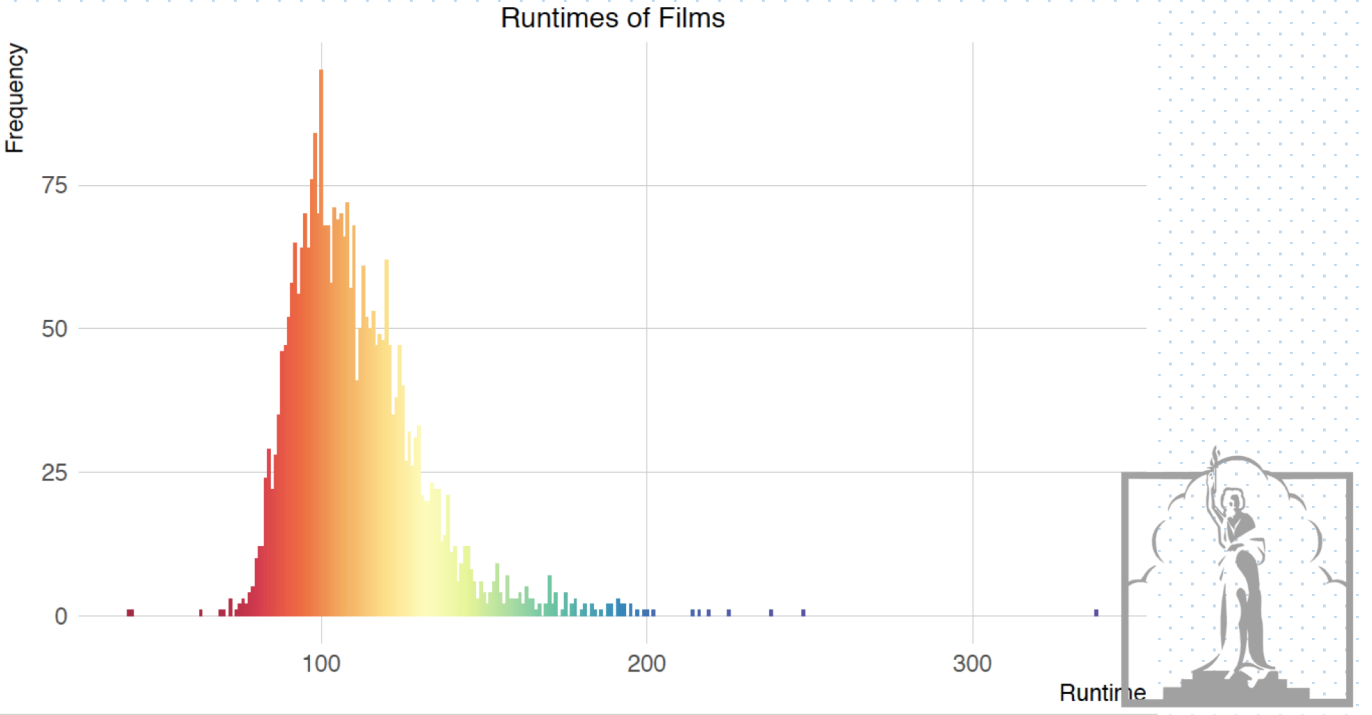
- crew – crew of the movie

02 Part Two
Exploratory Data Analysis

EDA – Vote & Runtime

- **Vote_average: vote_count/number of people who liked**
- **Vote_count: the number of likes for this movie**
- **Runtime: the running time of the movie in minutes**

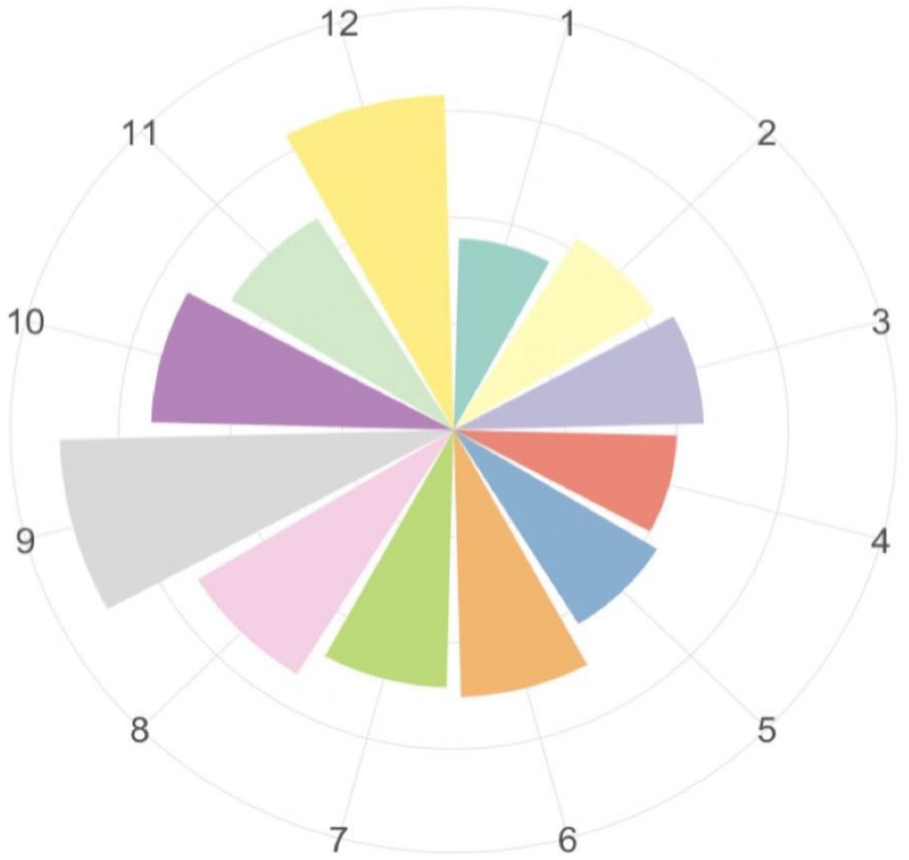


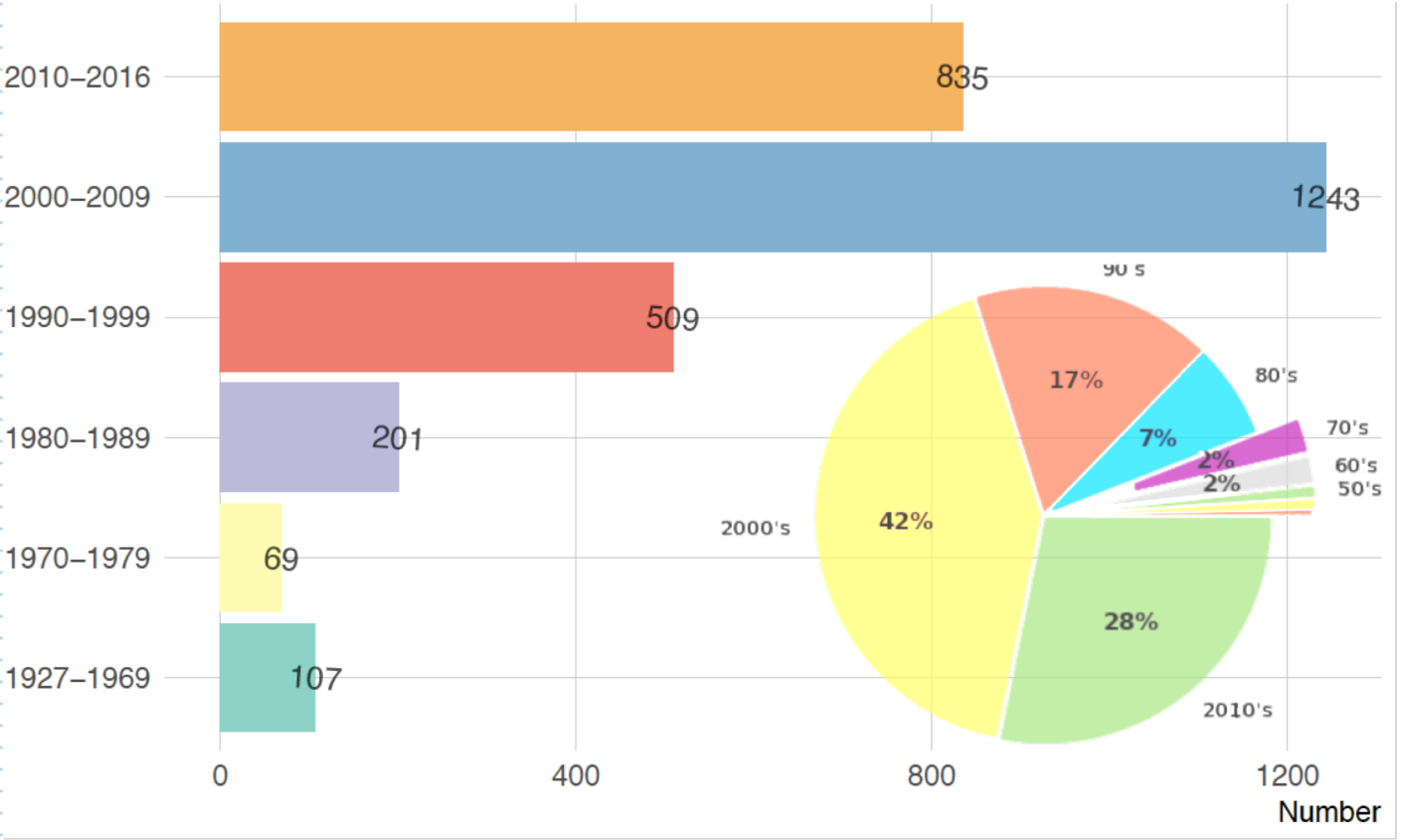


EDA – Time

- **Month**: convert to a factor variable;

  month 1 (January) is the reference group.

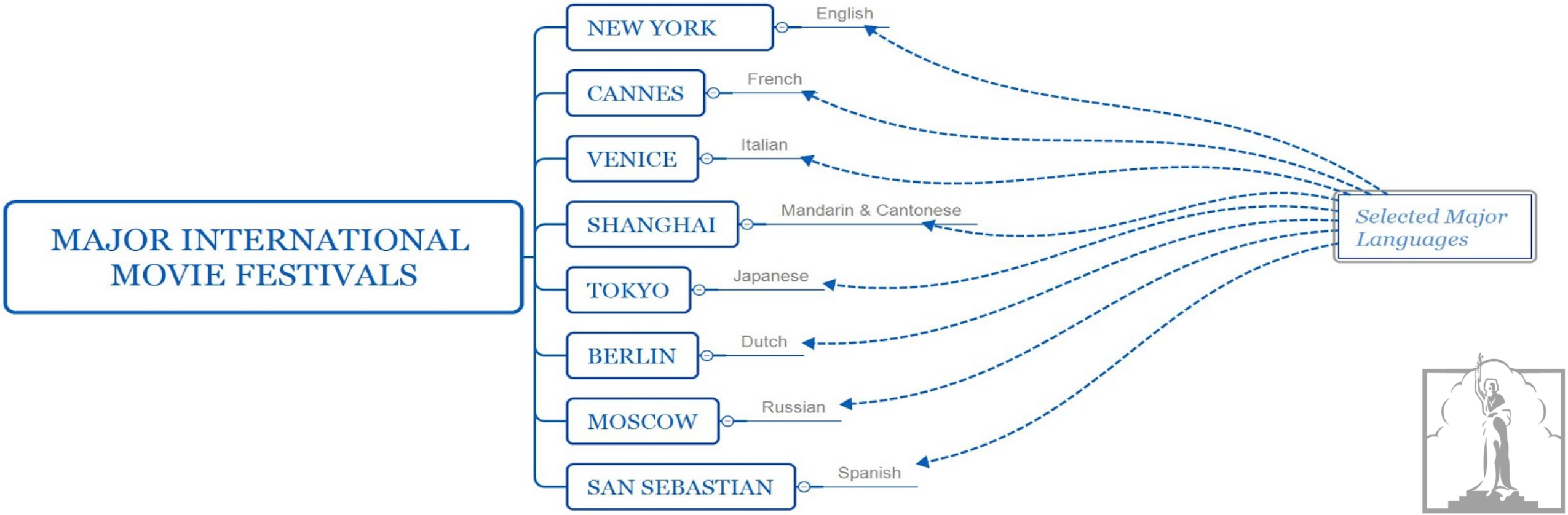




- **Year**: 1927-2016; spans 89 years; convert to a variable that has value 0 if year = 1927, has value 89 if year = 2016, etc.

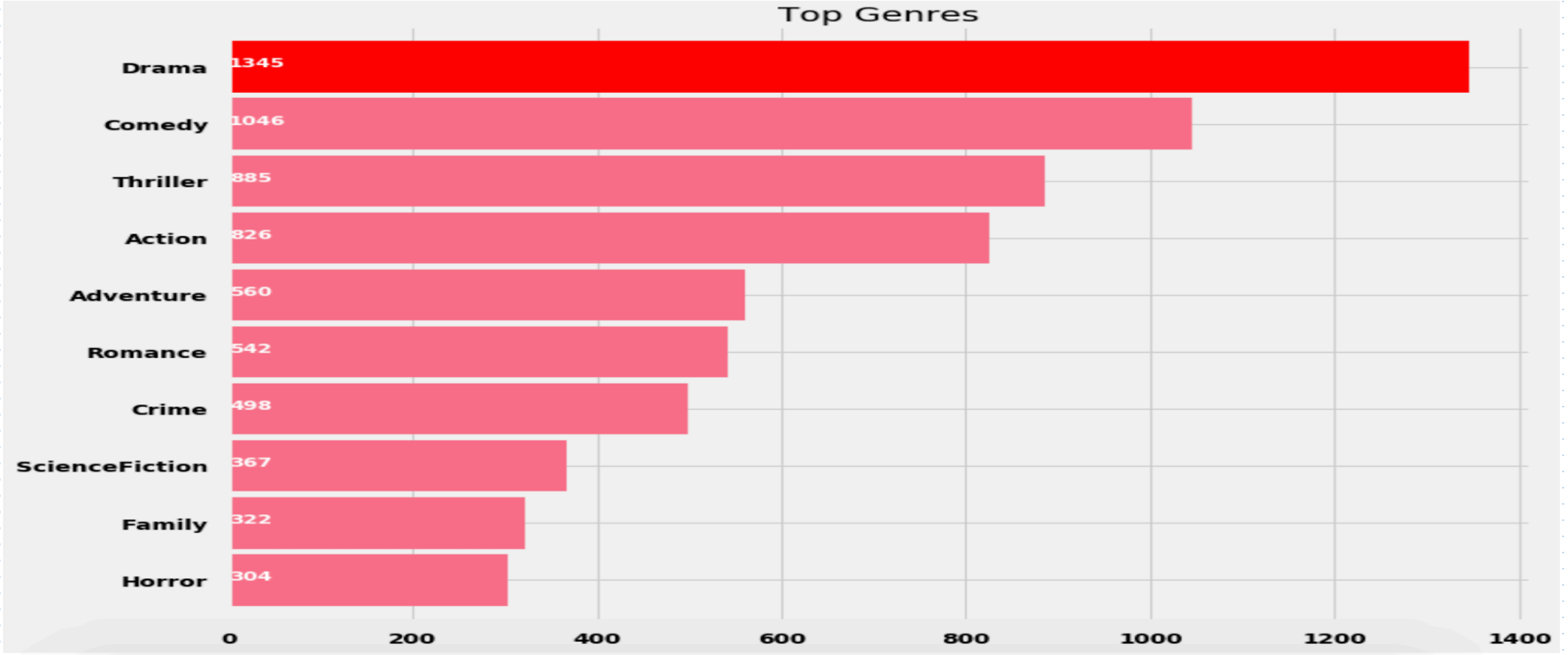
EDA – Spoken Language

- **Spoken Language**: 15 major language are encoded into multi-hot variables.
- **Min_language**: 40 minor languages are compressed in one variable



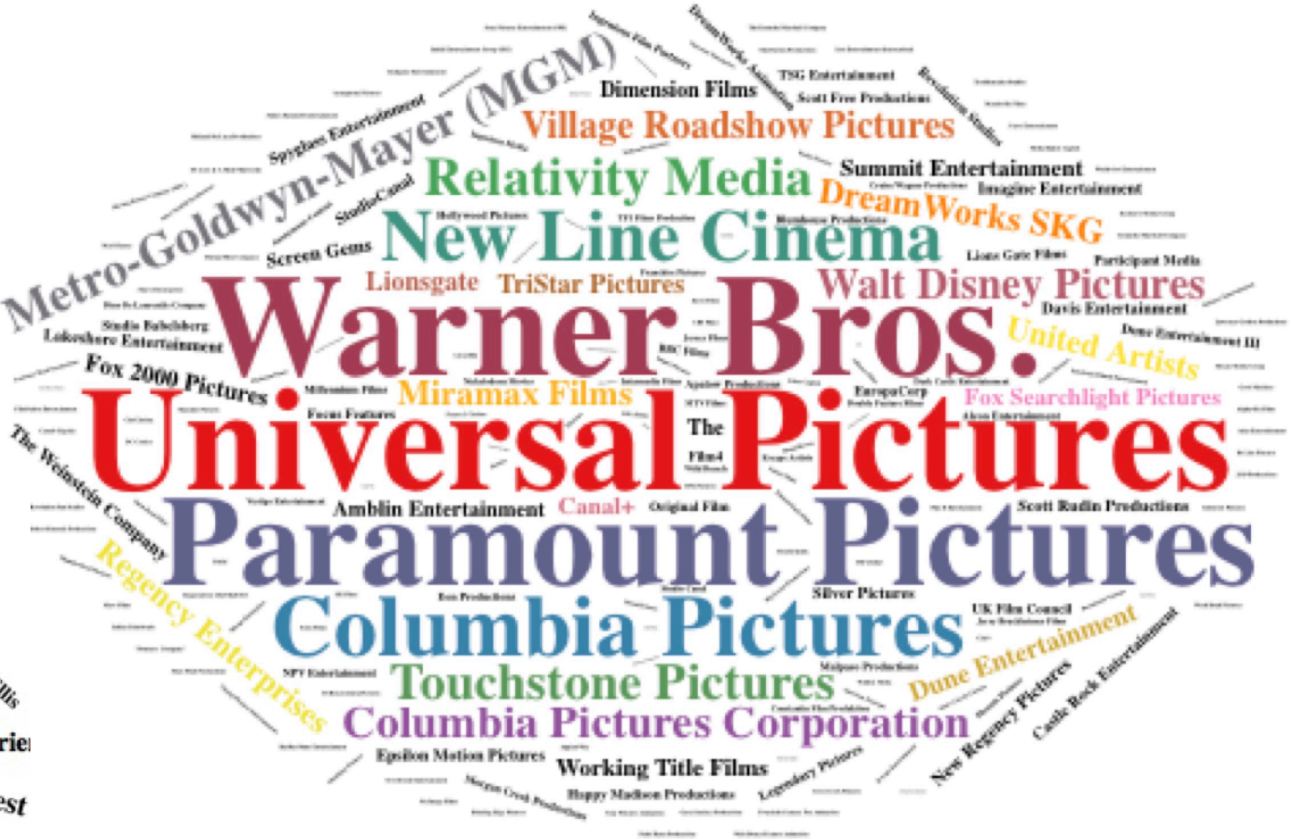
EDA – Genres

- Action, Comedy, Thriller etc.
- 19 genres are encoded into multi-hot variables



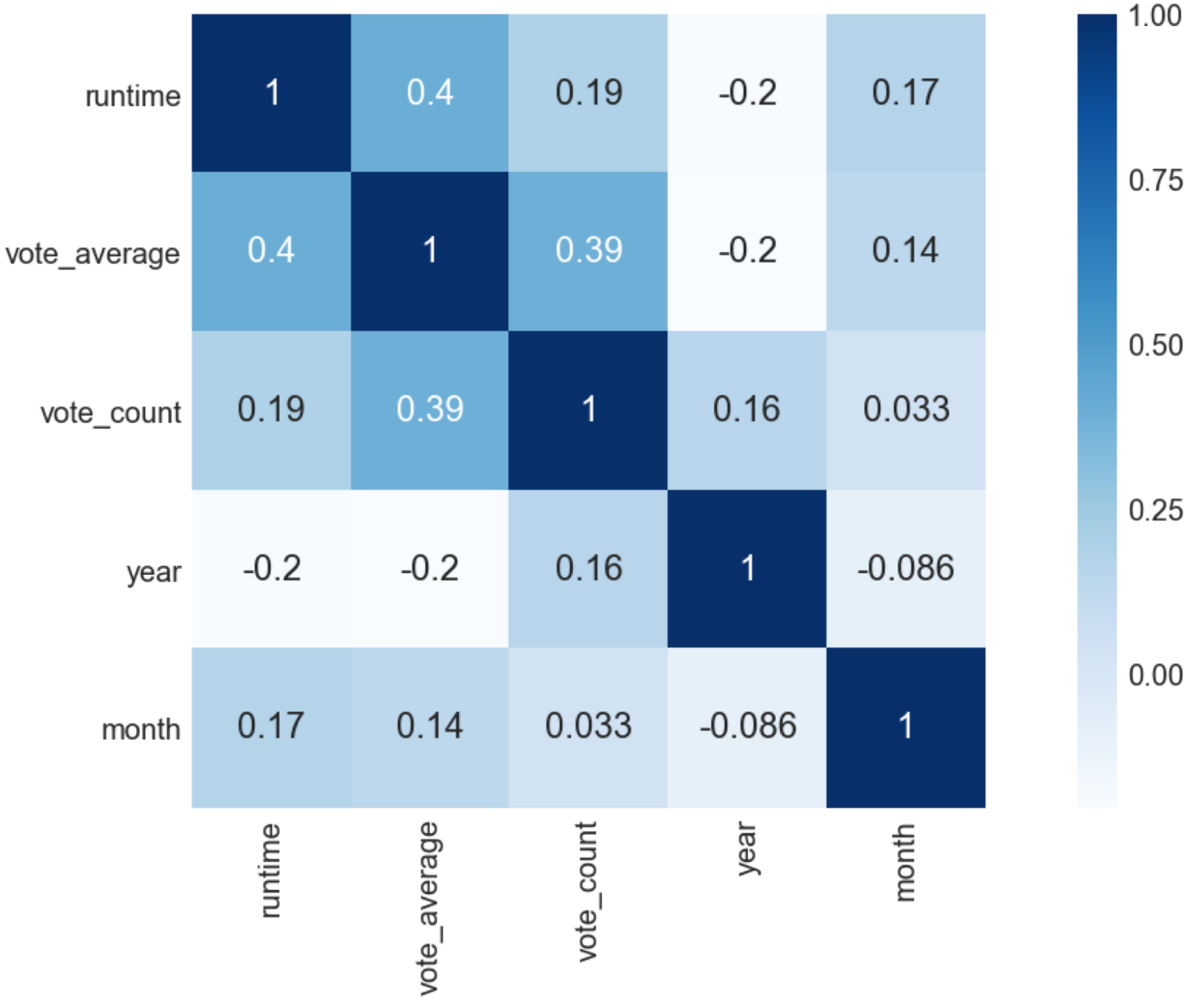
EDA – Director vs Studios

- **Director:** Draw ‘director’ feature from ‘crew’.



- **Studios**
- majority_studio: the number of top six production companies that involved in the movie.
- minority_studio: the number of other production companies that involved in the movie.

EDA – Correlation between Variables



03 Part Three
Linear Regression Model

Datasets

- VIFs of predictors in our dataset are very small and less than
  - no collinearity is detected
- Training data: include 75% of the cleaned data
- Testing data: include 25% of the cleaned data
- We train models on training data and assess their performances using testing data.

Linear Regression Model

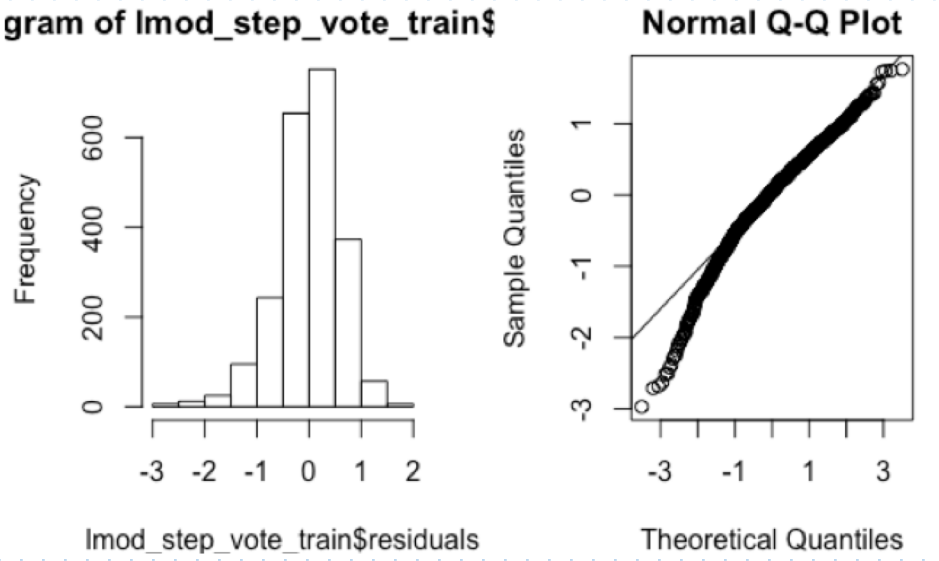
1. Model Selection
   - Stepwise selection using AIC
   - LASSO L1 regularization
     - 41 predictors, large p
2. Diagnosis of underlying assumptions
   - Linearity
   - Normality
   - Homoscedasticity:
   - Uncorrelated Variance
3. Corrective Measures
   - Transformation: Log, Box-cox
   - Build WLS
   - Ridge

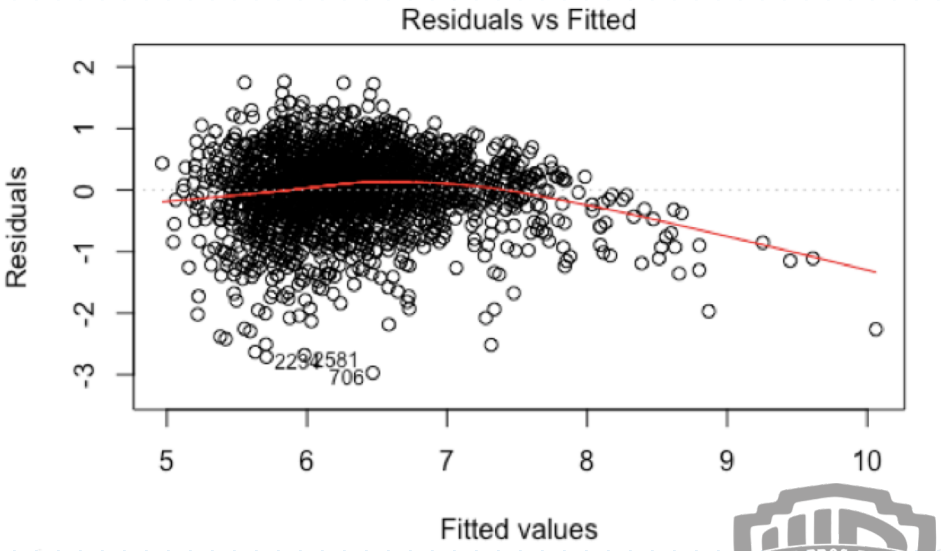
Linear Regression Model – Model Selection (Stepwise)

- **OLS model:**
  - The final model has the smallest AIC
- Vote_average ~ runtime + vote_count + year + month + Documentary + Crime + Foreign + Adventure + Action + Comedy + Science.Fiction + Fantasy + Drama + Animation + Family + Horror + L4 (Russian) + L9 (Dutch) + L15 (English) + L50 (Cantonese) + L53 (Thai) + min_language + majority_studios + minority_studios
- (24 predictors in total)

Linear Regression Model – Diagnostics

- Linearity & functional form
  - R-squared: 0.48
- Normality
- Homoscedasticity
  - Breusch-Pagan test against heteroskedasticity:
    p-value = 0.000627 < 0.05
  - Score Test for Non-Constant Error Variance:
    p-value = 0.010083 < 0.05
- Uncorrelated error
  - Durbin-Watson test: p-value = 0.626 > 0.05
- Outliers and influential points
  - Bonferroni Outlier Test： 706, 2234, 2581, 357 are detected
  - Plot Cook's distance: 2244, 2132, 182 are highly influential points.





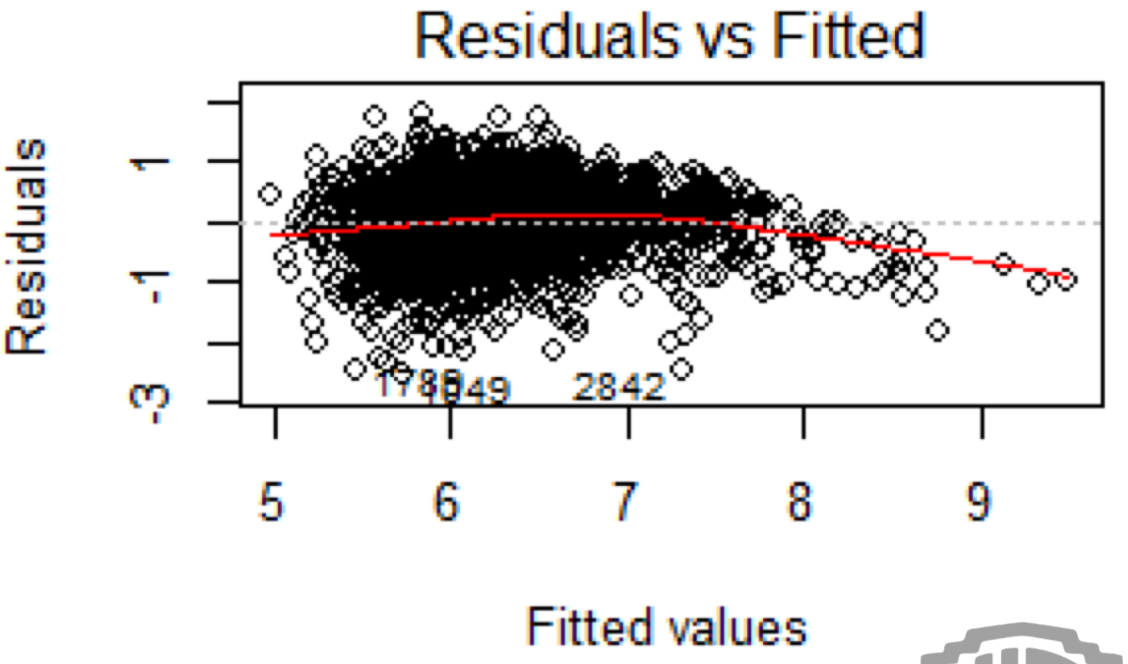
Most assumptions fail, except for uncorrelated error.
Need transformation!!

Linear Regression Model – Weighted Least Squares

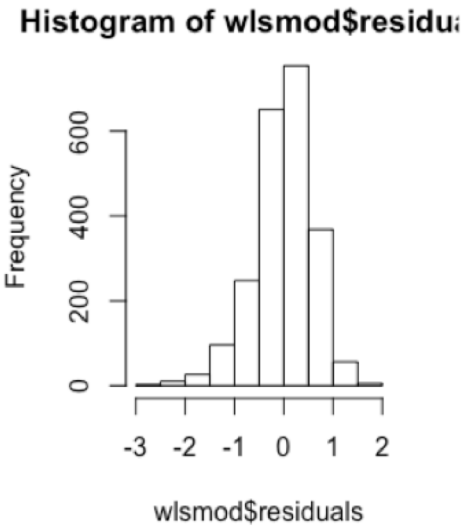
- The suggested model for heterskedasticity is:
  $\mathrm{Var}(\varepsilon_i) = \hat{\sigma}_i^2 = \hat{Y}_i^2$, where $\hat{Y}_i$ is the fitted value of OLS model.
- Solve for heteroscedasticity:
  1. Regress the absolute values of the residuals against the fitted values.
  2. Get new fitted values, denote them as $\hat{Y}_{new,i}$
  3. Let $\mathrm{weight}_i(W_i) = {}^{1}/_{\sigma_i^2} \approx {}^{1}/_{\hat{Y}_{new,i}^2}$, fit a linear mode

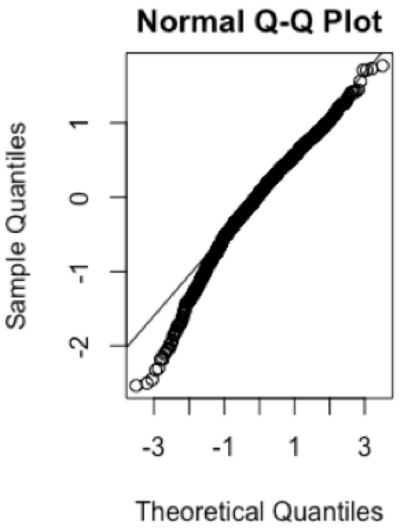
$$\hat{\beta}_{WLS} = \arg\min_{\beta} \sum_{i=1}^{n} \varepsilon_i^{*2} = (X^T W X)^{-1} X^T W Y$$

A "metaphone" shape, this indicates a possible solution for calculating weights in WLS.



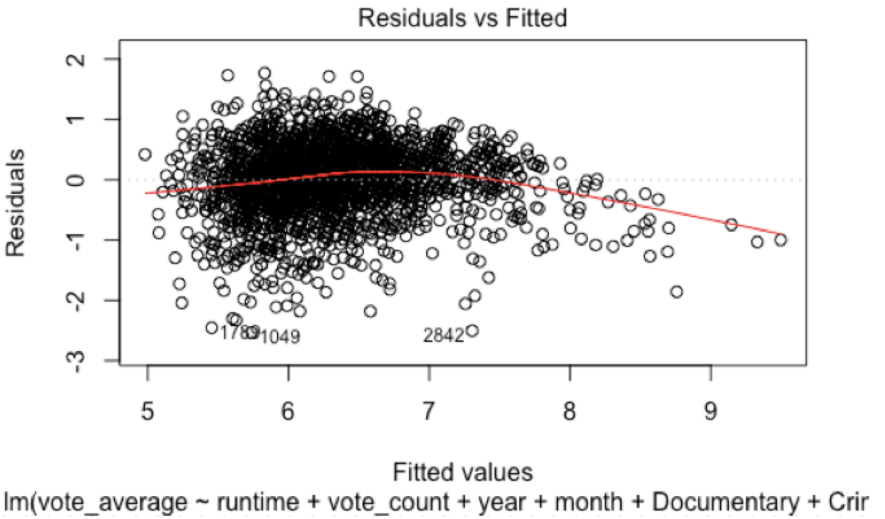
Linear Regression Model – Diagnostics





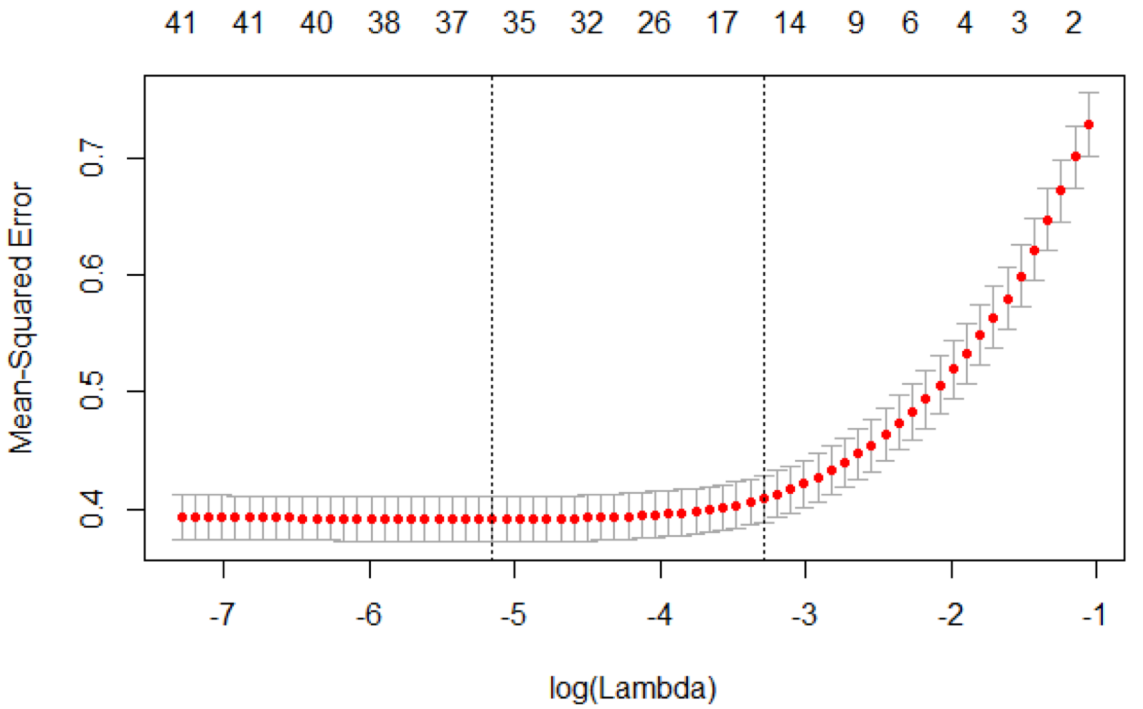
- Remove extreme points and fit WLS
- Diagnostics after building WLS
  - Linearity & functional form
    - R-squared: 0.5
  - Normality
  - Homoscedasticity
    - Score Test for Non-Constant Error Variance: p-value = 0.61733 > 0.05
    - Most error variances look constant from residuals vs fitted value plot.
  - Uncorrelated error
    - Durbin-Watson test: p-value = 0.982 > 0.05
  - Outliers and influential points
    - Bonferroni Outlier Test: Only “2842” is detected
    - Plot Cook’s distance: No influential points.

All Assumptions hold!



Linear Regression Model – Model Selection (LASSO)

- Selected Variables: runtime, vote_count, year, month, Documentary, Crime, Foreign, War, Adventure, Western, Music, Mystery, Action, Comedy, Science.Fiction, Romance, Fantasy, Drama, Animation, Family, Horror, L4, L6, L9, L10, L12, L13, L15, L33, L50, L52, L53, L54, min_language, majority_studios and minority_studios. (**36** predictors in total)

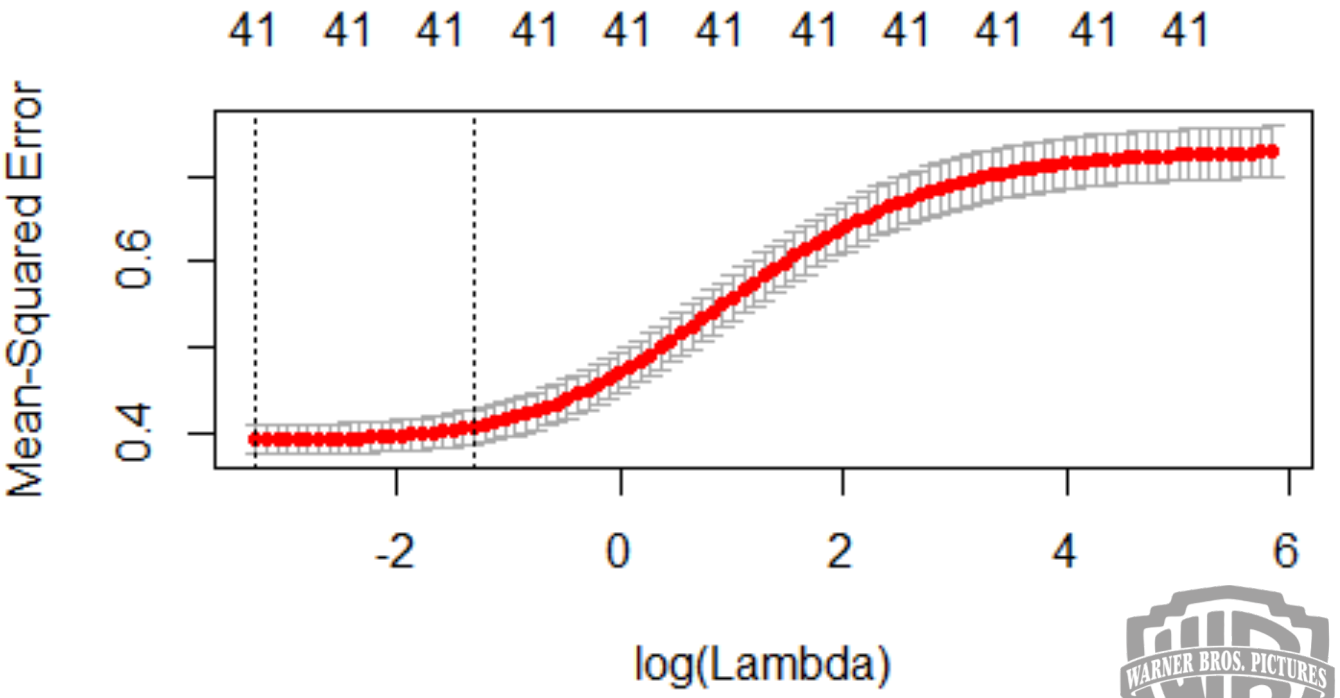


Linear Regression Model – Diagnostics & Weighted Least Squares

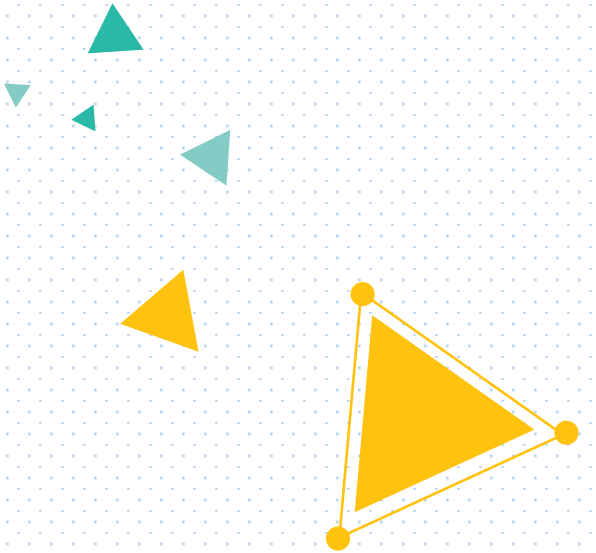
- Diagnostics
  - Linearity and Uncorrelated errors hold
  - Normality and Homoscedasticity are violated
  - Same extreme points are detected
- Transformation
  - Log, Box-cox can’t solve for unequal error variance
- WLS
  - All Assumptions hold!

Linear Regression Model – Ridge Regression

- Ridge regression is aimed to minimize: $\sum_i (y_i - x_i^T \beta)^2 + \lambda \sum_{j=1}^{p} \beta_j^2$
- Ridge regression does not have the function of variable selection
- Check of the assumptions
  - Linearity and Uncorrelated errors hold
  - Normality need not be assumed
  - Homoscedasticity are violated
- Use ridge on the predictors selected by LASSO



04 Part Four
Non-Linear Model

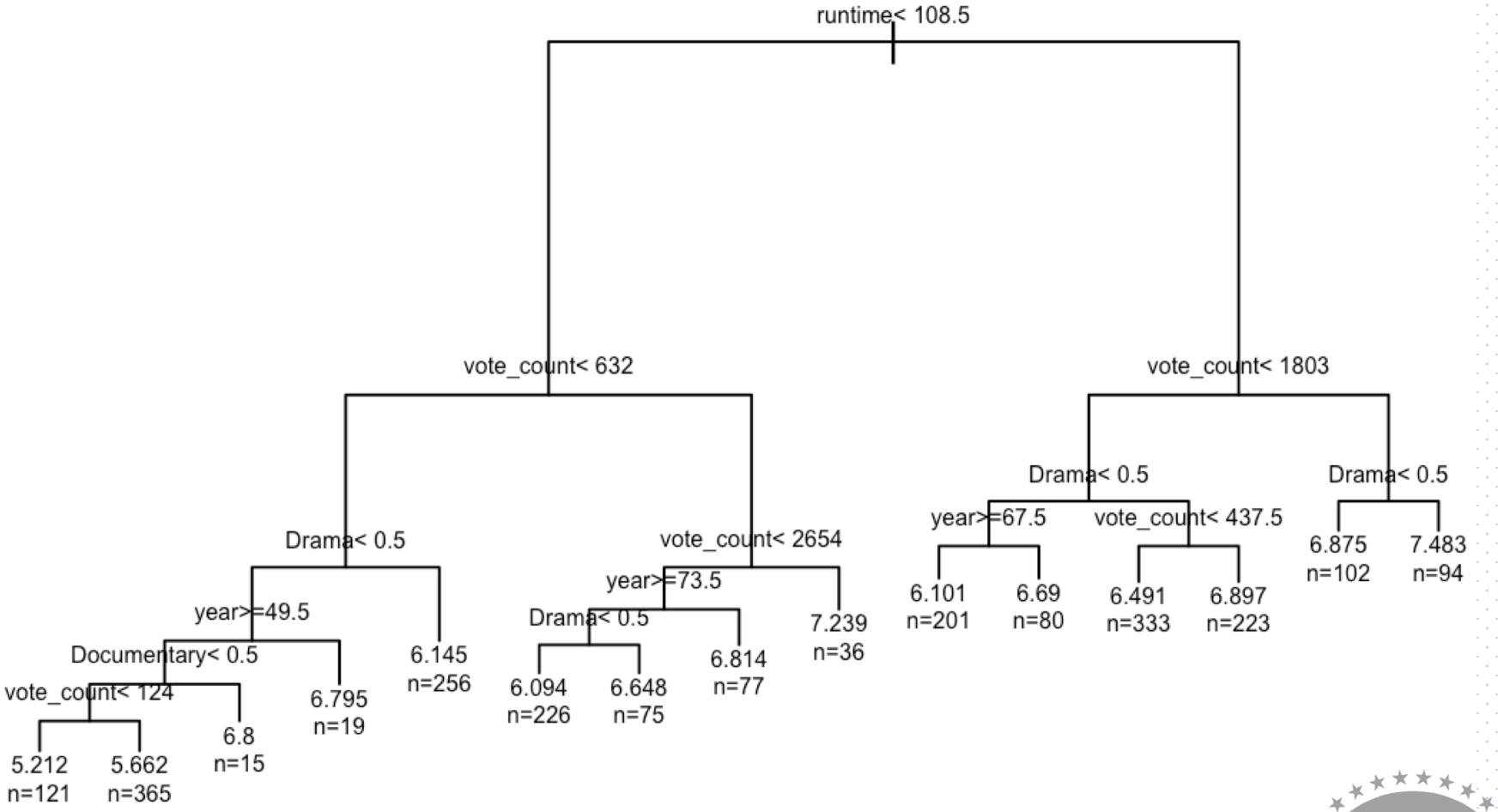


Nonlinear Model

1. Simple Tree Model
2. Random Forest
3. Xgboost
4. Neural Network

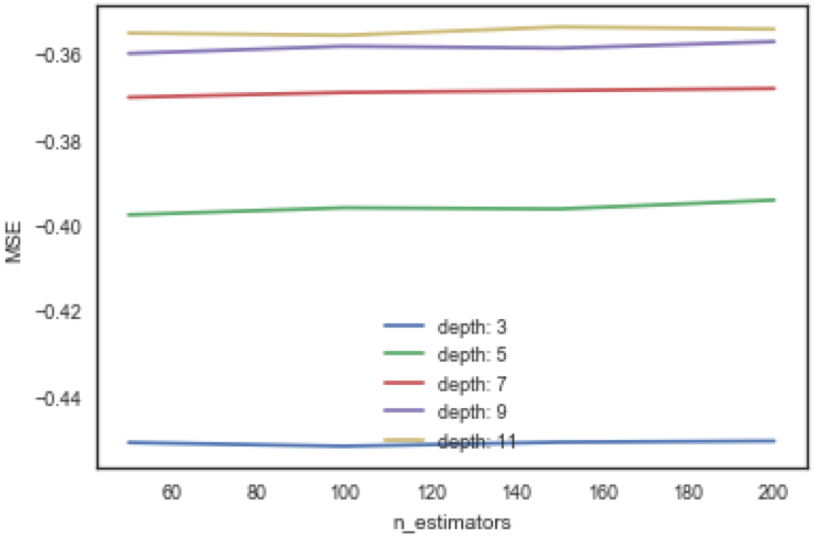
Nonlinear Model – Simple Tree Model

- Parameters:
  - Depth: 8
  - Split: 20
  - CP: 1%



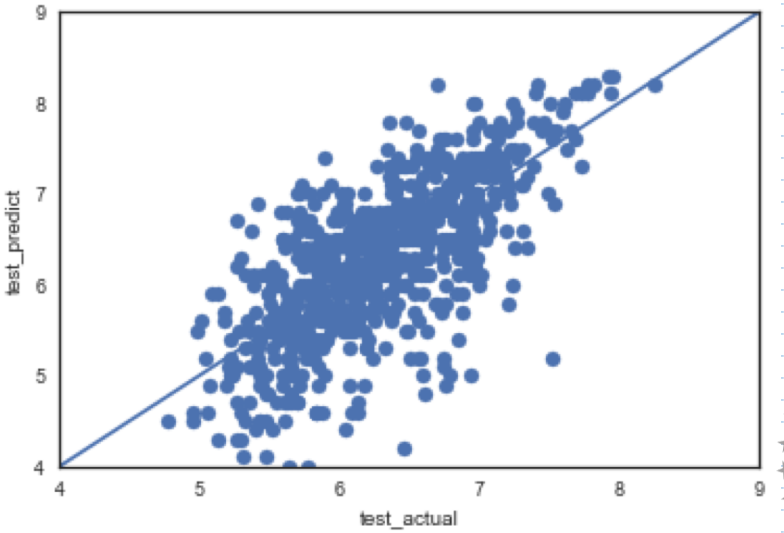
Nonlinear Model – Random Forest

- Model selection:
  - Max_depth = 11
  - N_estimators = 150



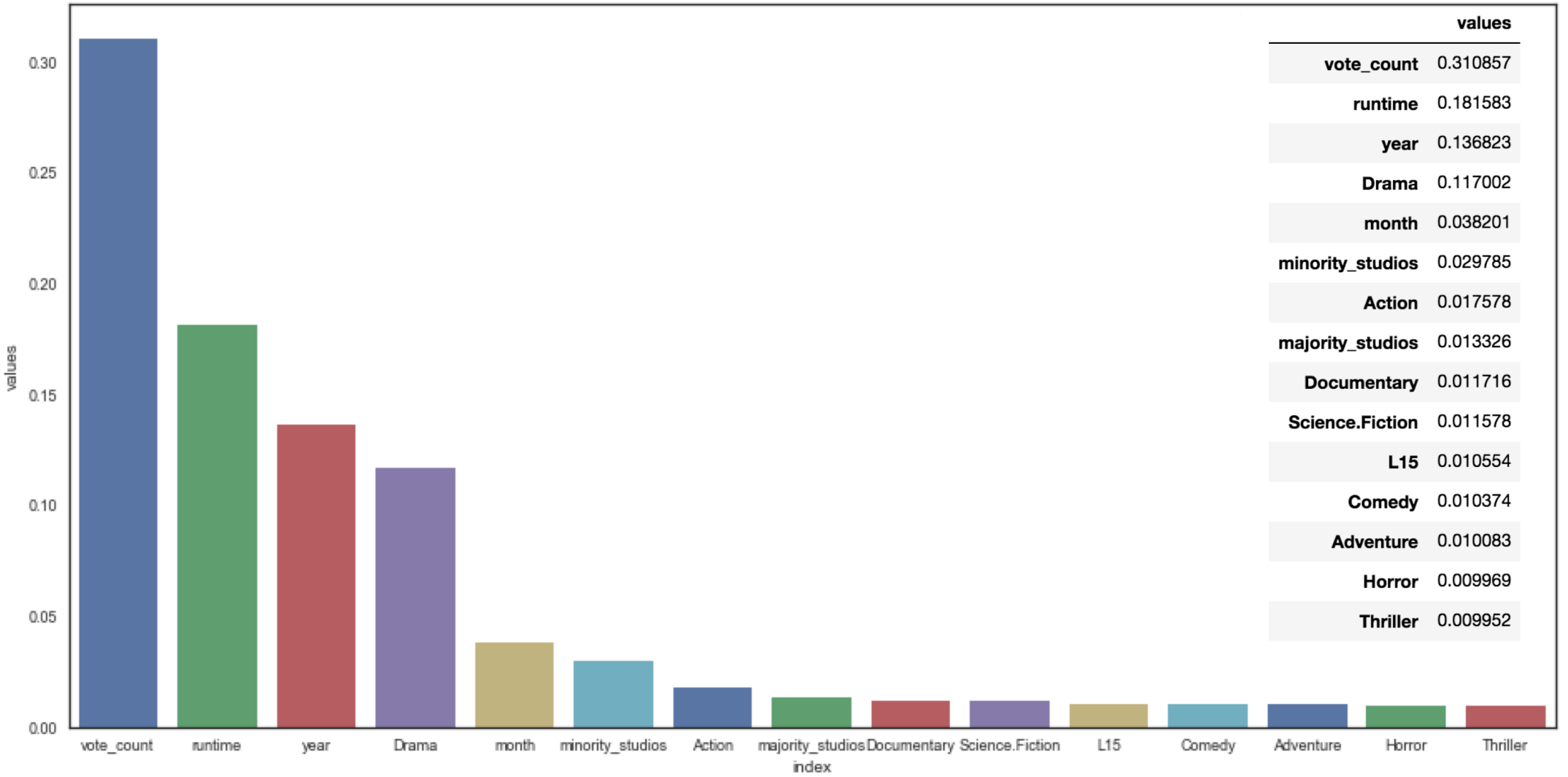

```
# R squared
best_model.score(X_vote_average_test, y_vote_average_test)
```

```
0.49996323304538326
```



Nonlinear Model – Random Forest

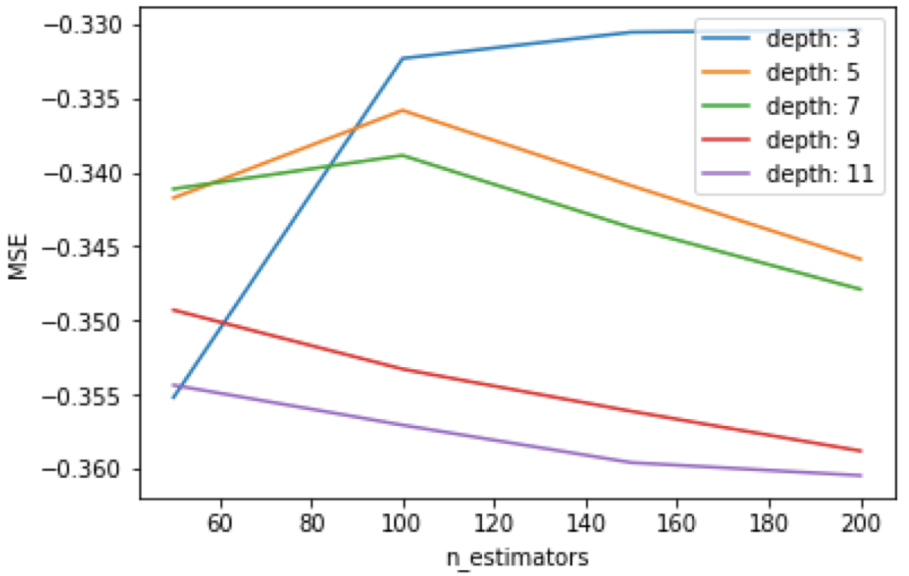
Feature Importance

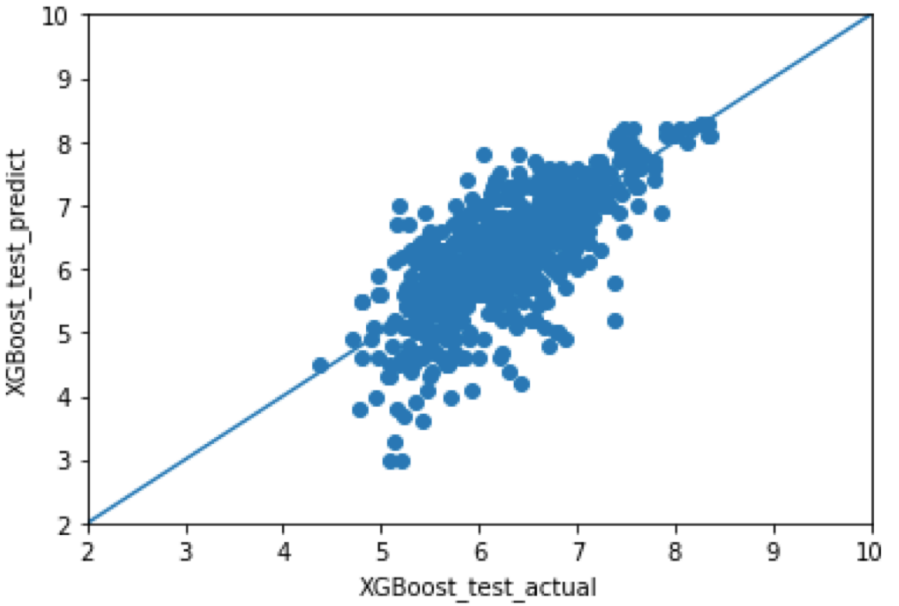


	values
vote_count	0.310857
runtime	0.181583
year	0.136823
Drama	0.117002
month	0.038201
minority_studios	0.029785
Action	0.017578
majority_studios	0.013326
Documentary	0.011716
Science.Fiction	0.011578
L15	0.010554
Comedy	0.010374
Adventure	0.010083
Horror	0.009969
Thriller	0.009952

Nonlinear Model – XGBoost

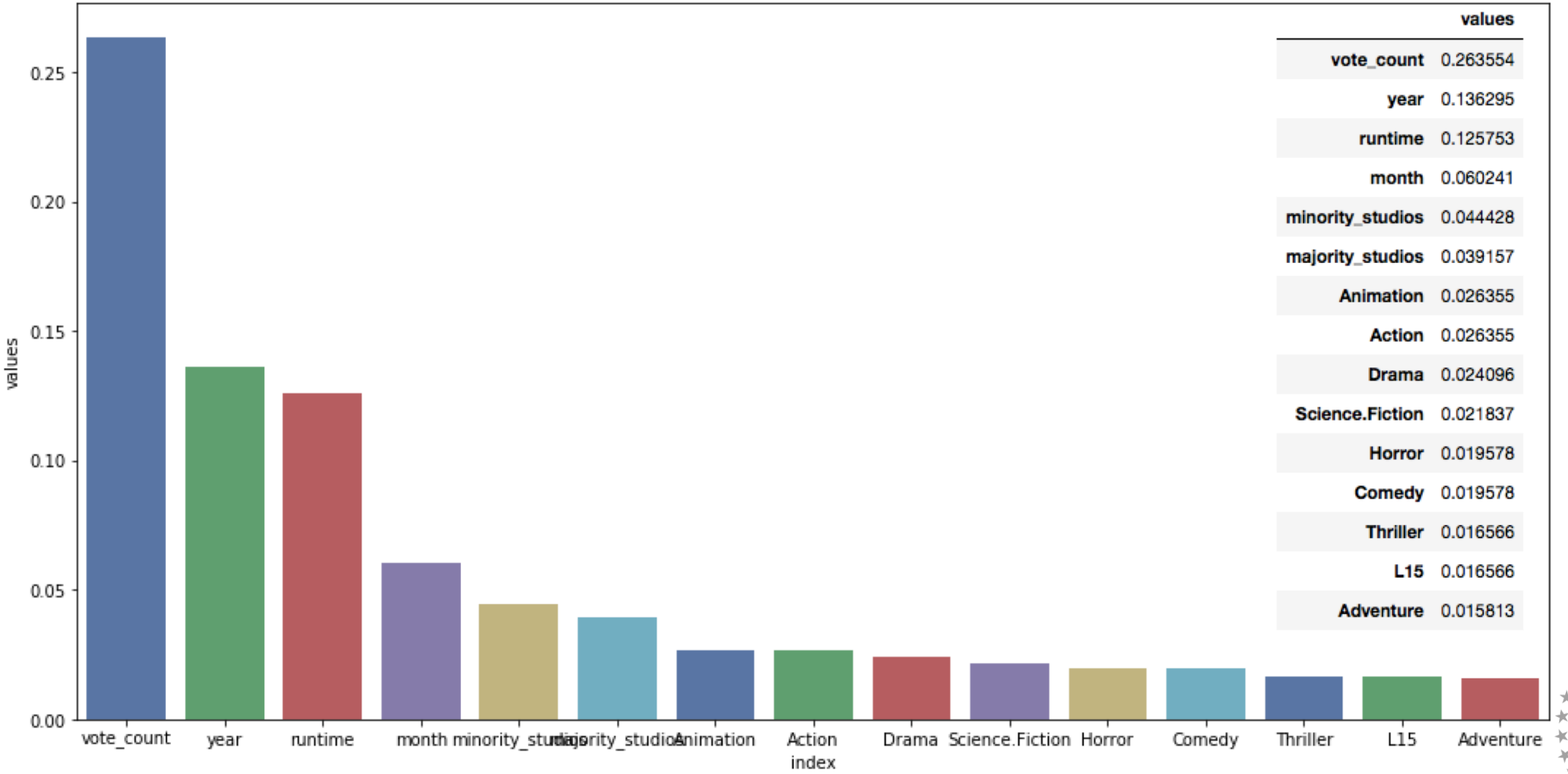
- Model selection:
  - Max_depth = 3
  - N_estimators = 200





Nonlinear Model – XGBoost

Feature Importance



	values
vote_count	0.263554
year	0.136295
runtime	0.125753
month	0.060241
minority_studios	0.044428
majority_studios	0.039157
Animation	0.026355
Action	0.026355
Drama	0.024096
Science.Fiction	0.021837
Horror	0.019578
Comedy	0.019578
Thriller	0.016566
L15	0.016566
Adventure	0.015813

Neural Network

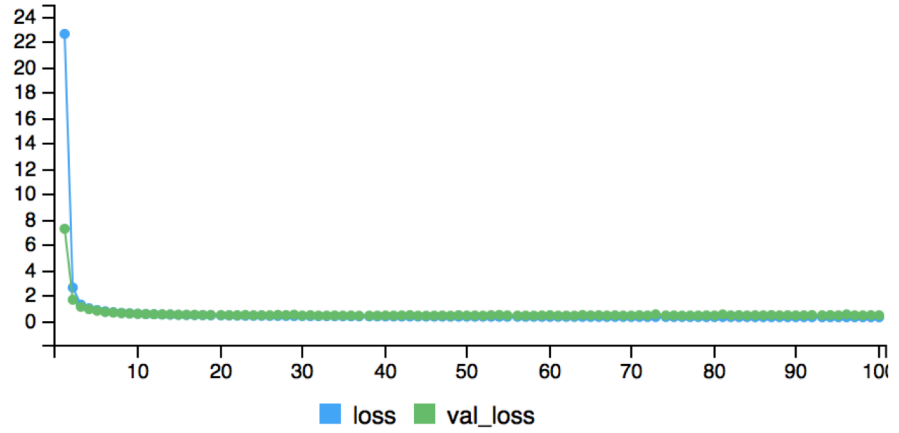
- Model specification
  - Two hidden dense layers followed by dropout layers
  - 16 neurons each

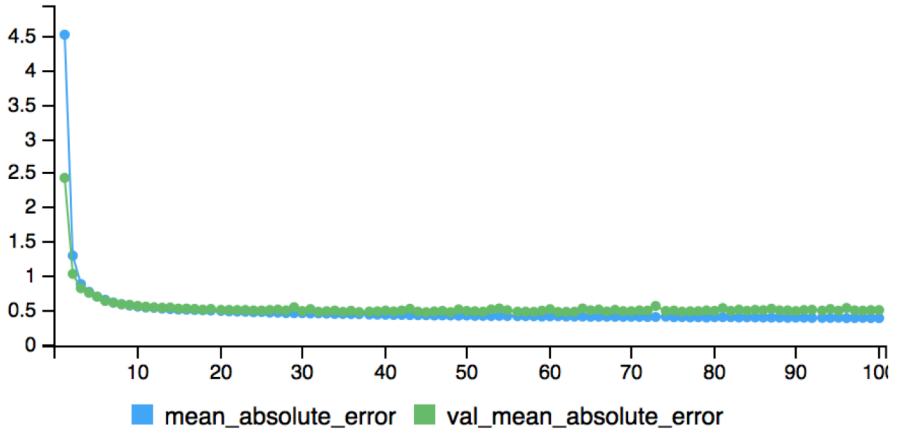
Layer (type)	Output Shape	Param #
dense_58 (Dense)	(None, 16)	672
dropout_34 (Dropout)	(None, 16)	0
dense_59 (Dense)	(None, 16)	272
dropout_35 (Dropout)	(None, 16)	0
dense_60 (Dense)	(None, 1)	17

Total params: 961
Trainable params: 961
Non-trainable params: 0

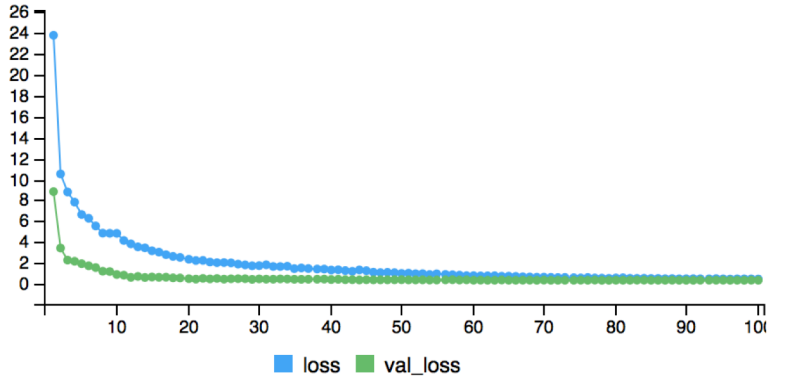
Neural Network

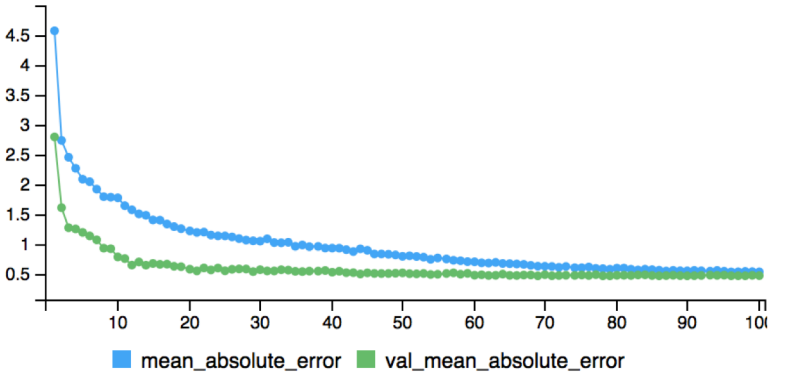
- Training without regularization
- Overfitting



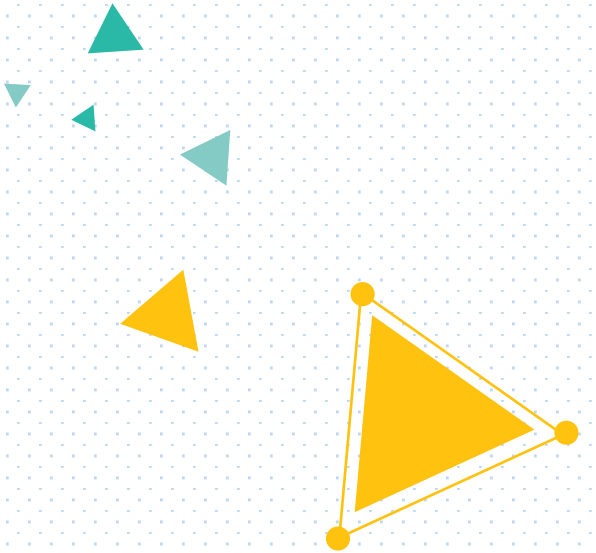


- Training with regularization (dropout)
- Small improvement
- Overfitting persists
- Test error similar to that of slm





05 Part Five
Conclusion



Model Comparison

- **Test Error (MAPE)**

Models	**Test Error (in %)**
Weighted Least Square (AIC)	8.37%
Ridge	8.38%
Weighted Least Square (LASSO)	13.43%
Tree Model	9.60%
Random Forest	8.21%
Xgboost	7.83%
Neural Network	8.21%

Conclusion

- Xgboost is the best model based on MAPE measurement
  - It can learn complex non-linear decision boundaries via boosting.
  - It is optimized for sparse input.
  - It has an additional custom regularization term in the objective function, which helps prevent overfitting.
- Further Study
  - Interpret models back to the real world
  - Get a different testing data
    - Predict upcoming movies' vote average, find prediction accuracies
      - Movies released in November

Thank You!

Q & A

Thank you

Add your text in here