



# **Data Mining II Project:**

*Analyzing Data Insights from the IMDb Platform*

## **Authors:**

Bruno Barbieri, Chiara Ferrara, Ankit Kumar Bhagat

*Academic Year 2024/2025*

# Contents

<b>1</b>	<b>Data Understanding and Preparation</b>	<b>2</b>
1.1	Feature Engineering . . . . .	2
<b>2</b>	<b>Outliers</b>	<b>4</b>
2.1	LOF . . . . .	4
2.2	Isolation Forest . . . . .	4
2.3	ABOD . . . . .	4
<b>3</b>	<b>Imbalanced Learning</b>	<b>4</b>
3.1	Undersampling . . . . .	4
3.2	Oversampling . . . . .	4
3.2.1	SMOTE . . . . .	4
<b>4</b>	<b>Advanced Classification</b>	<b>4</b>
4.1	Support Vector Machines . . . . .	4
4.2	Ensemble methods . . . . .	5
4.3	Neural Networks . . . . .	8
4.4	Model Comparison . . . . .	8
<b>5</b>	<b>Advanced Regression</b>	<b>8</b>

# Introduction

The goal of this report is to illustrate the characteristics of the given IMDb dataset, and to show key insights that can be obtained from it. In particular, the focus of many of the observations is based on aspects that could be useful for a product's creation and marketing, in order to optimize the chances of success of a product in the market.

## 1 Data Understanding and Preparation

**TODO: distrib graphs** The dataset contains 32 columns and 149531 rows of titles of different types. For each title, the dataset contains information regarding many different aspects. Table 1 lists the initial categorical features.

Feature	Description
<code>originalTitle</code>	Original title, in the original language (?)
<code>isAdult</code>	Whether or not the title is for adult
<code>canHaveEpisodes</code>	Whether the title can have episodes
<code>isRatable</code>	Whether the title can be rated by users
<code>titleType</code>	Type of the title (e.g., movie, tvseries)
<code>countryOfOrigin</code>	Countries where the title was primarily produced
<code>genres</code>	Genres associated with the title
<code>regions</code>	Regions for this version of the title
<code>soundMixes</code>	Technical specification of sound mixes
<code>worstRating</code> (ordinal)	Worst title rating
<code>bestRating</code> (ordinal)	Best title rating
<code>rating</code> (ordinal)	IMDB title rating class

Table 1: Initial categorical features of the IMDb dataset

Of the initial categorical attributes, the following were removed:

- `originalTitle`, as it did not provide particularly useful information;
- `isAdult`, as it was almost completely correlated with the *Adult* genre, so a logical OR operation was performed, and the genre only was kept; **Interesting to note the fact that in our representation, being that the genres are represented through freq enc, we don't have the info**
- `canHaveEpisodes`, as it was completely correlated with the title type being *tvSeries* or *tvMiniSeries*;
- `isRatable`, as it was always true;
- `soundMixes`, as it required some domain knowledge to be understood, as well as having issues with the values it contained.
- `worstRating` and `bestRating`, as they were always 1 and 10, respectively;
- `rating`, as it was obtainable from the `averageRating` continuous attribute, through a simple discretization.

Table 2 lists the initial numerical features.

Of the initial numerical attributes, the following were removed:

- `endYear`, was removed due to it not being meaningful for non-Series titles, and having around 50% of missing values for *tvSeries* and *tvMiniSeries*;
- `numVotes`, as it had a very high correlation with `ratingCount`;

### 1.1 Feature Engineering

- `totalImages`, `totalVideos` and `quotesTotal`, were merged through a simple sum operation into a single feature (`totalMedia`) because of their similar semantic meaning, as well as heavy right skewness;
- `awardWins` and `awardNominations`, were merged with the same procedure as above into `totalNominations`, since they represented the same concept;

Feature	Description
startYear	Release year of the title (series start year for TV)
endYear	TV Series end year
runtimeMinutes	Primary runtime of the title, in minutes
numVotes	Number of votes the title has received
numRegions	Number of regions for this version of the title
totalImages	Total number of images for the title
totalVideos	Total number of videos for the title
totalCredits	Total number of credits for the title
criticReviewsTotal	Total number of critic reviews
awardWins	Number of awards the title won
awardNominations	Number of award nominations excluding wins
ratingCount	Total number of user ratings submitted
userReviewsTotal	Total number of user reviews
castNumber	Total number of cast individuals
CompaniesNumber	Total number of companies that worked for the title
averageRating	Weighted average of all user ratings
externalLinks	Total number of external links on IMDb page
quotesTotal	Total number of quotes on IMDb page
writerCredits	Total number of writer credits
directorCredits	Total number of director credits

Table 2: Initial numerical features of the IMDb dataset

- `userReviewsTotal` and `criticReviewsTotal`, were merged with the same procedure as above into `reviewsTotal`, since they represented the same concept;
- `regions` and `countryOfOrigin` were merged through a simple union operation. The resulting feature was then represented through frequency encoding on the entire list, as well as counts of the number of countries from each continent. This resulted in eight new features (six continents, one for unknown country codes, and the last for the frequency encoding);
- `genre` attribute, it was observed that each record contained up to three genres, listed in alphabetical order—indicating that the order did not convey any semantic information about the title. To represent this information, three separate features were created, each corresponding to one of the genres. These features were encoded using frequency encoding, sorted in descending order of frequency across the dataset. A value of 0 was used to indicate missing genres—either when no genres were present or to fill the remaining slots when fewer than three were available;
- `runtimeMinutes` had a very high number of missing values (add %). Since the feature had high relevance in the domain, it was imputed with random sampling from a interquartile range, separately for each title type.

eventually, add description of the imputation procedure for tasks which involved `titleType`

`castNumber`, `writerCredits`, `directorCredits` with and without `totalCredits`; `deltacredits`

## 2 Outliers

### 2.1 LOF

### 2.2 Isolation Forest

### 2.3 ABOD

## 3 Imbalanced Learning

### 3.1 Undersampling

### 3.2 Oversampling

#### 3.2.1 SMOTE

## 4 Advanced Classification

In this section, classification results are showcased for two target variables: `averageRating` (properly binned into 5 classes), and `titleType` (with 6 classes).

We then applied multiple classification models using the data as preprocessed previously (see Section ??). The first target variable is `titleType`, which includes six categories: *movie*, *short*, *tvEpisode*, *tvSeries*, *tvSpecial*, and *video*. The classes are not equally distributed, with *tvSpecial* and *video* being significantly under-represented compared to the others. Entries labeled as *videoGame* were removed from both the training and testing sets, as they were too few to be useful for classification. The remaining categories were merged into broader groups according to the following mapping: *movie* and *tvMovie* were grouped as *movie*, *short* and *tvShort* were grouped as *short*, *tvSeries* and *tvMiniSeries* were grouped as *tvSeries*, while *tvEpisode*, *tvSpecial* and *video* were left unchanged. All feature columns were standardized using a *StandardScaler*. In addition, the variable `canHaveEpisodes` was removed prior to training, since it provides direct information about the target `titleType` and could therefore introduce data leakage.

### 4.1 Support Vector Machines

We applied Support Vector Machines (SVM) to the `titleType` classification task. Both linear and non-linear kernels were explored in order to evaluate how decision boundary complexity influences predictive performance. The first experiment used a Linear SVM trained on the full dataset. A grid search with five-fold cross validation was carried out on the parameters  $C \in \{0.01, 0.1, 1, 10, 100\}$  and  $max\_iter \in \{1000, 5000, 10000\}$ . The optimal configuration, with  $C = 100$  and  $max\_iter = 1000$ , achieved a test accuracy of 0.81. While precision and recall were high for majority classes (*movie*, *short*, *tvEpisode*), the classifier failed on *tvSeries*, *tvSpecial*, and *video*, indicating that a linear decision boundary is insufficient for this problem.

Non-linear kernels were then evaluated. A grid search was first performed on a stratified 10% subset of the training set to efficiently explore a wide range of hyperparameters for each kernel, since a full search on the complete dataset would have been computationally prohibitive. For the RBF kernel,  $C$  was varied from 0.01 to 1000 and  $\gamma$  between `scale` and `auto`. The polynomial kernel was tested with  $C$  from 0.01 to 100, degree 2–4,  $\gamma$  as `scale` or `auto`, and `coef0` 0 or 1. The sigmoid kernel was explored over  $C$  0.01–100,  $\gamma$  `scale/auto`, and `coef0` 0 or 1. Remember to fix C!

The best configuration for each kernel, reported in Table 3, was then retrained on the full dataset and evaluated on the test set. Both RBF and polynomial kernels reached approximately 0.90 test accuracy, substantially outperforming the linear baseline and sigmoid. The RBF kernel was selected as the reference non-linear model due to slightly more stable results and improved recall on the under-represented classes.

ROC curves were used to evaluate class separability showing excellent separation for majority classes, although minority categories remained problematic.

I will change the text and explain the figures better.

To address class imbalance, the RBF kernel was retrained with `class_weight=balanced`, which penalizes misclassification of under-represented classes. This model reached a slightly lower overall accuracy of 0.84, but recall for *tvSpecial* and *video* improved, providing a more equitable classification across categories. Confusion matrices (Figure 2) illustrate that *tvSpecial* and *video* ... Analysis of the support vectors confirmed this effect. In the unbalanced RBF, nearly all points of minority classes became support vectors, while in the balanced model the total number of support vectors increased and was more evenly distributed across classes, indicating a more complex but fairer decision function.

Table 3 summarizes the main results, including the parameters used for each kernel and the corresponding test performance.

Table 3: Comparison of SVM models on the IMDb classification task.

Model	Best Params (main)	Test Accuracy	Macro F1-score
Linear SVM	$C = 100$ , $max\_iter = 1000$	0.81	0.45
RBF kernel	$C = 10$ , $\gamma = \text{scale}$	0.90	0.64
Polynomial kernel	$C = 10$ , $\text{degree}=3$ , $\gamma = \text{auto}$	0.90	0.64
Sigmoid kernel	$C = 0.1$ , $\gamma = \text{auto}$	0.65	0.36
RBF (balanced)	$C = 10$ , $\gamma = \text{scale}$ , balanced	0.84	0.65

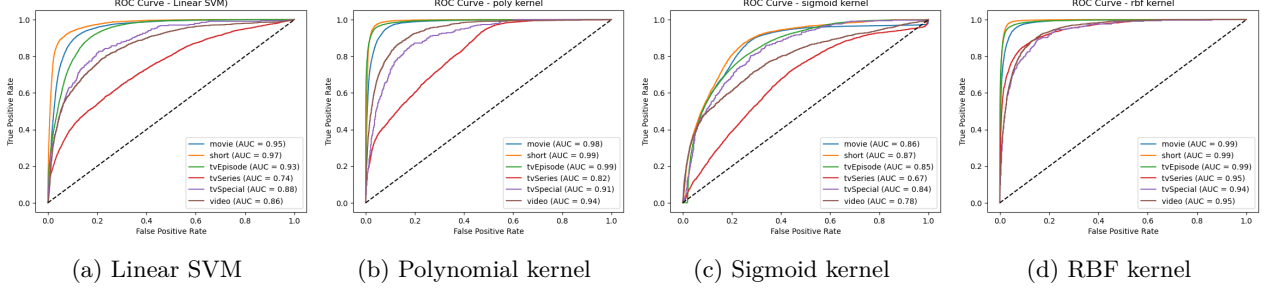


Figure 1: ...

We also applied SVM to the **averageRating** classification task. The same kernels and hyperparameter search strategies were used as for **titleType**.

We then applied the same methodology to the **rating** classification task.

A Linear SVM was first tested using the same hyperparameter grid as before. The best configuration ( $C = 100$ ,  $max\_iter = 1000$ ) achieved only 0.37 accuracy and a macro F1-score of 0.28, confirming (perchè confirming?) that a linear decision boundary is inadequate for this task.

We therefore moved to non-linear kernels. As for the previous experiment, a grid search on a stratified 10% subset of the training set was conducted. The optimal configurations were  $C = 10$ ,  $\gamma = \text{auto}$  for the RBF kernel,  $C = 10$ ,  $\text{degree}=2$ ,  $\gamma = \text{scale}$ ,  $\text{coef0} = 1$  for the polynomial kernel, and  $C = 0.1$ ,  $\gamma = \text{auto}$ ,  $\text{coef0} = 0$  for the sigmoid kernel. These models were then retrained on the full dataset.

Results were generally lower than in the **titleType** task, with the RBF and polynomial kernels both reaching around 0.42 macro F1, while sigmoid performed substantially worse (macro F1  $\approx 0.36$ ). Confusion matrices showed that the models correctly identified the most populated bins, but failed on the tails ( $[1,6)$  and  $[9,10)$ ). Finally, to mitigate imbalance, the RBF kernel was retrained with  $\text{class\_weight} = \text{balanced}$ . This increased recall on minority classes, at the cost of a slight drop in overall accuracy, producing a fairer but more complex decision function. However, even the balanced model struggled to capture the extremes of the rating distribution.

## 4.2 Ensemble methods

Boosting and Random Forest models were trained on the classification, while being optimized via Stratified Randomized Search with 5-fold cross-validation over a predefined hyperparameter space.

For the **averageRating** classification task, the best hyperparameters for the Random Forest model were: `n_estimators=42, max_depth=19, min_samples_split=4, min_samples_leaf=3, max_features=0.74, criterion='gini', class_weight=None`.

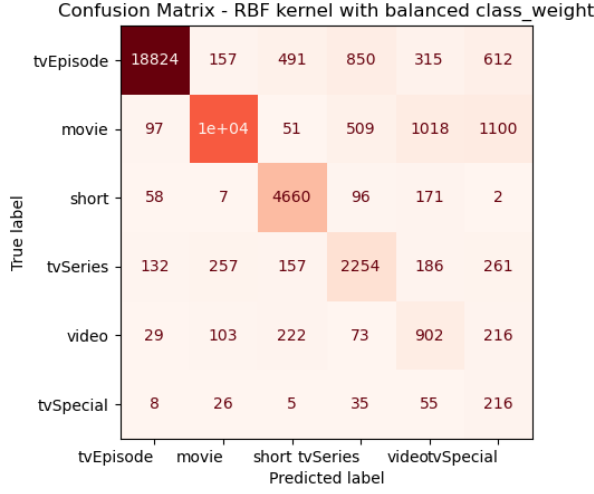
For the AdaBoost model, the best hyperparameters were: `n_estimators=56, learning_rate=0.47, estimator__max_depth=estimator__min_samples_split=16, estimator__min_samples_leaf=16`.

The table below summarizes the classification report for both models.

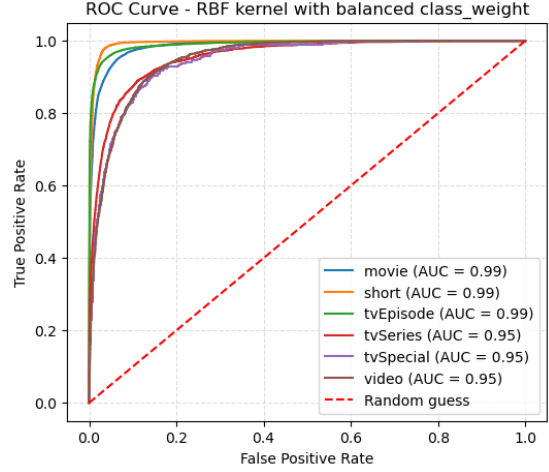
Model	Accuracy	Macro Precision	Macro Recall	Macro F1-score
Random Forest	0.49	0.51	0.41	0.42
AdaBoost	0.39	0.40	0.33	0.34

Table 4: Performances of the models on the **averageRating** classification task.

The Random Forest model outperforms AdaBoost in all metrics. The biggest difference is found in the recall. Figure 5a and Figure 5b show the confusion matrices for the models.

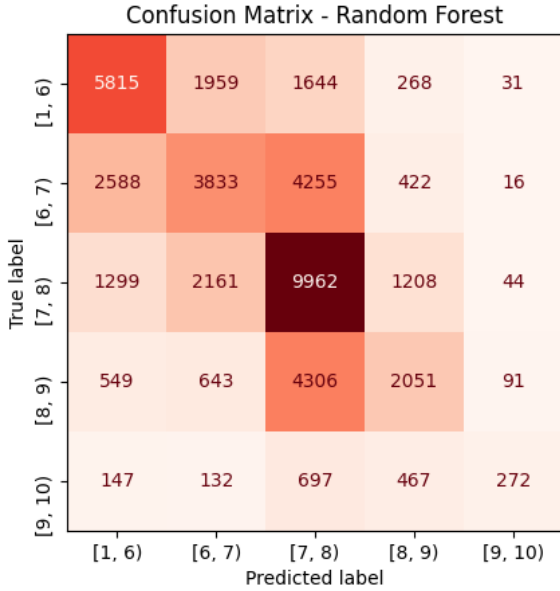


(a) Confusion Matrix RBF balanced

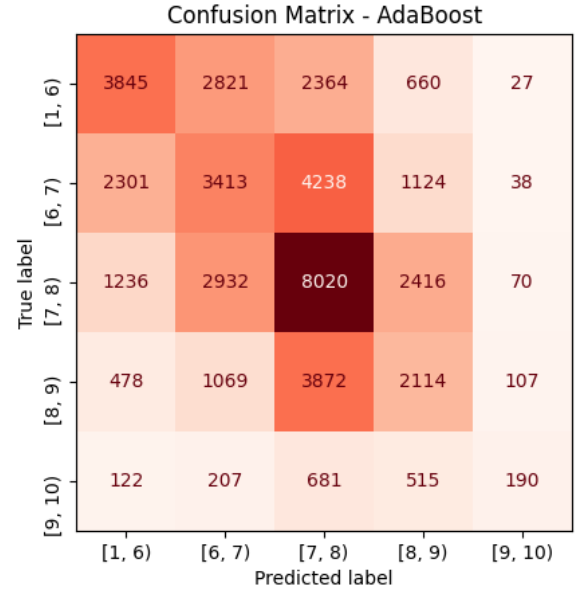


(b) ROC RBF balanced

Figure 2: Confusion Matrix and ROC Curve for the SVM (kernel rbf and balanced class weight) on the titleType classification task.



(a) Confusion Matrix - Random Forest



(b) Confusion Matrix - AdaBoost

Figure 3: Confusion matrices for the ensemble models on the averageRating classification task.

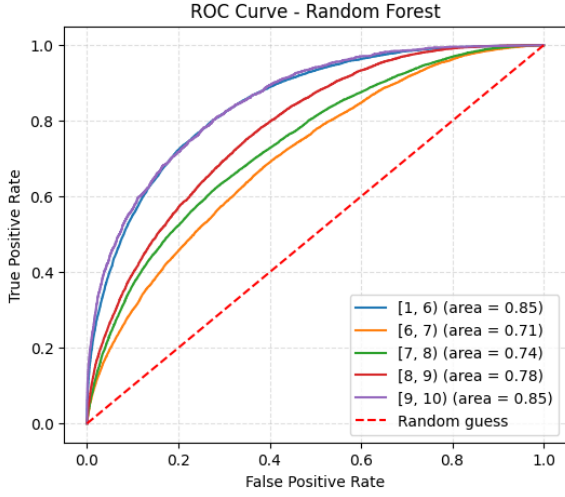
From these, it can be seen why the recall is much lower for AdaBoost, with regards to Random Forest: the former tends to classify less aggressively as the most represented class. It's also worth noting that Random Forest tends to assign most of the misclassifications to the adjacent classes, while AdaBoost spreads them more evenly across all classes.

Figures 6a and 6b show the ROC curves for the two models. From these representations, it can be seen that AdaBoost has poorer performances in all classes, but especially struggles with the under-represented ones, which lead to the biggest difference in Area Under The Curve (AUC).

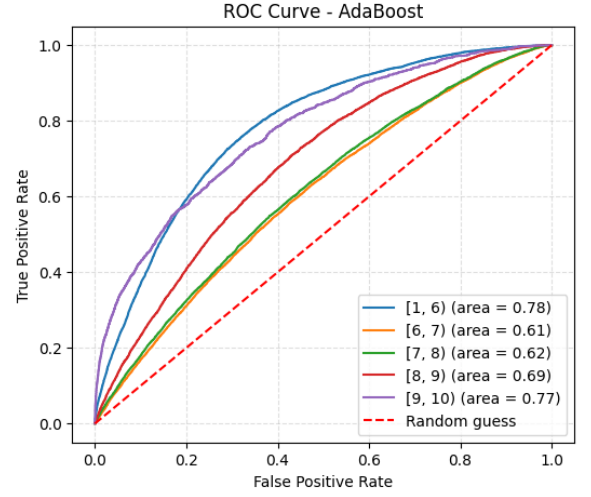
On the titleType classification task, the best hyperparameters obtained for the Random Forest model were: `n_estimators=42`, `max_depth=19`, `min_samples_split=4`, `min_samples_leaf=3`, `max_features=0.74`, `criterion='gini'`, `class_weight=None`.

For the AdaBoost model, the best hyperparameters were: `n_estimators=56`, `learning_rate=0.47`, `estimator__max_depth=16`, `estimator__min_samples_split=16`, `estimator__min_samples_leaf=16`.

The table below summarizes the classification report for both models.



(a) ROC Curve - Random Forest



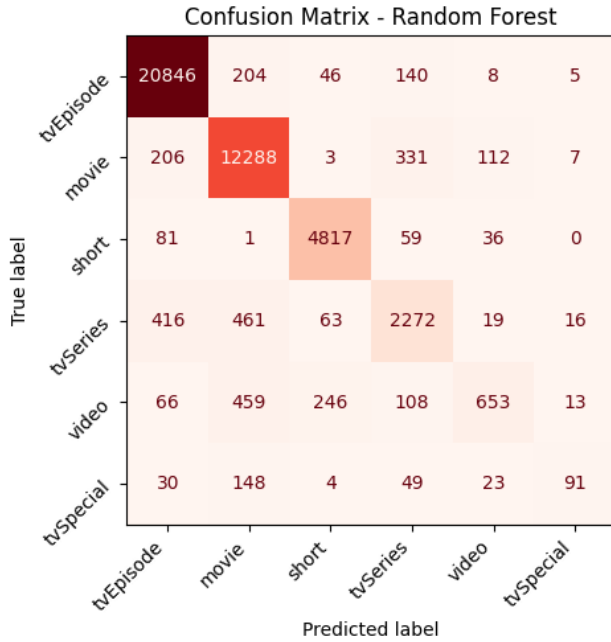
(b) ROC Curve - AdaBoost

Figure 4: ROC curves for the ensemble models on the `averageRating` classification task.

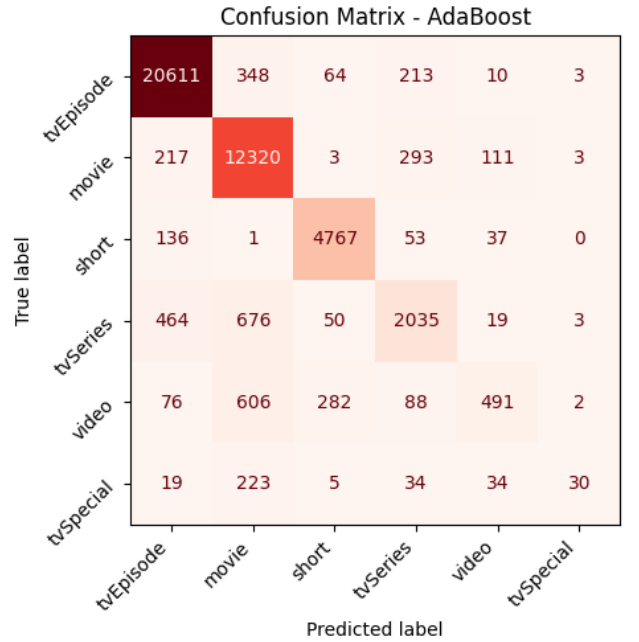
Model	Accuracy	Macro Precision	Macro Recall	Macro F1-score
Random Forest	0.92	0.84	0.71	0.75
AdaBoost	0.90	0.82	0.65	0.68

Table 5: Performances of the models on the `titleType` classification task.

Figure 5a and Figure 5b show the confusion matrices for the models.



(a) Confusion Matrix - Random Forest



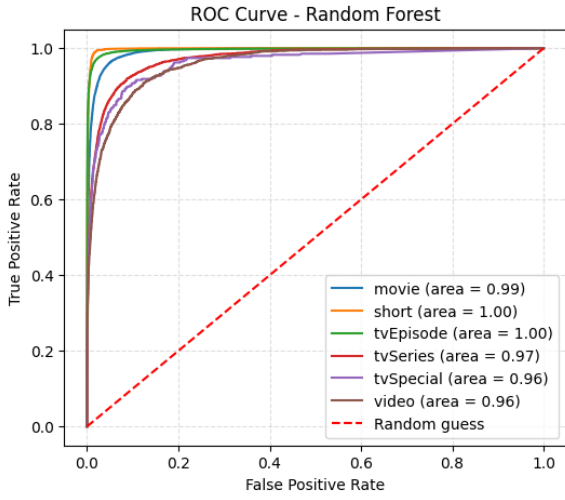
(b) Confusion Matrix - AdaBoost

Figure 5: Confusion matrices for the ensemble models on the `titleType` classification task.

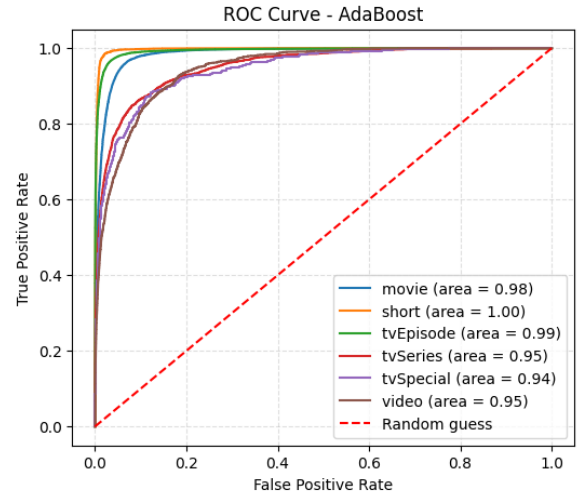
Both models perform well on the first four classes, while struggling with `/textttvideo` and `/texttttvSpecial`, which are the most under-represented classes. In general, the two models show similar performances, with Random Forest generally outperforming AdaBoost by a slight margin. Contrary to the results, the models base their decisions on different feature importances: while Random Forest assigns over half of the importance to `runtimeMinutes`, AdaBoost spreads the importance evenly across multiple features, with the top being `runtimeMinutes` with around 15%.

The ROC curves for the two models are shown in Figure 6a and Figure 6b.



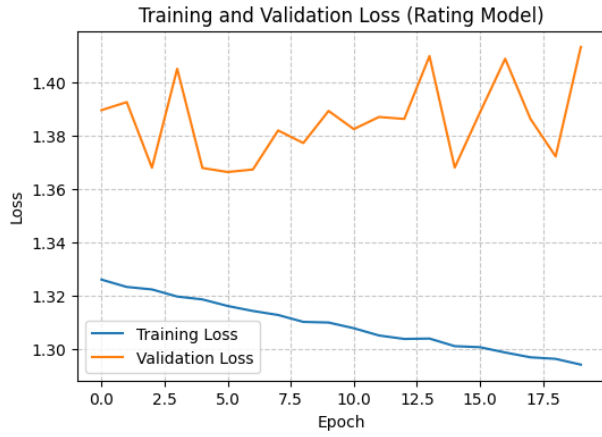


(a) ROC Curve - Random Forest

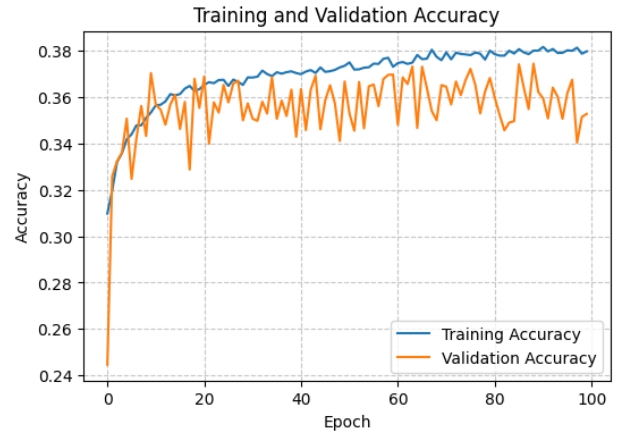


(b) ROC Curve - AdaBoost

Figure 6: ROC curves for the ensemble models on the `titleType` classification task.



(a) Loss - Neural Network



(b) Accuracy - Neural Network

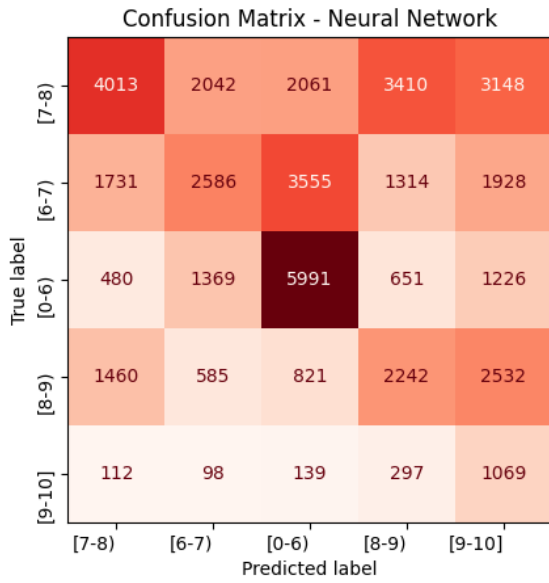
Figure 7: Training and validation loss and accuracy for the neural network on the `averageRating` classification task.

Again, similar performances are observed. The biggest difference seems to be found in the under-represented classes, which seem to have a bigger difference in Area Under The Curve (AUC).

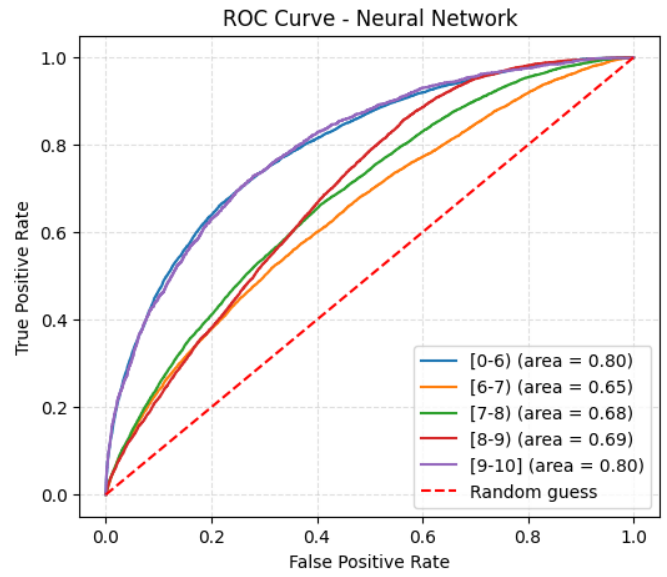
### 4.3 Neural Networks

### 4.4 Model Comparison

## 5 Advanced Regression

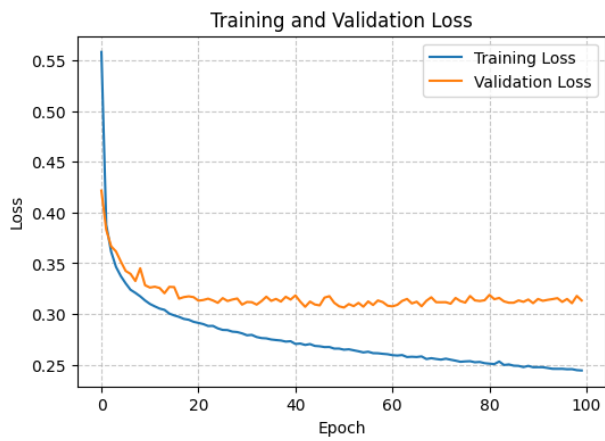


(a) Confusion Matrix - Neural Network

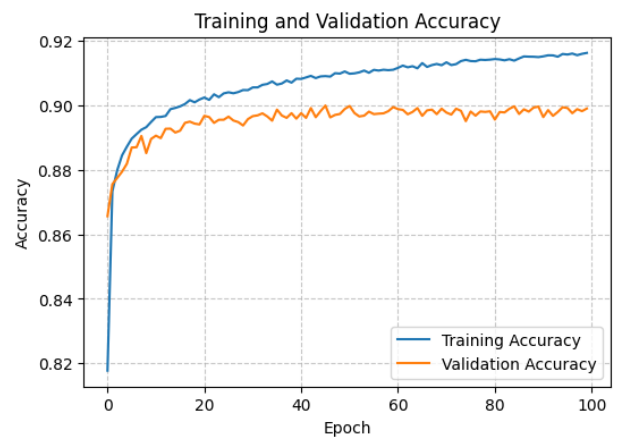


(b) ROC Curve - Neural Network

Figure 8: Confusion Matrix and ROC Curve for the Neural Network on the `averageRating` classification task.

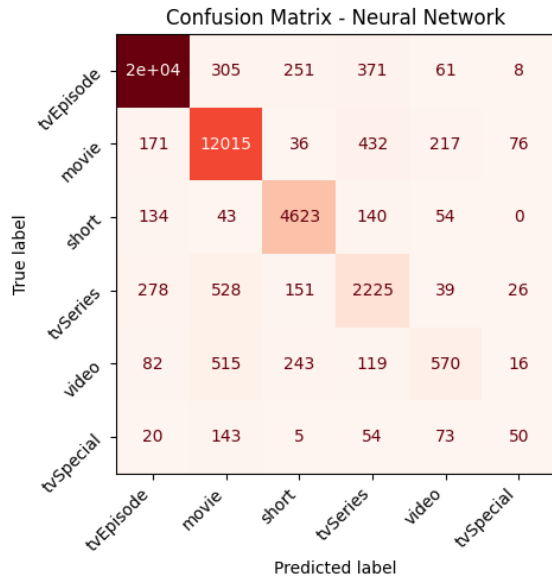


(a) Loss - Neural Network

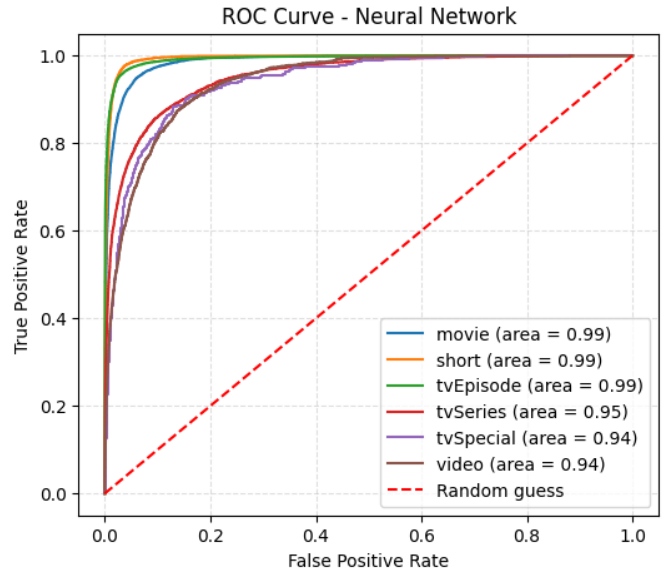


(b) Accuracy - Neural Network

Figure 9: Training and validation loss and accuracy for the neural network on the `titleType` classification task.



(a) Confusion Matrix - Neural Network



(b) ROC Curve - Neural Network

Figure 10: Confusion Matrix and ROC Curve for the Neural Network on the `titleType` classification task.