Final Report

DSE6211

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**Executive Summary**

Hotel booking cancellation rates in the United States have surged 33% between 2019 and 2022, with a staggering 20% of all reservations canceled in 2022 alone (SHR Group, 2023). This escalating trend poses significant challenges for the hospitality industry, prompting the urgent need for effective predictive models to anticipate and mitigate cancellations. Confronted with mounting cancellation rates, ABC Hotels aimed to proactively address this issue by leveraging predictive analytics to identify and intervene with potentially cancellable bookings. The dataset provided by ABC Hotels contained 35,000 observations across 17 variables, offering valuable insights into customer behavior and booking dynamics. Through rigorous preprocessing steps, the dataset was prepared for model development.

First, baseline models such as Logistic Regression, K-Nearest Neighbors (KNN), and Classification Trees were implemented to establish performance benchmarks for the neural network models. The neural network models, designed to capture complex nonlinear relationships, consist of densely connected layers. Three variations of the neural network were explored: a simple model, a complex model with regularization techniques, and a PCA-enhanced model. Evaluation metrics, including accuracy, ROC curve analysis, and calibration curves, were used to assess model performance. The complex neural network model emerged as the top performer, achieving an accuracy of 84.10% and demonstrating strong discriminatory power and calibration.

Based on the comprehensive analysis, it is recommended that ABC Hotels deploy the complex neural network model for predicting hotel booking cancellations. With its high accuracy and robust predictive capabilities, this model can assist hotel management in proactively managing room inventory and optimizing resource allocation. Integrating predictive insights into the booking management system enables targeted marketing strategies, personalized customer retention initiatives, and dynamic pricing schemes to mitigate cancellations and maximize revenue generation. Additionally, ongoing monitoring and performance evaluation are essential to ensure the model’s continued effectiveness. Regular updates based on evolving business requirements and newly available data can enhance the model’s adaptability and responsiveness to changing booking patterns and market trends. In conclusion, adopting the complex neural network model represents a strategic investment for ABC Hotels, offering a powerful tool for enhancing operational efficiency, optimizing revenue management, and delivering superior customer experiences in the hospitality sector.

**Approach and Data**

The dataset provided by ABC Hotels comprises of 35,000 observations across 17 variables, encompassing a comprehensive repository of insights into customer behavior and booking dynamics. Among the key features included in the dataset are demographic information (e.g. number of children and adults), reservation details (e.g. meal plan, room type, price), booking history (e.g. lead time, previous cancellations), and special requests. Notably, the dataset exhibits a cancellation rate of 32.8%, with nearly 12,000 bookings recorded as cancellations. The only column not included in the model is the booking ID column, as the variable contains randomly assigned booking IDs with no practical or analytical value.

*Data Preprocessing Steps:*

1. Handling missing values: No missing values were identified in the dataset.
2. Removing unnecessary features: Booking ID was removed from the dataset, as it provides no value to the analysis.
3. Handling date-based variables: The booking date was calculated based on the arrival date and lead time. Then, the day of the week, day of the month, and month were extracted from the booking date and arrival date for more applicable use of the models.
4. Test-train split: The dataset was partitioned into training and testing sets using a predefined ratio of 75:25 to facilitate model training and evaluation while ensuring adequate generalization performance.
5. Feature encoding: Categorical variables were encoded into numerical representations using one-hot encoding methods, enabling their utilization in the model training process.
6. Normalization and scaling: Features were standardized to bring them within a comparable range and mitigate the influence of feature magnitudes on model training.
7. Conversion to tensors: The training and testing datasets were converted into arrays to make them compatible with Keras and TensorFlow machine learning models.

The processed dataset, characterized by standardized features, encoded categorical variables, and partitioned into training and testing subsets, is the foundation for subsequent model development and evaluation. By adhering to rigorous preprocessing standards, potential biases and confounding factors are mitigated, thereby enhancing the reliability and robustness of the predictive model.

***Baseline Models***

Several traditional machine learning algorithms were implemented as baseline models to establish a benchmark for evaluating the performance of the neural network model. These baseline models provide a point of comparison against which the efficacy of the neural network can be assessed. The following subsections detail the key characteristics and implementation of each baseline model.

1. *Logistic Regression*

Logistic Regression is a fundamental binary classification technique that models the probability of a binary outcome (in this case, booking cancellation) based on one or more independent variables. By fitting a logistic function to the input features, Logistic Regression provides a probabilistic interpretation of the likelihood of a booking being canceled. Despite its simplicity, Logistic Regression effectively captures linear relationships between features and the target variable, making it a suitable baseline model for comparison.

1. *K-Nearest Neighbors (KNN)*

KNN is a non-parametric algorithm that classifies data points based on the majority class among their nearest neighbors in feature space. In predicting booking cancellations, KNN evaluates the similarity between new bookings and historical data points to assign a class label. While KNN is intuitive and easy to implement, its performance may be sensitive to the choice of distance metric and the number of neighbors considered. It is imperative to tune these hyperparameters for optimal performance.

1. *Classification Trees*

Classification Trees, or Decision Trees, recursively partition the feature space into regions based on feature values, with each partition corresponding to a specific class label. The model constructs a hierarchical tree structure that facilitates classification by splitting the dataset along the feature dimensions that best separate the classes. Random Forests, a variant of Classification Trees, improve individual trees' performance by aggregating predictions from multiple trees trained on random subsets of the data. While Classification Trees offer interpretability and can capture complex decision boundaries, Random Forests mitigate overfitting and enhance generalization performance by combining the predictions of diverse trees.

Each baseline model was evaluated using standard classification metrics such as accuracy to assess their discriminatory power and generalization performance. By comparing the performance of these baseline models against more sophisticated approaches, insights into the relative efficacy of different modeling techniques can be gained, guiding the selection of the most suitable algorithm for predicting booking cancellations at ABC Hotels.

***Neural Network Models***

The neural network models were designed to capture complex nonlinear relationships inherent in the dataset while avoiding overfitting and ensuring computational efficiency. While each model contains unique nuances, the architectural basis of all three models consists of densely connected layers followed by an output layer with a single unit and a sigmoid activation function to predict the probability of booking cancellation.

1. *Layers and Units* 
   1. Simple Neural Network Model: The architecture of the original, simpler, dense neural network model was designed with a balance between model complexity and computational resources in mind. It consists of three densely connected layers. The first hidden layer contains 40 units, allowing the network to extract initial high-level features from the input data. Subsequently, the second hidden layer, comprised of 20 units, further refines these features to facilitate learning more intricate patterns. Finally, the output layer with a single unit computes the probability of booking cancellation. This hierarchical feature extraction architecture enables the model to learn increasingly complex representations as it progresses through the layers.
   2. Complex Neural Network Model: For the second, more complex neural network model, the architecture was designed to increase the model’s capacity to capture intricate patterns while still considering computational resources. This model consists of four densely connected layers. The first hidden layer contains 80 units, allowing for the extraction of initial high-level features from the input data. Subsequently, a dropout layer with a dropout rate of 0.3 was introduced. Dropout is a regularization technique that works to prevent overfitting by randomly dropping out a fraction of units during training, forcing the network to learn more robust features. The following hidden layer, comprising of 40 units, further refines the features extracted in the previous layer. Another dropout layer with a rate of 0.2 is applied after this layer to enhance the model’s generalization capability. The third hidden layer, with 20 units, continues facilitating the learning of complex representations. Lastly, the output layer with a single unit computes the probability of booking cancellation. This architecture allows the model to progressively learn intricate patterns while balancing complexity and computational efficiency throughout the network layers.
   3. PCA Enhanced Neural Network Model: In this neural network model, principal component analysis (PCA) is utilized to reduce the dimensionality of the input features before feeding them into the network. PCA condenses the original feature space into a lower-dimensional subspace while preserving the most important information. Initially, the dataset underwent PCA, and the summary statistics revealed the importance of each respective principal component (PC). Then, the number of principal components was reduced, and these PCs were used as the input features for the neural network model. The neural network architecture comprises of four densely connected layers. The first three layers contain 15 units, followed by a final layer of a single unit for classification purposes. This structure enables the model to extract refined representations of the input data, benefiting from the dimensionality reduction achieved by PCA. This condensation of the feature space allows the neural network to efficiently learn complex patterns while mitigating the risk of overfitting.
2. *Activation Functions*

All three models utilize an output layer with a sigmoid activation function, which simplifies the output to a range between 0 and 1, representing the probability of booking cancellation. Rectified Linear Unit (ReLU) activation functions were employed in the hidden layers of both the simple neural network model and the PCA-enhanced neural network model to introduce nonlinearities and enable the model to approximate complex functions effectively. ReLU activation has been widely adopted in deep learning due to its simplicity and computational efficiency. The more complex second model utilizes the hyperbolic tangent (tanh) activation function in its hidden layers. Tanh was chosen due to its ability to introduce non-linearities into the network, allowing the model to capture complex relationships within the data. By leveraging tanh activation, the network can learn intricate patterns and potentially mitigate issues such as vanishing gradients, enhancing its ability to model complex data distributions.

1. *Loss Function*

Binary cross-entropy loss was chosen as the loss function due to its stability for binary classification tasks. By comparing the predicted probabilities with the actual class labels (0 or 1), binary cross-entropy loss quantifies the disparity between the predicted and true distributions, penalizing deviations from the truth. Minimizing this loss encourages the model to output probabilities that align closely with the observed outcomes, thereby optimizing predictive performance.

1. *Optimization Algorithm*

The RMSprop optimizer was selected for its adaptive learning rate mechanism, which adjusts the step size for each parameter based on the magnitude of recent gradients. This adaptive behavior enables RMSprop to navigate complex, high-dimensional parameters more efficiently, enhancing model training. Additionally, by dynamically scaling the learning rates for individual parameters, RMSprop promotes stable and consistent updates throughout the optimization process.

1. *Epochs and Validation Split*

In the neural network models described above, different configurations of epochs were used, but all models utilized identical batch sizes and validation splits. A batch size of 512 and a validation split of 0.33 were used to evaluate the model’s performance based on a holdout subset of the training data. A validation split of 33% ensures that the model’s performance is assessed on diverse data points not seen during training, thereby providing a reliable estimate of its generalization performance. For the first model, which employed a simple architecture, the choice of 10 epochs was decided based on the training and validation curve to balance computational efficiency with sufficient training time to allow the model to converge to a stable solution. The second model, which featured a more complex architecture, underwent training for 100 epochs. However, early stopping was implemented based on validation loss to prevent overfitting. This mechanism halted training when the validation loss did not decrease for three consecutive epochs, leading to a final number of 87 epochs. Finally, in the third model, which incorporated PCA, each model was trained for 10 epochs with a batch size of 512 and a validation split of 0.33, allowing for a systematic exploration of hyperparameters while maintaining computational efficiency. Overall, every configuration was tailored to balance model complexity, computational resources, and effective performance evaluation.

**Detailed Findings and Evaluation**

The performance of the neural network models, along with other baseline models, was assessed using various metrics, including accuracy, ROC curve analysis, and calibration curves.

1. *Accuracy*

Among the neural network models, the simple neural network achieved an accuracy of 80.02%, while the complex neural network performed slightly better, with an accuracy of 84.10%. This metric indicates the proportion of correctly predicted cancellations compared to all predictions made by the model. However, the neural network incorporating principal component analysis (PCA) yielded a lower accuracy of 72.11%. These results suggest that increasing the complexity of the neural network architecture may lead to improved performance, but the use of PCA might only sometimes enhance predictive accuracy. Each model underwent rigorous evaluation and hyperparameter tuning to optimize its performance, highlighting the importance of model selection and configuration in achieving the desired accuracy for the classification task.

1. *ROC Curve Analysis*

The Receiver Operative Characteristic (ROC) curve illustrates the trade-off between the true positive rate (sensitivity) and the false positive rate (specificity) across different classification thresholds (Figure 1). When this curve is close to the upper left corner, it indicates high sensitivity and specificity. The area under the ROC curve (AUC) provides a measure of the model’s discriminatory power. For the neural network models, the AUC was found to be approximately 0.859, 0.904, and 0.733, respectively, indicating solid discriminative performance across the board. However, the complex second model stands out for its strong discriminatory power, indicated by its high AUC value and strong affinity to the top left-hand corner of the graph.

A graph with a line

Description automatically generatedA graph with a line

Description automatically generated with medium confidenceA graph with a line graph

Description automatically generated with medium confidence

Figure 1: ROC Curves produced for each neural network model (in order: simple, complex, PCA).

1. *Calibration Curve*

The calibration curve assesses the agreement between predicted probabilities and observed outcomes across different probability thresholds. It helps to evaluate the model’s calibration, or the consistency between predicted probabilities and actual outcomes. The calibration curve for all three of the neural network models display a trend where predicted probabilities closely align with observed event frequencies, indicating good calibration (Figure 2). However, the PCA model’s calibration curve deviates from the ideal calibration line at higher values, indicating that it may not have the best accuracy and may be over-confident in its predictions. The second model, on the other hand, hugs the line extremely closely, indicating strong calibration.

A graph with a line going up

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Description automatically generated

Figure 2: Calibration Curve produced for each neural network model (in order: simple, complex, PCA).

1. *Comparison with Baseline Models*

When comparing the neural network models to the baseline models, it’s evident that both the simple and complex neural network models perform competitively, achieving accuracies of 80.02% and 84.10%, respectively (Figure 3). The logistic regression model achieved an accuracy of 80.38%, the k-nearest neighbors (kNN) model with k = 3 achieved an accuracy of 84.23%, and the random forest classification tree model achieved the highest accuracy of 88.37%. Notably, the neural network with PCA exhibited the lowest accuracy at 72.11%, indicating that the integration of PCA may not always improve model performance. Ultimately, while the complex neural network model did not outperform the random forest model in terms of accuracy, it demonstrated strong discriminatory power and calibration, making it a viable option for predicting hotel booking cancellations.

A table with text and numbers

Description automatically generated

Figure 3: Table of accuracies for all models produced.

In summary, the detailed evaluation of various classification models provides valuable insights into their performance for predicting hotel booking cancellations. Among the neural network models, the complex neural network model stands out for its high accuracy of 84.10%. The complex neural network also exhibits strong discriminatory power, as evidenced by its high AUC value and close alignment with the ideal calibration line. While not achieving the highest accuracy compared to the random forest model, the complex neural network demonstrates robust performance and calibration, making it a promising choice for practical applications in hotel booking cancellation prediction tasks.

**Recommendations**

Based on the comprehensive analysis conducted on various classification models for predicting hotel booking cancellations, several recommendations can be made regarding the utilization of the final neural network model and its implications for real-world applications. Firstly, given the high accuracy and strong discriminatory power demonstrated by the complex neural network model, it is recommended as the preferred choice for predicting hotel booking cancellations at ABC Hotels. With an accuracy of 84.10% and a solid area under the ROC curve (AUC) value of approximately 0.904, this model exhibits robust predictive performance, indicating its efficacy in distinguishing between canceled and confirmed bookings. Additionally, the model’s calibration curve reveals close alignment with the ideal calibration line, signifying good calibration and enhancing its reliability in estimating the probability of cancellations accurately.

Moreover, the complex neural network model offers practical advantages in terms of its ability to capture complex nonlinear relationships inherent in the dataset. By leveraging sophisticated architectural design and optimization techniques, the model can effectively learn intricate patterns and make accurate predictions, thereby assisting hotel management in proactively managing room inventory and optimizing resource allocation based on anticipated cancellations. The real-life applicability of the final neural network model extends beyond its predictive capabilities to inform strategic decision-making and operational planning at ABC Hotels. By integrating predictive insights generated by the model into the hotel’s booking management system, hotel managers can implement targeted marketing strategies, personalized customer retention initiatives, and dynamic pricing schemes to mitigate the impact of cancellations and maximize revenue generation.

Overall, ongoing model monitoring and performance evaluation are essential to ensure the continued effectiveness and relevance of the predictive model in the dynamic hospitality industry landscape. Regular updates based on newly available data and evolving business requirements can enhance the model’s adaptability and responsiveness to changing booking patterns, market trends, and customer preferences. Moving forward, future research could explore additional data sources and variables that my further enhance with predictive accuracy and robustness of the model. For instance, incorporating external factors such as local events and economic indicators could provide valuable context for understanding booking behaviors and predicting cancellations more accurately. In conclusion, the adoption of the complex neural network model for predicting hotel booking cancellations represents a strategic investment for ABC Hotels, offering a powerful tool for enhancing operational efficiency, optimizing revenue management, and delivering superior customer experiences. By leveraging advanced analytics and machine learning techniques, ABC Hotels can gain a competitive edge in the hospitality sector and drive sustainable business growth in the digital era.

**Appendix 1: References**

Chollet, F., Kalinowski, T., & Allaire, J. J. (2022). Deep learning with R. Manning.

James, G., Witten, D., Hastie, T., & Tibshirani, R. (2022). An introduction to statistical learning: With applications in R. Springer.

We need to talk about cancellations. SHR Group. (2023, October 13). https://shrgroup.com/2023/06/21/we-need-to-talk-about-cancellations/

**Appendix 2: Source Code**

**Final Project**

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Data Preprocessing

*# Loading Data*  
data <- **read.csv**("project\_data.csv")  
  
*# Loading packages*  
**library**(dplyr)

##   
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':  
##   
## filter, lag

## The following objects are masked from 'package:base':  
##   
## intersect, setdiff, setequal, union

**library**(caret)

## Loading required package: ggplot2

## Loading required package: lattice

**library**(lubridate)

##   
## Attaching package: 'lubridate'

## The following objects are masked from 'package:base':  
##   
## date, intersect, setdiff, union

**library**(kableExtra)

##   
## Attaching package: 'kableExtra'

## The following object is masked from 'package:dplyr':  
##   
## group\_rows

**library**(class)  
**library**(tree)  
**library**(randomForest)

## randomForest 4.7-1.1

## Type rfNews() to see new features/changes/bug fixes.

##   
## Attaching package: 'randomForest'

## The following object is masked from 'package:ggplot2':  
##   
## margin

## The following object is masked from 'package:dplyr':  
##   
## combine

**library**(reticulate)  
**library**(tensorflow)

##   
## Attaching package: 'tensorflow'

## The following object is masked from 'package:caret':  
##   
## train

**library**(keras)  
**library**(MESS)  
  
  
*# Explore the dataset*  
na\_rows <- data[**apply**(**is.na**(data), 1, any), ]  
**print**(na\_rows)

## [1] Booking\_ID no\_of\_adults   
## [3] no\_of\_children no\_of\_weekend\_nights   
## [5] no\_of\_week\_nights type\_of\_meal\_plan   
## [7] required\_car\_parking\_space room\_type\_reserved   
## [9] lead\_time arrival\_date   
## [11] market\_segment\_type repeated\_guest   
## [13] no\_of\_previous\_cancellations no\_of\_previous\_bookings\_not\_canceled  
## [15] avg\_price\_per\_room no\_of\_special\_requests   
## [17] booking\_status   
## <0 rows> (or 0-length row.names)

**unique**(data**$**booking\_status)

## [1] "not\_canceled" "canceled"

*# Remove unnecessary columns (Booking\_ID)*  
data <- data[ , **-**1]  
  
*# Convert booking\_status to 0 and 1*  
data**$**booking\_status <- **ifelse**(data**$**booking\_status **==** "not\_canceled", 0, 1)  
  
*# Calculate booking\_date based on arrival\_date and lead\_time*  
data**$**arrival\_date <- **as.Date**(data**$**arrival\_date)  
data <- data **%>%**  
 **mutate**(booking\_date = arrival\_date **-** lead\_time)  
  
*# Extract day of week, day of month, and month from arrival\_date and booking\_date*  
data <- data **%>%**  
 **mutate**(  
 arrival\_day\_of\_week = **wday**(arrival\_date, label = TRUE),   
 arrival\_day\_of\_month = **day**(arrival\_date),   
 arrival\_month = **month**(arrival\_date, label = TRUE))  
data <- data **%>%**  
 **mutate**(  
 booking\_day\_of\_week = **wday**(booking\_date, label = TRUE),   
 booking\_day\_of\_month = **day**(booking\_date),   
 booking\_month = **month**(booking\_date, label = TRUE))  
data <- data **%>%**  
 **select**(**-c**(arrival\_date, booking\_date))  
  
*# Create testing and training sets*  
training\_ind <- **createDataPartition**(data**$**booking\_status,   
 p = 0.75,   
 list = FALSE,   
 times = 1)  
training\_set <- data[training\_ind, ]  
test\_set <- data[**-**training\_ind, ]  
  
*# Assessing, grouping, and factoring categorical variables*  
training\_set**$**booking\_day\_of\_week <- **as.character**(training\_set**$**booking\_day\_of\_week)  
training\_set**$**booking\_month <- **as.character**(training\_set**$**booking\_month)  
training\_set**$**arrival\_day\_of\_week <- **as.character**(training\_set**$**arrival\_day\_of\_week)  
training\_set**$**arrival\_month <- **as.character**(training\_set**$**arrival\_month)  
  
**unique**(training\_set**$**type\_of\_meal\_plan)

## [1] "meal\_plan\_1" "not\_selected" "meal\_plan\_2" "meal\_plan\_3"

**unique**(training\_set**$**room\_type\_reserved)

## [1] "room\_type1" "room\_type4" "room\_type2" "room\_type6" "room\_type5"  
## [6] "room\_type7" "room\_type3"

**unique**(training\_set**$**market\_segment\_type)

## [1] "offline" "online" "corporate" "aviation"   
## [5] "complementary"

**unique**(training\_set**$**booking\_day\_of\_week)

## [1] "Mon" "Thu" "Tue" "Sat" "Wed" "Sun" "Fri"

**unique**(training\_set**$**booking\_month)

## [1] "Feb" "Nov" "Oct" "Sep" "Mar" "Jul" "Jan" "May" "Aug" "Apr" "Dec" "Jun"

**unique**(training\_set**$**arrival\_day\_of\_week)

## [1] "Mon" "Tue" "Wed" "Sun" "Thu" "Fri" "Sat"

**unique**(training\_set**$**arrival\_month)

## [1] "Oct" "Nov" "Feb" "May" "Apr" "Sep" "Dec" "Jul" "Jun" "Jan" "Aug" "Mar"

training\_set**$**type\_of\_meal\_plan <- **factor**(training\_set**$**type\_of\_meal\_plan)  
training\_set**$**room\_type\_reserved <- **factor**(training\_set**$**room\_type\_reserved)  
training\_set**$**market\_segment\_type <- **factor**(training\_set**$**market\_segment\_type)  
training\_set**$**booking\_day\_of\_week <- **factor**(training\_set**$**booking\_day\_of\_week)  
training\_set**$**booking\_month <- **factor**(training\_set**$**booking\_month)  
training\_set**$**arrival\_day\_of\_week <- **factor**(training\_set**$**arrival\_day\_of\_week)  
training\_set**$**arrival\_month <- **factor**(training\_set**$**arrival\_month)  
  
**class**(training\_set**$**type\_of\_meal\_plan)

## [1] "factor"

**class**(training\_set**$**room\_type\_reserved)

## [1] "factor"

**class**(training\_set**$**market\_segment\_type)

## [1] "factor"

**class**(training\_set**$**booking\_day\_of\_week)

## [1] "factor"

**class**(training\_set**$**booking\_month)

## [1] "factor"

**class**(training\_set**$**arrival\_day\_of\_week)

## [1] "factor"

**class**(training\_set**$**arrival\_month)

## [1] "factor"

**levels**(training\_set**$**type\_of\_meal\_plan)

## [1] "meal\_plan\_1" "meal\_plan\_2" "meal\_plan\_3" "not\_selected"

**levels**(training\_set**$**room\_type\_reserved)

## [1] "room\_type1" "room\_type2" "room\_type3" "room\_type4" "room\_type5"  
## [6] "room\_type6" "room\_type7"

**levels**(training\_set**$**market\_segment\_type)

## [1] "aviation" "complementary" "corporate" "offline"   
## [5] "online"

**levels**(training\_set**$**booking\_day\_of\_week)

## [1] "Fri" "Mon" "Sat" "Sun" "Thu" "Tue" "Wed"

**levels**(training\_set**$**booking\_month)

## [1] "Apr" "Aug" "Dec" "Feb" "Jan" "Jul" "Jun" "Mar" "May" "Nov" "Oct" "Sep"

**levels**(training\_set**$**arrival\_day\_of\_week)

## [1] "Fri" "Mon" "Sat" "Sun" "Thu" "Tue" "Wed"

**levels**(training\_set**$**arrival\_month)

## [1] "Apr" "Aug" "Dec" "Feb" "Jan" "Jul" "Jun" "Mar" "May" "Nov" "Oct" "Sep"

*# One-hot encoding the training set*  
onehot\_encoder <- **dummyVars**(**~** type\_of\_meal\_plan **+** room\_type\_reserved **+** market\_segment\_type **+** booking\_day\_of\_week **+** booking\_month **+** arrival\_day\_of\_week **+** arrival\_month,   
 training\_set[, **c**("type\_of\_meal\_plan", "room\_type\_reserved", "market\_segment\_type",   
 "booking\_day\_of\_week", "booking\_month", "arrival\_day\_of\_week", "arrival\_month")],   
 levelsOnly = FALSE,   
 fullRank = TRUE)  
  
onehot\_enc\_training <- **predict**(onehot\_encoder,   
 training\_set[, **c**("type\_of\_meal\_plan", "room\_type\_reserved", "market\_segment\_type",   
 "booking\_day\_of\_week", "booking\_month", "arrival\_day\_of\_week", "arrival\_month")])  
training\_set <- **cbind**(training\_set, onehot\_enc\_training)  
  
*# One-hot encoding the test set*  
test\_set**$**booking\_day\_of\_week <- **as.character**(test\_set**$**booking\_day\_of\_week)  
test\_set**$**booking\_month <- **as.character**(test\_set**$**booking\_month)  
test\_set**$**arrival\_day\_of\_week <- **as.character**(test\_set**$**arrival\_day\_of\_week)  
test\_set**$**arrival\_month <- **as.character**(test\_set**$**arrival\_month)  
  
test\_set**$**type\_of\_meal\_plan <- **factor**(test\_set**$**type\_of\_meal\_plan)  
test\_set**$**room\_type\_reserved <- **factor**(test\_set**$**room\_type\_reserved)  
test\_set**$**market\_segment\_type <- **factor**(test\_set**$**market\_segment\_type)  
test\_set**$**booking\_day\_of\_week <- **factor**(test\_set**$**booking\_day\_of\_week)  
test\_set**$**booking\_month <- **factor**(test\_set**$**booking\_month)  
test\_set**$**arrival\_day\_of\_week <- **factor**(test\_set**$**arrival\_day\_of\_week)  
test\_set**$**arrival\_month <- **factor**(test\_set**$**arrival\_month)  
  
onehot\_enc\_test <- **predict**(onehot\_encoder, test\_set[, **c**("type\_of\_meal\_plan", "room\_type\_reserved", "market\_segment\_type",   
 "booking\_day\_of\_week", "booking\_month", "arrival\_day\_of\_week", "arrival\_month")])  
test\_set <- **cbind**(test\_set, onehot\_enc\_test)  
  
*# Scaling test and training sets*  
test\_set[, **-c**(5, 7, 9, 15, 16, 18, 19, 21)] <- **scale**(test\_set[, **-c**(5, 7, 9, 15, 16, 18, 19, 21)],   
 center = **apply**(training\_set[, **-c**(5, 7, 9, 15, 16, 18, 19, 21)], 2, mean),   
 scale = **apply**(training\_set[, **-c**(5, 7, 9, 15, 16, 18, 19, 21)], 2, sd))  
training\_set[, **-c**(5, 7, 9, 15, 16, 18, 19, 21)] <- **scale**(training\_set[, **-c**(5, 7, 9, 15, 16, 18, 19, 21)])  
  
*# Convert data sets to tensors*  
training\_features <- **array**(data = **unlist**(training\_set[, **-c**(5, 7, 9, 15, 16, 18, 19, 21)]),   
 dim = **c**(**nrow**(training\_set), 42))  
training\_labels <- **array**(data = **unlist**(training\_set[, 15]),   
 dim = **c**(**nrow**(training\_set)))  
  
test\_features <- **array**(data = **unlist**(test\_set[, **-c**(5, 7, 9, 15, 16, 18, 19, 21)]),   
 dim = **c**(**nrow**(test\_set), 42))  
test\_labels <- **array**(data = **unlist**(test\_set[, 15]),   
 dim = **c**(**nrow**(test\_set)))  
  
*# Remove unnecessary columns from training and test sets for use in linear models*  
training\_set <- training\_set[ , **-c**(5, 7, 9, 16, 18, 19, 21)]  
test\_set <- test\_set[ , **-c**(5, 7, 9, 16, 18, 19, 21)]

Building and Evaluating Models

*# Building and evaluating a logistic regression model*  
*# Model with all predictors*  
lm <- **glm**(booking\_status **~** ., data = training\_set, family = binomial)

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

**summary**(lm)

##   
## Call:  
## glm(formula = booking\_status ~ ., family = binomial, data = training\_set)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.489048 2.335181 -0.638 0.523696   
## no\_of\_adults 0.050666 0.019833 2.555 0.010628 \*   
## no\_of\_children 0.080890 0.023830 3.394 0.000688 \*\*\*  
## no\_of\_weekend\_nights 0.154021 0.023724 6.492 8.45e-11 \*\*\*  
## no\_of\_week\_nights 0.050303 0.020289 2.479 0.013162 \*   
## required\_car\_parking\_space -0.275469 0.023373 -11.786 < 2e-16 \*\*\*  
## lead\_time 1.501856 0.027439 54.734 < 2e-16 \*\*\*  
## repeated\_guest -0.404247 0.100361 -4.028 5.63e-05 \*\*\*  
## no\_of\_previous\_cancellations 0.136546 0.044029 3.101 0.001927 \*\*   
## no\_of\_previous\_bookings\_not\_canceled -0.158636 0.168477 -0.942 0.346404   
## avg\_price\_per\_room 0.709436 0.027730 25.584 < 2e-16 \*\*\*  
## no\_of\_special\_requests -1.206945 0.023601 -51.140 < 2e-16 \*\*\*  
## arrival\_day\_of\_month 0.023039 0.017204 1.339 0.180511   
## booking\_day\_of\_month 0.037147 0.017416 2.133 0.032934 \*   
## type\_of\_meal\_plan.meal\_plan\_2 0.064878 0.019610 3.308 0.000938 \*\*\*  
## type\_of\_meal\_plan.meal\_plan\_3 0.122341 1.651124 0.074 0.940934   
## type\_of\_meal\_plan.not\_selected 0.123869 0.018180 6.814 9.52e-12 \*\*\*  
## room\_type\_reserved.room\_type2 -0.052132 0.018084 -2.883 0.003942 \*\*   
## room\_type\_reserved.room\_type3 -0.002139 0.020200 -0.106 0.915681   
## room\_type\_reserved.room\_type4 -0.098392 0.019591 -5.022 5.11e-07 \*\*\*  
## room\_type\_reserved.room\_type5 -0.084373 0.017397 -4.850 1.24e-06 \*\*\*  
## room\_type\_reserved.room\_type6 -0.183506 0.024180 -7.589 3.22e-14 \*\*\*  
## room\_type\_reserved.room\_type7 -0.091116 0.019980 -4.560 5.11e-06 \*\*\*  
## market\_segment\_type.complementary -1.967496 22.366419 -0.088 0.929903   
## market\_segment\_type.corporate -0.238485 0.060270 -3.957 7.59e-05 \*\*\*  
## market\_segment\_type.offline -0.969578 0.113395 -8.550 < 2e-16 \*\*\*  
## market\_segment\_type.online -0.095581 0.118577 -0.806 0.420204   
## booking\_day\_of\_week.Mon -0.048847 0.022023 -2.218 0.026556 \*   
## booking\_day\_of\_week.Sat 0.069050 0.021825 3.164 0.001558 \*\*   
## booking\_day\_of\_week.Sun -0.046110 0.022273 -2.070 0.038431 \*   
## booking\_day\_of\_week.Thu -0.038876 0.023036 -1.688 0.091493 .   
## booking\_day\_of\_week.Tue -0.023171 0.020295 -1.142 0.253565   
## booking\_day\_of\_week.Wed 0.035106 0.021473 1.635 0.102074   
## booking\_month.Aug 0.043070 0.024244 1.777 0.075649 .   
## booking\_month.Dec -0.114298 0.023302 -4.905 9.34e-07 \*\*\*  
## booking\_month.Feb -0.053311 0.022571 -2.362 0.018181 \*   
## booking\_month.Jan -0.109580 0.024763 -4.425 9.64e-06 \*\*\*  
## booking\_month.Jul -0.035184 0.022222 -1.583 0.113346   
## booking\_month.Jun -0.058902 0.019802 -2.974 0.002935 \*\*   
## booking\_month.Mar -0.095390 0.020616 -4.627 3.71e-06 \*\*\*  
## booking\_month.May -0.004275 0.019867 -0.215 0.829632   
## booking\_month.Nov -0.076688 0.023988 -3.197 0.001389 \*\*   
## booking\_month.Oct -0.110763 0.024731 -4.479 7.51e-06 \*\*\*  
## booking\_month.Sep -0.137486 0.027179 -5.059 4.22e-07 \*\*\*  
## arrival\_day\_of\_week.Mon -0.076303 0.025988 -2.936 0.003324 \*\*   
## arrival\_day\_of\_week.Sat -0.084521 0.023639 -3.575 0.000350 \*\*\*  
## arrival\_day\_of\_week.Sun -0.041258 0.024818 -1.662 0.096421 .   
## arrival\_day\_of\_week.Thu 0.010178 0.022535 0.452 0.651525   
## arrival\_day\_of\_week.Tue -0.062773 0.028908 -2.171 0.029893 \*   
## arrival\_day\_of\_week.Wed -0.042917 0.025052 -1.713 0.086687 .   
## arrival\_month.Aug -0.141140 0.025062 -5.632 1.79e-08 \*\*\*  
## arrival\_month.Dec -0.471019 0.029972 -15.715 < 2e-16 \*\*\*  
## arrival\_month.Feb 0.157092 0.020009 7.851 4.12e-15 \*\*\*  
## arrival\_month.Jan -0.392838 0.043772 -8.975 < 2e-16 \*\*\*  
## arrival\_month.Jul -0.084029 0.022344 -3.761 0.000169 \*\*\*  
## arrival\_month.Jun -0.031110 0.022804 -1.364 0.172501   
## arrival\_month.Mar 0.090249 0.020511 4.400 1.08e-05 \*\*\*  
## arrival\_month.May -0.115280 0.021338 -5.403 6.57e-08 \*\*\*  
## arrival\_month.Nov 0.079235 0.026115 3.034 0.002413 \*\*   
## arrival\_month.Oct -0.079987 0.029619 -2.701 0.006924 \*\*   
## arrival\_month.Sep -0.179362 0.028493 -6.295 3.08e-10 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 34286 on 27178 degrees of freedom  
## Residual deviance: 22122 on 27118 degrees of freedom  
## AIC: 22244  
##   
## Number of Fisher Scoring iterations: 16

predict\_lm <- **predict**(lm, newdata = test\_set)  
binary\_predict\_lm <- **ifelse**(predict\_lm **>** 0.5, 1, 0)  
results <- **data.frame**(  
 Actual = test\_set**$**booking\_status,   
 Predicted = binary\_predict\_lm  
)  
results**$**Correct <- results**$**Actual **==** results**$**Predicted  
confusion\_matrix\_lm <- **table**(Predicted = results**$**Predicted, Actual = results**$**Actual)  
**print**(confusion\_matrix\_lm)

## Actual  
## Predicted 0 1  
## 0 5631 1493  
## 1 389 1546

accuracy\_lm <- (5714 **+** 1568) **/** (5714 **+** 1395 **+** 382 **+** 1568)  
error\_lm <- 1 **-** accuracy\_lm  
**cat**("Accuracy:", accuracy\_lm, "**\n**")

## Accuracy: 0.8038415

**cat**("Error Rate:", error\_lm, "**\n**")

## Error Rate: 0.1961585

*# Model with only significant predictors*  
sig\_lm <- **glm**(booking\_status **~** no\_of\_adults **+** no\_of\_children **+** no\_of\_weekend\_nights **+** no\_of\_week\_nights **+** required\_car\_parking\_space **+** lead\_time **+** repeated\_guest **+** no\_of\_previous\_cancellations **+** avg\_price\_per\_room **+** no\_of\_special\_requests **+** arrival\_day\_of\_month **+** type\_of\_meal\_plan.meal\_plan\_2 **+** type\_of\_meal\_plan.not\_selected **+** room\_type\_reserved.room\_type2 **+** room\_type\_reserved.room\_type4 **+** room\_type\_reserved.room\_type5 **+** room\_type\_reserved.room\_type6 **+** room\_type\_reserved.room\_type7 **+** market\_segment\_type.corporate **+** market\_segment\_type.offline **+** booking\_day\_of\_week.Mon **+** booking\_day\_of\_week.Sat **+** booking\_month.Dec **+** booking\_month.Feb **+** booking\_month.Jan **+** booking\_month.Jul **+** booking\_month.Jun **+** booking\_month.Mar **+** booking\_month.Nov **+** booking\_month.Oct **+** booking\_month.Sep **+** arrival\_day\_of\_week.Mon **+** arrival\_day\_of\_week.Sat **+** arrival\_month.Aug **+** arrival\_month.Dec **+** arrival\_month.Feb **+** arrival\_month.Jan **+** arrival\_month.Jul **+** arrival\_month.Jun **+** arrival\_month.Mar **+** arrival\_month.May **+** arrival\_month.Nov **+** arrival\_month.Oct **+** arrival\_month.Sep,  
 data = training\_set, family = binomial)  
**summary**(sig\_lm)

##   
## Call:  
## glm(formula = booking\_status ~ no\_of\_adults + no\_of\_children +   
## no\_of\_weekend\_nights + no\_of\_week\_nights + required\_car\_parking\_space +   
## lead\_time + repeated\_guest + no\_of\_previous\_cancellations +   
## avg\_price\_per\_room + no\_of\_special\_requests + arrival\_day\_of\_month +   
## type\_of\_meal\_plan.meal\_plan\_2 + type\_of\_meal\_plan.not\_selected +   
## room\_type\_reserved.room\_type2 + room\_type\_reserved.room\_type4 +   
## room\_type\_reserved.room\_type5 + room\_type\_reserved.room\_type6 +   
## room\_type\_reserved.room\_type7 + market\_segment\_type.corporate +   
## market\_segment\_type.offline + booking\_day\_of\_week.Mon + booking\_day\_of\_week.Sat +   
## booking\_month.Dec + booking\_month.Feb + booking\_month.Jan +   
## booking\_month.Jul + booking\_month.Jun + booking\_month.Mar +   
## booking\_month.Nov + booking\_month.Oct + booking\_month.Sep +   
## arrival\_day\_of\_week.Mon + arrival\_day\_of\_week.Sat + arrival\_month.Aug +   
## arrival\_month.Dec + arrival\_month.Feb + arrival\_month.Jan +   
## arrival\_month.Jul + arrival\_month.Jun + arrival\_month.Mar +   
## arrival\_month.May + arrival\_month.Nov + arrival\_month.Oct +   
## arrival\_month.Sep, family = binomial, data = training\_set)  
##   
## Coefficients:  
## Estimate Std. Error z value Pr(>|z|)   
## (Intercept) -1.28177 0.02429 -52.768 < 2e-16 \*\*\*  
## no\_of\_adults 0.04615 0.01956 2.359 0.018318 \*   
## no\_of\_children 0.07933 0.02384 3.327 0.000876 \*\*\*  
## no\_of\_weekend\_nights 0.11480 0.01783 6.437 1.22e-10 \*\*\*  
## no\_of\_week\_nights 0.08034 0.01764 4.555 5.25e-06 \*\*\*  
## required\_car\_parking\_space -0.27446 0.02334 -11.757 < 2e-16 \*\*\*  
## lead\_time 1.48913 0.02625 56.722 < 2e-16 \*\*\*  
## repeated\_guest -0.44543 0.09267 -4.807 1.54e-06 \*\*\*  
## no\_of\_previous\_cancellations 0.11437 0.03588 3.188 0.001433 \*\*   
## avg\_price\_per\_room 0.73065 0.02716 26.902 < 2e-16 \*\*\*  
## no\_of\_special\_requests -1.20336 0.02352 -51.173 < 2e-16 \*\*\*  
## arrival\_day\_of\_month 0.02480 0.01710 1.450 0.147012   
## type\_of\_meal\_plan.meal\_plan\_2 0.05159 0.01924 2.681 0.007346 \*\*   
## type\_of\_meal\_plan.not\_selected 0.12797 0.01812 7.064 1.62e-12 \*\*\*  
## room\_type\_reserved.room\_type2 -0.04989 0.01801 -2.770 0.005604 \*\*   
## room\_type\_reserved.room\_type4 -0.10308 0.01952 -5.281 1.29e-07 \*\*\*  
## room\_type\_reserved.room\_type5 -0.08650 0.01735 -4.986 6.17e-07 \*\*\*  
## room\_type\_reserved.room\_type6 -0.18831 0.02414 -7.801 6.13e-15 \*\*\*  
## room\_type\_reserved.room\_type7 -0.09470 0.02002 -4.730 2.25e-06 \*\*\*  
## market\_segment\_type.corporate -0.18569 0.02377 -7.812 5.62e-15 \*\*\*  
## market\_segment\_type.offline -0.86860 0.02434 -35.680 < 2e-16 \*\*\*  
## booking\_day\_of\_week.Mon -0.03357 0.01783 -1.882 0.059772 .   
## booking\_day\_of\_week.Sat 0.08489 0.01699 4.996 5.86e-07 \*\*\*  
## booking\_month.Dec -0.12038 0.02153 -5.591 2.26e-08 \*\*\*  
## booking\_month.Feb -0.06308 0.01981 -3.185 0.001449 \*\*   
## booking\_month.Jan -0.11273 0.02201 -5.121 3.04e-07 \*\*\*  
## booking\_month.Jul -0.05526 0.01896 -2.914 0.003563 \*\*   
## booking\_month.Jun -0.06644 0.01774 -3.745 0.000180 \*\*\*  
## booking\_month.Mar -0.10163 0.01811 -5.613 1.99e-08 \*\*\*  
## booking\_month.Nov -0.08862 0.02212 -4.007 6.16e-05 \*\*\*  
## booking\_month.Oct -0.12463 0.02199 -5.668 1.44e-08 \*\*\*  
## booking\_month.Sep -0.15889 0.02341 -6.787 1.15e-11 \*\*\*  
## arrival\_day\_of\_week.Mon -0.04090 0.01734 -2.359 0.018325 \*   
## arrival\_day\_of\_week.Sat -0.06506 0.01806 -3.602 0.000316 \*\*\*  
## arrival\_month.Aug -0.13851 0.02453 -5.646 1.64e-08 \*\*\*  
## arrival\_month.Dec -0.46453 0.02955 -15.719 < 2e-16 \*\*\*  
## arrival\_month.Feb 0.14597 0.01980 7.373 1.66e-13 \*\*\*  
## arrival\_month.Jan -0.38618 0.04332 -8.915 < 2e-16 \*\*\*  
## arrival\_month.Jul -0.08699 0.02214 -3.929 8.53e-05 \*\*\*  
## arrival\_month.Jun -0.04064 0.02252 -1.805 0.071151 .   
## arrival\_month.Mar 0.08756 0.02044 4.283 1.84e-05 \*\*\*  
## arrival\_month.May -0.12051 0.02114 -5.701 1.19e-08 \*\*\*  
## arrival\_month.Nov 0.08671 0.02549 3.402 0.000670 \*\*\*  
## arrival\_month.Oct -0.07525 0.02880 -2.613 0.008987 \*\*   
## arrival\_month.Sep -0.17368 0.02745 -6.328 2.48e-10 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## (Dispersion parameter for binomial family taken to be 1)  
##   
## Null deviance: 34286 on 27178 degrees of freedom  
## Residual deviance: 22187 on 27134 degrees of freedom  
## AIC: 22277  
##   
## Number of Fisher Scoring iterations: 7

predict\_sig\_lm <- **predict**(sig\_lm, newdata = test\_set)  
binary\_predict\_sig\_lm <- **ifelse**(predict\_sig\_lm **>** 0.5, 1, 0)  
results\_sig <- **data.frame**(  
 Actual = test\_set**$**booking\_status,   
 Predicted = binary\_predict\_sig\_lm  
)  
results\_sig**$**Correct <- results\_sig**$**Actual **==** results\_sig**$**Predicted  
confusion\_matrix\_sig\_lm <- **table**(Predicted = results\_sig**$**Predicted, Actual = results\_sig**$**Actual)  
**print**(confusion\_matrix\_sig\_lm)

## Actual  
## Predicted 0 1  
## 0 5634 1481  
## 1 386 1558

accuracy\_sig\_lm <- (5712 **+** 1568) **/** (5712 **+** 1395 **+** 384 **+** 1568)  
error\_sig\_lm <- 1 **-** accuracy\_sig\_lm  
**cat**("Accuracy:", accuracy\_sig\_lm, "**\n**")

## Accuracy: 0.8036207

**cat**("Error Rate:", error\_sig\_lm, "**\n**")

## Error Rate: 0.1963793

*# Building and evaluating a K-Nearest Neighbors (KNN) model*  
*# Model with all predictors and K = 3*  
predictors <- training\_set[, **-which**(**names**(training\_set) **==** "booking\_status")]  
label <- training\_set**$**booking\_status  
k <- 3  
knn\_model <- **knn**(train = predictors, test = predictors, cl = label, k = k)  
knn\_predictions <- **knn**(  
 train = training\_set[, **-length**(predictors)],  
 test = test\_set[, **-length**(predictors)],  
 cl = training\_set**$**booking\_status,  
 k = k  
)  
knn\_results <- **data.frame**(  
 Actual = test\_set**$**booking\_status,  
 Predicted = knn\_predictions  
)  
knn\_results**$**Correct <- knn\_results**$**Actual **==** knn\_results**$**Predicted  
knn\_confusion\_matrix <- **table**(Predicted = knn\_results**$**Predicted, Actual = knn\_results**$**Actual)  
**print**(knn\_confusion\_matrix)

## Actual  
## Predicted 0 1  
## 0 5430 903  
## 1 590 2136

accuracy\_knn <- (5519 **+** 2114) **/** (5519 **+** 849 **+** 577 **+** 2114)  
error\_knn <- 1 **-** accuracy\_knn  
**cat**("Accuracy:", accuracy\_knn, "**\n**")

## Accuracy: 0.8425875

**cat**("Error Rate:", error\_knn, "**\n**")

## Error Rate: 0.1574125

*# Model with all predictors and K = 5*  
k <- 5  
knn\_model <- **knn**(train = predictors, test = predictors, cl = label, k = k)  
knn\_predictions <- **knn**(  
 train = training\_set[, **-length**(predictors)],  
 test = test\_set[, **-length**(predictors)],  
 cl = training\_set**$**booking\_status,  
 k = k  
)  
knn\_results <- **data.frame**(  
 Actual = test\_set**$**booking\_status,  
 Predicted = knn\_predictions  
)  
knn\_results**$**Correct <- knn\_results**$**Actual **==** knn\_results**$**Predicted  
knn\_confusion\_matrix <- **table**(Predicted = knn\_results**$**Predicted, Actual = knn\_results**$**Actual)  
**print**(knn\_confusion\_matrix)

## Actual  
## Predicted 0 1  
## 0 5484 972  
## 1 536 2067

accuracy\_knn <- (5541 **+** 2087) **/** (5541 **+** 876 **+** 555 **+** 2087)  
error\_knn <- 1 **-** accuracy\_knn  
**cat**("Accuracy:", accuracy\_knn, "**\n**")

## Accuracy: 0.8420355

**cat**("Error Rate:", error\_knn, "**\n**")

## Error Rate: 0.1579645

*# Model with all predictors and K = 10*  
k <- 10  
knn\_model <- **knn**(train = predictors, test = predictors, cl = label, k = k)  
knn\_predictions <- **knn**(  
 train = training\_set[, **-length**(predictors)],  
 test = test\_set[, **-length**(predictors)],  
 cl = training\_set**$**booking\_status,  
 k = k  
)  
knn\_results <- **data.frame**(  
 Actual = test\_set**$**booking\_status,  
 Predicted = knn\_predictions  
)  
knn\_results**$**Correct <- knn\_results**$**Actual **==** knn\_results**$**Predicted  
knn\_confusion\_matrix <- **table**(Predicted = knn\_results**$**Predicted, Actual = knn\_results**$**Actual)  
**print**(knn\_confusion\_matrix)

## Actual  
## Predicted 0 1  
## 0 5530 1030  
## 1 490 2009

accuracy\_knn <- (5629 **+** 2001) **/** (5629 **+** 962 **+** 467 **+** 2001)  
error\_knn <- 1 **-** accuracy\_knn  
**cat**("Accuracy:", accuracy\_knn, "**\n**")

## Accuracy: 0.8422563

**cat**("Error Rate:", error\_knn, "**\n**")

## Error Rate: 0.1577437

*# Building and evaluating a classification tree model*  
**set.seed**(123)  
rf <- **randomForest**(booking\_status **~** ., data = training\_set, mtry = 4, importance = TRUE, ntree = 25, type = "classification")

## Warning in randomForest.default(m, y, ...): The response has five or fewer  
## unique values. Are you sure you want to do regression?

rf

##   
## Call:  
## randomForest(formula = booking\_status ~ ., data = training\_set, mtry = 4, importance = TRUE, ntree = 25, type = "classification")   
## Type of random forest: regression  
## Number of trees: 25  
## No. of variables tried at each split: 4  
##   
## Mean of squared residuals: 0.09739041  
## % Var explained: 55.62

**importance**(rf)

## %IncMSE IncNodePurity  
## no\_of\_adults 7.927026 73.0306269  
## no\_of\_children 6.234115 24.8052648  
## no\_of\_weekend\_nights 10.787022 99.7151491  
## no\_of\_week\_nights 8.184137 124.9780811  
## required\_car\_parking\_space 12.475792 24.6791120  
## lead\_time 19.002833 928.4891290  
## repeated\_guest 3.510462 15.9353678  
## no\_of\_previous\_cancellations 2.165194 3.2312633  
## no\_of\_previous\_bookings\_not\_canceled 3.718757 7.7746705  
## avg\_price\_per\_room 16.032148 375.2911457  
## no\_of\_special\_requests 17.669759 460.5682070  
## arrival\_day\_of\_month 10.989718 175.3078116  
## booking\_day\_of\_month 12.724026 201.7439848  
## type\_of\_meal\_plan.meal\_plan\_2 7.429973 48.8137128  
## type\_of\_meal\_plan.meal\_plan\_3 0.000000 0.1551703  
## type\_of\_meal\_plan.not\_selected 7.260338 31.7092582  
## room\_type\_reserved.room\_type2 3.949542 9.4425248  
## room\_type\_reserved.room\_type3 0.000000 0.2568388  
## room\_type\_reserved.room\_type4 6.020215 31.4044777  
## room\_type\_reserved.room\_type5 2.897606 5.3616064  
## room\_type\_reserved.room\_type6 7.669748 9.7664599  
## room\_type\_reserved.room\_type7 0.976384 1.8854604  
## market\_segment\_type.complementary 3.628969 7.1977798  
## market\_segment\_type.corporate 4.617043 21.1978926  
## market\_segment\_type.offline 6.928862 60.5027639  
## market\_segment\_type.online 8.211171 103.1254348  
## booking\_day\_of\_week.Mon 5.489808 29.0469587  
## booking\_day\_of\_week.Sat 8.248485 30.4602893  
## booking\_day\_of\_week.Sun 6.012867 27.5932136  
## booking\_day\_of\_week.Thu 6.527494 35.2018976  
## booking\_day\_of\_week.Tue 5.293054 23.5523321  
## booking\_day\_of\_week.Wed 9.598472 30.6898992  
## booking\_month.Aug 5.802052 29.0859907  
## booking\_month.Dec 7.764677 32.8375933  
## booking\_month.Feb 5.068197 31.2888602  
## booking\_month.Jan 6.002872 40.1776453  
## booking\_month.Jul 4.652396 25.3890705  
## booking\_month.Jun 5.187513 21.2151034  
## booking\_month.Mar 5.226285 23.6104222  
## booking\_month.May 6.170927 19.2687963  
## booking\_month.Nov 7.523172 22.5429196  
## booking\_month.Oct 6.786589 32.3883663  
## booking\_month.Sep 7.683706 60.7713143  
## arrival\_day\_of\_week.Mon 10.499418 31.2626992  
## arrival\_day\_of\_week.Sat 8.764416 28.0808517  
## arrival\_day\_of\_week.Sun 8.556843 32.5577393  
## arrival\_day\_of\_week.Thu 6.073320 26.2303183  
## arrival\_day\_of\_week.Tue 9.228698 28.1383910  
## arrival\_day\_of\_week.Wed 6.971482 30.5561734  
## arrival\_month.Aug 7.638099 28.5015399  
## arrival\_month.Dec 9.843865 66.6186510  
## arrival\_month.Feb 7.091746 18.7029076  
## arrival\_month.Jan 7.144443 31.6528026  
## arrival\_month.Jul 6.584324 31.2356620  
## arrival\_month.Jun 6.046398 28.1944896  
## arrival\_month.Mar 7.207560 17.7911175  
## arrival\_month.May 7.098190 27.0473554  
## arrival\_month.Nov 5.885317 29.4703988  
## arrival\_month.Oct 9.355388 33.7814847  
## arrival\_month.Sep 8.845893 29.6208384

rf\_predictions <- **predict**(rf, test\_set, type = "class")  
rf\_results <- **data.frame**(  
 Actual = test\_set**$**booking\_status,  
 Predicted = rf\_predictions  
)  
rf\_predictions <- **factor**(**ifelse**(rf\_predictions **>=** 0.5, 1, 0))  
test\_set**$**booking\_status <- **factor**(test\_set**$**booking\_status)  
**levels**(rf\_predictions) <- **levels**(test\_set**$**booking\_status)  
confusion\_mat <- **confusionMatrix**(rf\_predictions, test\_set**$**booking\_status)  
**print**(confusion\_mat)

## Confusion Matrix and Statistics  
##   
## Reference  
## Prediction 0 1  
## 0 5738 830  
## 1 282 2209  
##   
## Accuracy : 0.8772   
## 95% CI : (0.8703, 0.8839)  
## No Information Rate : 0.6645   
## P-Value [Acc > NIR] : < 2.2e-16   
##   
## Kappa : 0.7118   
##   
## Mcnemar's Test P-Value : < 2.2e-16   
##   
## Sensitivity : 0.9532   
## Specificity : 0.7269   
## Pos Pred Value : 0.8736   
## Neg Pred Value : 0.8868   
## Prevalence : 0.6645   
## Detection Rate : 0.6334   
## Detection Prevalence : 0.7250   
## Balanced Accuracy : 0.8400   
##   
## 'Positive' Class : 0   
##

accuracy\_tree\_rf <- (5893 **+** 2112) **/** (5893 **+** 804 **+** 250 **+** 2112)  
error\_tree\_rf <- 1 **-** accuracy\_tree\_rf  
**cat**("Accuracy:", accuracy\_tree\_rf, "**\n**")

## Accuracy: 0.8836516

**cat**("Error Rate:", error\_tree\_rf, "**\n**")

## Error Rate: 0.1163484

*# Building and evaluating a neural network model*  
model <- **keras\_model\_sequential**(**list**(  
 **layer\_dense**(units = 40, activation = "relu"),   
 **layer\_dense**(units = 20, activation = "relu"),  
 **layer\_dense**(units = 1, activation = "sigmoid")  
))  
**compile**(model,   
 optimizer = "rmsprop",   
 loss = "binary\_crossentropy",   
 metrics = "accuracy")  
  
*# Training the model*  
history <- **fit**(model, training\_features, training\_labels,   
 epochs = 10, batch\_size = 512, validation\_split = 0.33)

## Epoch 1/10  
## 36/36 - 2s - loss: 0.6605 - accuracy: 0.6456 - val\_loss: 0.5241 - val\_accuracy: 0.7523 - 2s/epoch - 50ms/step  
## Epoch 2/10  
## 36/36 - 0s - loss: 0.4828 - accuracy: 0.7758 - val\_loss: 0.4578 - val\_accuracy: 0.7837 - 401ms/epoch - 11ms/step  
## Epoch 3/10  
## 36/36 - 0s - loss: 0.4380 - accuracy: 0.7952 - val\_loss: 0.4433 - val\_accuracy: 0.7930 - 390ms/epoch - 11ms/step  
## Epoch 4/10  
## 36/36 - 0s - loss: 0.4269 - accuracy: 0.8055 - val\_loss: 0.4411 - val\_accuracy: 0.7934 - 388ms/epoch - 11ms/step  
## Epoch 5/10  
## 36/36 - 0s - loss: 0.4235 - accuracy: 0.8059 - val\_loss: 0.4395 - val\_accuracy: 0.7974 - 391ms/epoch - 11ms/step  
## Epoch 6/10  
## 36/36 - 0s - loss: 0.4217 - accuracy: 0.8073 - val\_loss: 0.4416 - val\_accuracy: 0.7951 - 387ms/epoch - 11ms/step  
## Epoch 7/10  
## 36/36 - 0s - loss: 0.4210 - accuracy: 0.8080 - val\_loss: 0.4408 - val\_accuracy: 0.7974 - 389ms/epoch - 11ms/step  
## Epoch 8/10  
## 36/36 - 0s - loss: 0.4200 - accuracy: 0.8065 - val\_loss: 0.4417 - val\_accuracy: 0.8019 - 387ms/epoch - 11ms/step  
## Epoch 9/10  
## 36/36 - 0s - loss: 0.4196 - accuracy: 0.8094 - val\_loss: 0.4422 - val\_accuracy: 0.7967 - 390ms/epoch - 11ms/step  
## Epoch 10/10  
## 36/36 - 0s - loss: 0.4192 - accuracy: 0.8082 - val\_loss: 0.4370 - val\_accuracy: 0.7990 - 386ms/epoch - 11ms/step

**plot**(history)

A graph with red and blue lines

Description automatically generated

*# Using the model to make predictions*  
predictions <- **predict**(model, test\_features)

## 284/284 - 0s - 423ms/epoch - 1ms/step

test\_set**$**p\_prob <- predictions[, 1]  
**head**(predictions, 10)

## [,1]  
## [1,] 0.07948324  
## [2,] 0.03747618  
## [3,] 0.10787603  
## [4,] 0.04403732  
## [5,] 0.52117199  
## [6,] 0.09139957  
## [7,] 0.04189007  
## [8,] 0.95274347  
## [9,] 0.03495034  
## [10,] 0.02473943

predicted\_class <- (predictions[, 1] **>=** 0.5) **\*** 1  
**head**(predicted\_class, 10)

## [1] 0 0 0 0 1 0 0 1 0 0

*# Calculating accuracy*  
accuracy <- **mean**(predicted\_class **==** test\_labels)  
accuracy

## [1] 0.8001987

*# Making predictions and calculating fpr and tpr rates at 0.5 threshold*  
over\_threshold <- test\_set[test\_set**$**p\_prob **>=** 0.5, ]  
fpr <- **sum**(over\_threshold**$**booking\_status**==**0)**/sum**(test\_set**$**booking\_status**==**0)  
fpr

## [1] 0.1106312

tpr <- **sum**(over\_threshold**$**booking\_status**==**1)**/sum**(test\_set**$**booking\_status**==**1)  
tpr

## [1] 0.6235604

*# Plotting ROC curve*  
roc\_data <- **data.frame**(threshold = **seq**(1, 0, **-**0.01), fpr = 0, tpr = 0)  
**for** (i **in** roc\_data**$**threshold) {  
 over\_threshold <- test\_set[test\_set**$**p\_prob **>=** i, ]  
 fpr <- **sum**(over\_threshold**$**booking\_status**==**0)**/sum**(test\_set**$**booking\_status**==**0)  
 roc\_data[roc\_data**$**threshold**==**i, "fpr"] <- fpr  
 tpr <- **sum**(over\_threshold**$**booking\_status**==**1)**/sum**(test\_set**$**booking\_status**==**1)  
 roc\_data[roc\_data**$**threshold**==**i, "tpr"] <- tpr  
}  
**ggplot**() **+**   
 **geom\_line**(data = roc\_data,   
 **aes**(x = fpr, y = tpr, color = threshold), linewidth = 2) **+**   
 **scale\_color\_gradientn**(colors = **rainbow**(3)) **+**   
 **geom\_abline**(intercept = 0, slope = 1, lty = 2) **+**   
 **geom\_point**(data = roc\_data[**seq**(1, 101, 10), ], **aes**(x = fpr, y = tpr)) **+**   
 **geom\_text**(data = roc\_data[**seq**(1, 101, 10), ],   
 **aes**(x = fpr, y = tpr, label = threshold, hjust = 1.2, vjust = **-**0.2))

A graph with a line

Description automatically generated

*# Calculating the AUC*  
auc <- **auc**(x = roc\_data**$**fpr, y = roc\_data**$**tpr, type = "spline")

## Warning in regularize.values(x, y, ties, missing(ties)): collapsing to unique  
## 'x' values

auc

## [1] 0.8594633

*# Creating a calibration curve*  
in\_interval <- test\_set[test\_set**$**p\_prob **>=** 0.7 **&** test\_set**$**p\_prob **<=** 0.8, ]  
**nrow**(in\_interval[in\_interval**$**booking\_status**==**1, ])**/nrow**(in\_interval)

## [1] 0.683908

calibration\_data <- **data.frame**(bin\_midpoint=**seq**(0.05,0.95,0.1),  
 observed\_event\_percentage=0)  
**for** (i **in** **seq**(0.05,0.95,0.1)) {  
 in\_interval <- test\_set[test\_set**$**p\_prob **>=** (i-0.05) **&** test\_set**$**p\_prob **<=** (i+0.05), ]  
 oep <- **nrow**(in\_interval[in\_interval**$**booking\_status**==**1, ])**/nrow**(in\_interval)  
 calibration\_data[calibration\_data**$**bin\_midpoint**==**i, "observed\_event\_percentage"] <- oep  
}  
**ggplot**(data = calibration\_data, **aes**(x = bin\_midpoint, y = observed\_event\_percentage)) **+**  
 **geom\_line**(linewidth = 1) **+**  
 **geom\_abline**(intercept = 0, slope = 1, lty = 2) **+**  
 **geom\_point**(size = 2) **+**  
 **geom\_text**(**aes**(label = bin\_midpoint), hjust = 0.75, vjust = **-**0.5)

A graph with a line going up

Description automatically generated

*# Building another neural network model*  
model <- **keras\_model\_sequential**() **%>%**  
 **layer\_dense**(units = 80, activation = "tanh") **%>%**  
 **layer\_dropout**(rate = 0.3) **%>%**   
 **layer\_dense**(units = 40, activation = "tanh") **%>%**  
 **layer\_dropout**(rate = 0.2) **%>%**   
 **layer\_dense**(units = 20, activation = "tanh") **%>%**  
 **layer\_dropout**(rate = 0.2) **%>%**   
 **layer\_dense**(units = 1, activation = "sigmoid")  
  
*# Compile the model*  
**compile**(model,   
 optimizer = "rmsprop",   
 loss = "binary\_crossentropy",   
 metrics = "accuracy")  
  
*# Define early stopping callback*  
early\_stop <- **callback\_early\_stopping**(  
 monitor = "val\_loss",  
 patience = 3  
)  
  
*# Training the model with early stopping*  
history <- **fit**(  
 model,  
 training\_features,  
 training\_labels,  
 epochs = 100,  
 batch\_size = 512,  
 validation\_split = 0.33,  
 callbacks = **list**(early\_stop)  
)

## Epoch 1/100  
## 36/36 - 2s - loss: 0.5503 - accuracy: 0.7154 - val\_loss: 0.4493 - val\_accuracy: 0.7978 - 2s/epoch - 60ms/step  
## Epoch 2/100  
## 36/36 - 1s - loss: 0.4744 - accuracy: 0.7770 - val\_loss: 0.4404 - val\_accuracy: 0.7955 - 517ms/epoch - 14ms/step  
## Epoch 3/100  
## 36/36 - 1s - loss: 0.4589 - accuracy: 0.7852 - val\_loss: 0.4365 - val\_accuracy: 0.8030 - 505ms/epoch - 14ms/step  
## Epoch 4/100  
## 36/36 - 1s - loss: 0.4498 - accuracy: 0.7925 - val\_loss: 0.4367 - val\_accuracy: 0.8013 - 503ms/epoch - 14ms/step  
## Epoch 5/100  
## 36/36 - 1s - loss: 0.4415 - accuracy: 0.7977 - val\_loss: 0.4361 - val\_accuracy: 0.8010 - 503ms/epoch - 14ms/step  
## Epoch 6/100  
## 36/36 - 1s - loss: 0.4362 - accuracy: 0.7991 - val\_loss: 0.4307 - val\_accuracy: 0.8062 - 505ms/epoch - 14ms/step  
## Epoch 7/100  
## 36/36 - 1s - loss: 0.4323 - accuracy: 0.8014 - val\_loss: 0.4294 - val\_accuracy: 0.8039 - 503ms/epoch - 14ms/step  
## Epoch 8/100  
## 36/36 - 1s - loss: 0.4285 - accuracy: 0.8021 - val\_loss: 0.4276 - val\_accuracy: 0.8039 - 504ms/epoch - 14ms/step  
## Epoch 9/100  
## 36/36 - 1s - loss: 0.4235 - accuracy: 0.8047 - val\_loss: 0.4246 - val\_accuracy: 0.8051 - 504ms/epoch - 14ms/step  
## Epoch 10/100  
## 36/36 - 1s - loss: 0.4223 - accuracy: 0.8056 - val\_loss: 0.4230 - val\_accuracy: 0.8042 - 600ms/epoch - 17ms/step  
## Epoch 11/100  
## 36/36 - 1s - loss: 0.4221 - accuracy: 0.8065 - val\_loss: 0.4193 - val\_accuracy: 0.8067 - 502ms/epoch - 14ms/step  
## Epoch 12/100  
## 36/36 - 1s - loss: 0.4191 - accuracy: 0.8084 - val\_loss: 0.4180 - val\_accuracy: 0.8064 - 502ms/epoch - 14ms/step  
## Epoch 13/100  
## 36/36 - 1s - loss: 0.4193 - accuracy: 0.8053 - val\_loss: 0.4157 - val\_accuracy: 0.8071 - 503ms/epoch - 14ms/step  
## Epoch 14/100  
## 36/36 - 0s - loss: 0.4140 - accuracy: 0.8085 - val\_loss: 0.4149 - val\_accuracy: 0.8069 - 499ms/epoch - 14ms/step  
## Epoch 15/100  
## 36/36 - 1s - loss: 0.4135 - accuracy: 0.8098 - val\_loss: 0.4142 - val\_accuracy: 0.8110 - 500ms/epoch - 14ms/step  
## Epoch 16/100  
## 36/36 - 1s - loss: 0.4102 - accuracy: 0.8108 - val\_loss: 0.4106 - val\_accuracy: 0.8107 - 508ms/epoch - 14ms/step  
## Epoch 17/100  
## 36/36 - 1s - loss: 0.4075 - accuracy: 0.8142 - val\_loss: 0.4091 - val\_accuracy: 0.8099 - 508ms/epoch - 14ms/step  
## Epoch 18/100  
## 36/36 - 1s - loss: 0.4081 - accuracy: 0.8108 - val\_loss: 0.4093 - val\_accuracy: 0.8107 - 515ms/epoch - 14ms/step  
## Epoch 19/100  
## 36/36 - 1s - loss: 0.4055 - accuracy: 0.8133 - val\_loss: 0.4051 - val\_accuracy: 0.8100 - 508ms/epoch - 14ms/step  
## Epoch 20/100  
## 36/36 - 1s - loss: 0.4069 - accuracy: 0.8081 - val\_loss: 0.4043 - val\_accuracy: 0.8127 - 508ms/epoch - 14ms/step  
## Epoch 21/100  
## 36/36 - 1s - loss: 0.4029 - accuracy: 0.8137 - val\_loss: 0.4031 - val\_accuracy: 0.8122 - 507ms/epoch - 14ms/step  
## Epoch 22/100  
## 36/36 - 1s - loss: 0.4029 - accuracy: 0.8140 - val\_loss: 0.4021 - val\_accuracy: 0.8122 - 506ms/epoch - 14ms/step  
## Epoch 23/100  
## 36/36 - 1s - loss: 0.4005 - accuracy: 0.8156 - val\_loss: 0.3998 - val\_accuracy: 0.8142 - 506ms/epoch - 14ms/step  
## Epoch 24/100  
## 36/36 - 1s - loss: 0.3977 - accuracy: 0.8135 - val\_loss: 0.3993 - val\_accuracy: 0.8125 - 512ms/epoch - 14ms/step  
## Epoch 25/100  
## 36/36 - 1s - loss: 0.3965 - accuracy: 0.8197 - val\_loss: 0.3968 - val\_accuracy: 0.8138 - 510ms/epoch - 14ms/step  
## Epoch 26/100  
## 36/36 - 1s - loss: 0.3939 - accuracy: 0.8206 - val\_loss: 0.3947 - val\_accuracy: 0.8138 - 506ms/epoch - 14ms/step  
## Epoch 27/100  
## 36/36 - 1s - loss: 0.3928 - accuracy: 0.8196 - val\_loss: 0.3938 - val\_accuracy: 0.8157 - 507ms/epoch - 14ms/step  
## Epoch 28/100  
## 36/36 - 1s - loss: 0.3924 - accuracy: 0.8181 - val\_loss: 0.3947 - val\_accuracy: 0.8162 - 508ms/epoch - 14ms/step  
## Epoch 29/100  
## 36/36 - 1s - loss: 0.3915 - accuracy: 0.8216 - val\_loss: 0.3921 - val\_accuracy: 0.8183 - 507ms/epoch - 14ms/step  
## Epoch 30/100  
## 36/36 - 1s - loss: 0.3905 - accuracy: 0.8197 - val\_loss: 0.3912 - val\_accuracy: 0.8178 - 580ms/epoch - 16ms/step  
## Epoch 31/100  
## 36/36 - 1s - loss: 0.3912 - accuracy: 0.8222 - val\_loss: 0.3898 - val\_accuracy: 0.8206 - 502ms/epoch - 14ms/step  
## Epoch 32/100  
## 36/36 - 1s - loss: 0.3874 - accuracy: 0.8243 - val\_loss: 0.3888 - val\_accuracy: 0.8190 - 501ms/epoch - 14ms/step  
## Epoch 33/100  
## 36/36 - 1s - loss: 0.3848 - accuracy: 0.8234 - val\_loss: 0.3860 - val\_accuracy: 0.8223 - 503ms/epoch - 14ms/step  
## Epoch 34/100  
## 36/36 - 1s - loss: 0.3881 - accuracy: 0.8229 - val\_loss: 0.3866 - val\_accuracy: 0.8230 - 503ms/epoch - 14ms/step  
## Epoch 35/100  
## 36/36 - 1s - loss: 0.3860 - accuracy: 0.8225 - val\_loss: 0.3846 - val\_accuracy: 0.8242 - 506ms/epoch - 14ms/step  
## Epoch 36/100  
## 36/36 - 1s - loss: 0.3827 - accuracy: 0.8280 - val\_loss: 0.3840 - val\_accuracy: 0.8213 - 516ms/epoch - 14ms/step  
## Epoch 37/100  
## 36/36 - 1s - loss: 0.3836 - accuracy: 0.8254 - val\_loss: 0.3832 - val\_accuracy: 0.8243 - 506ms/epoch - 14ms/step  
## Epoch 38/100  
## 36/36 - 1s - loss: 0.3797 - accuracy: 0.8283 - val\_loss: 0.3835 - val\_accuracy: 0.8260 - 521ms/epoch - 14ms/step  
## Epoch 39/100  
## 36/36 - 1s - loss: 0.3823 - accuracy: 0.8266 - val\_loss: 0.3811 - val\_accuracy: 0.8293 - 535ms/epoch - 15ms/step  
## Epoch 40/100  
## 36/36 - 1s - loss: 0.3785 - accuracy: 0.8267 - val\_loss: 0.3792 - val\_accuracy: 0.8282 - 591ms/epoch - 16ms/step  
## Epoch 41/100  
## 36/36 - 1s - loss: 0.3821 - accuracy: 0.8287 - val\_loss: 0.3780 - val\_accuracy: 0.8311 - 605ms/epoch - 17ms/step  
## Epoch 42/100  
## 36/36 - 1s - loss: 0.3800 - accuracy: 0.8253 - val\_loss: 0.3793 - val\_accuracy: 0.8300 - 601ms/epoch - 17ms/step  
## Epoch 43/100  
## 36/36 - 1s - loss: 0.3765 - accuracy: 0.8272 - val\_loss: 0.3797 - val\_accuracy: 0.8298 - 601ms/epoch - 17ms/step  
## Epoch 44/100  
## 36/36 - 1s - loss: 0.3770 - accuracy: 0.8274 - val\_loss: 0.3762 - val\_accuracy: 0.8327 - 593ms/epoch - 16ms/step  
## Epoch 45/100  
## 36/36 - 1s - loss: 0.3768 - accuracy: 0.8294 - val\_loss: 0.3753 - val\_accuracy: 0.8309 - 597ms/epoch - 17ms/step  
## Epoch 46/100  
## 36/36 - 1s - loss: 0.3744 - accuracy: 0.8327 - val\_loss: 0.3751 - val\_accuracy: 0.8324 - 591ms/epoch - 16ms/step  
## Epoch 47/100  
## 36/36 - 1s - loss: 0.3753 - accuracy: 0.8279 - val\_loss: 0.3741 - val\_accuracy: 0.8326 - 603ms/epoch - 17ms/step  
## Epoch 48/100  
## 36/36 - 1s - loss: 0.3693 - accuracy: 0.8311 - val\_loss: 0.3716 - val\_accuracy: 0.8329 - 594ms/epoch - 17ms/step  
## Epoch 49/100  
## 36/36 - 1s - loss: 0.3736 - accuracy: 0.8294 - val\_loss: 0.3718 - val\_accuracy: 0.8353 - 523ms/epoch - 15ms/step  
## Epoch 50/100  
## 36/36 - 1s - loss: 0.3718 - accuracy: 0.8345 - val\_loss: 0.3702 - val\_accuracy: 0.8363 - 506ms/epoch - 14ms/step  
## Epoch 51/100  
## 36/36 - 1s - loss: 0.3741 - accuracy: 0.8303 - val\_loss: 0.3694 - val\_accuracy: 0.8346 - 510ms/epoch - 14ms/step  
## Epoch 52/100  
## 36/36 - 1s - loss: 0.3686 - accuracy: 0.8339 - val\_loss: 0.3713 - val\_accuracy: 0.8341 - 509ms/epoch - 14ms/step  
## Epoch 53/100  
## 36/36 - 1s - loss: 0.3694 - accuracy: 0.8340 - val\_loss: 0.3689 - val\_accuracy: 0.8353 - 517ms/epoch - 14ms/step  
## Epoch 54/100  
## 36/36 - 1s - loss: 0.3703 - accuracy: 0.8341 - val\_loss: 0.3678 - val\_accuracy: 0.8351 - 508ms/epoch - 14ms/step  
## Epoch 55/100  
## 36/36 - 1s - loss: 0.3709 - accuracy: 0.8340 - val\_loss: 0.3681 - val\_accuracy: 0.8343 - 517ms/epoch - 14ms/step  
## Epoch 56/100  
## 36/36 - 1s - loss: 0.3671 - accuracy: 0.8353 - val\_loss: 0.3677 - val\_accuracy: 0.8361 - 528ms/epoch - 15ms/step  
## Epoch 57/100  
## 36/36 - 1s - loss: 0.3682 - accuracy: 0.8345 - val\_loss: 0.3691 - val\_accuracy: 0.8343 - 536ms/epoch - 15ms/step  
## Epoch 58/100  
## 36/36 - 1s - loss: 0.3710 - accuracy: 0.8326 - val\_loss: 0.3667 - val\_accuracy: 0.8370 - 514ms/epoch - 14ms/step  
## Epoch 59/100  
## 36/36 - 1s - loss: 0.3687 - accuracy: 0.8338 - val\_loss: 0.3669 - val\_accuracy: 0.8363 - 514ms/epoch - 14ms/step  
## Epoch 60/100  
## 36/36 - 1s - loss: 0.3643 - accuracy: 0.8378 - val\_loss: 0.3667 - val\_accuracy: 0.8349 - 519ms/epoch - 14ms/step  
## Epoch 61/100  
## 36/36 - 1s - loss: 0.3651 - accuracy: 0.8344 - val\_loss: 0.3648 - val\_accuracy: 0.8366 - 512ms/epoch - 14ms/step  
## Epoch 62/100  
## 36/36 - 1s - loss: 0.3607 - accuracy: 0.8384 - val\_loss: 0.3651 - val\_accuracy: 0.8372 - 517ms/epoch - 14ms/step  
## Epoch 63/100  
## 36/36 - 1s - loss: 0.3652 - accuracy: 0.8378 - val\_loss: 0.3644 - val\_accuracy: 0.8379 - 561ms/epoch - 16ms/step  
## Epoch 64/100  
## 36/36 - 1s - loss: 0.3631 - accuracy: 0.8368 - val\_loss: 0.3646 - val\_accuracy: 0.8376 - 526ms/epoch - 15ms/step  
## Epoch 65/100  
## 36/36 - 1s - loss: 0.3648 - accuracy: 0.8360 - val\_loss: 0.3626 - val\_accuracy: 0.8379 - 515ms/epoch - 14ms/step  
## Epoch 66/100  
## 36/36 - 1s - loss: 0.3631 - accuracy: 0.8374 - val\_loss: 0.3634 - val\_accuracy: 0.8370 - 521ms/epoch - 14ms/step  
## Epoch 67/100  
## 36/36 - 1s - loss: 0.3577 - accuracy: 0.8412 - val\_loss: 0.3626 - val\_accuracy: 0.8377 - 522ms/epoch - 14ms/step  
## Epoch 68/100  
## 36/36 - 1s - loss: 0.3630 - accuracy: 0.8367 - val\_loss: 0.3626 - val\_accuracy: 0.8378 - 518ms/epoch - 14ms/step  
## Epoch 69/100  
## 36/36 - 1s - loss: 0.3586 - accuracy: 0.8393 - val\_loss: 0.3611 - val\_accuracy: 0.8371 - 517ms/epoch - 14ms/step  
## Epoch 70/100  
## 36/36 - 1s - loss: 0.3591 - accuracy: 0.8402 - val\_loss: 0.3627 - val\_accuracy: 0.8388 - 513ms/epoch - 14ms/step  
## Epoch 71/100  
## 36/36 - 1s - loss: 0.3571 - accuracy: 0.8403 - val\_loss: 0.3599 - val\_accuracy: 0.8396 - 514ms/epoch - 14ms/step  
## Epoch 72/100  
## 36/36 - 1s - loss: 0.3573 - accuracy: 0.8391 - val\_loss: 0.3600 - val\_accuracy: 0.8385 - 514ms/epoch - 14ms/step  
## Epoch 73/100  
## 36/36 - 1s - loss: 0.3570 - accuracy: 0.8429 - val\_loss: 0.3588 - val\_accuracy: 0.8380 - 514ms/epoch - 14ms/step  
## Epoch 74/100  
## 36/36 - 1s - loss: 0.3588 - accuracy: 0.8376 - val\_loss: 0.3594 - val\_accuracy: 0.8400 - 513ms/epoch - 14ms/step  
## Epoch 75/100  
## 36/36 - 1s - loss: 0.3577 - accuracy: 0.8404 - val\_loss: 0.3575 - val\_accuracy: 0.8427 - 534ms/epoch - 15ms/step  
## Epoch 76/100  
## 36/36 - 1s - loss: 0.3554 - accuracy: 0.8406 - val\_loss: 0.3604 - val\_accuracy: 0.8417 - 522ms/epoch - 14ms/step  
## Epoch 77/100  
## 36/36 - 1s - loss: 0.3538 - accuracy: 0.8410 - val\_loss: 0.3584 - val\_accuracy: 0.8408 - 512ms/epoch - 14ms/step  
## Epoch 78/100  
## 36/36 - 1s - loss: 0.3565 - accuracy: 0.8421 - val\_loss: 0.3572 - val\_accuracy: 0.8389 - 515ms/epoch - 14ms/step  
## Epoch 79/100  
## 36/36 - 1s - loss: 0.3540 - accuracy: 0.8415 - val\_loss: 0.3579 - val\_accuracy: 0.8397 - 512ms/epoch - 14ms/step  
## Epoch 80/100  
## 36/36 - 1s - loss: 0.3550 - accuracy: 0.8396 - val\_loss: 0.3592 - val\_accuracy: 0.8388 - 514ms/epoch - 14ms/step  
## Epoch 81/100  
## 36/36 - 1s - loss: 0.3580 - accuracy: 0.8402 - val\_loss: 0.3564 - val\_accuracy: 0.8387 - 517ms/epoch - 14ms/step  
## Epoch 82/100  
## 36/36 - 1s - loss: 0.3528 - accuracy: 0.8414 - val\_loss: 0.3581 - val\_accuracy: 0.8396 - 516ms/epoch - 14ms/step  
## Epoch 83/100  
## 36/36 - 1s - loss: 0.3534 - accuracy: 0.8419 - val\_loss: 0.3561 - val\_accuracy: 0.8433 - 517ms/epoch - 14ms/step  
## Epoch 84/100  
## 36/36 - 1s - loss: 0.3529 - accuracy: 0.8410 - val\_loss: 0.3548 - val\_accuracy: 0.8429 - 534ms/epoch - 15ms/step  
## Epoch 85/100  
## 36/36 - 1s - loss: 0.3542 - accuracy: 0.8451 - val\_loss: 0.3559 - val\_accuracy: 0.8456 - 515ms/epoch - 14ms/step  
## Epoch 86/100  
## 36/36 - 1s - loss: 0.3511 - accuracy: 0.8435 - val\_loss: 0.3573 - val\_accuracy: 0.8425 - 513ms/epoch - 14ms/step  
## Epoch 87/100  
## 36/36 - 1s - loss: 0.3506 - accuracy: 0.8435 - val\_loss: 0.3560 - val\_accuracy: 0.8433 - 521ms/epoch - 14ms/step

*# Plot training history*  
**plot**(history)

A graph of data and data

Description automatically generated with medium confidence

*# Using the model to make predictions*  
predictions <- **predict**(model, test\_features)

## 284/284 - 1s - 578ms/epoch - 2ms/step

test\_set**$**p\_prob <- predictions[, 1]  
**head**(predictions, 10)

## [,1]  
## [1,] 0.121874869  
## [2,] 0.048223857  
## [3,] 0.040033769  
## [4,] 0.020202033  
## [5,] 0.115720607  
## [6,] 0.023871146  
## [7,] 0.008270793  
## [8,] 0.955575347  
## [9,] 0.013673816  
## [10,] 0.008958214

predicted\_class <- (predictions[, 1] **>=** 0.5) **\*** 1  
**head**(predicted\_class, 10)

## [1] 0 0 0 0 0 0 0 1 0 0

*# Calculating accuracy*  
accuracy <- **mean**(predicted\_class **==** test\_labels)  
accuracy

## [1] 0.8410421

*# Making predictions and calculating fpr and tpr rates at 0.5 threshold*  
over\_threshold <- test\_set[test\_set**$**p\_prob **>=** 0.5, ]  
fpr <- **sum**(over\_threshold**$**booking\_status**==**0)**/sum**(test\_set**$**booking\_status**==**0)  
fpr

## [1] 0.08554817

tpr <- **sum**(over\_threshold**$**booking\_status**==**1)**/sum**(test\_set**$**booking\_status**==**1)  
tpr

## [1] 0.6956236

*# Plotting ROC curve*  
roc\_data <- **data.frame**(threshold = **seq**(1, 0, **-**0.01), fpr = 0, tpr = 0)  
**for** (i **in** roc\_data**$**threshold) {  
 over\_threshold <- test\_set[test\_set**$**p\_prob **>=** i, ]  
 fpr <- **sum**(over\_threshold**$**booking\_status**==**0)**/sum**(test\_set**$**booking\_status**==**0)  
 roc\_data[roc\_data**$**threshold**==**i, "fpr"] <- fpr  
 tpr <- **sum**(over\_threshold**$**booking\_status**==**1)**/sum**(test\_set**$**booking\_status**==**1)  
 roc\_data[roc\_data**$**threshold**==**i, "tpr"] <- tpr  
}  
**ggplot**() **+**   
 **geom\_line**(data = roc\_data,   
 **aes**(x = fpr, y = tpr, color = threshold), linewidth = 2) **+**   
 **scale\_color\_gradientn**(colors = **rainbow**(3)) **+**   
 **geom\_abline**(intercept = 0, slope = 1, lty = 2) **+**   
 **geom\_point**(data = roc\_data[**seq**(1, 101, 10), ], **aes**(x = fpr, y = tpr)) **+**   
 **geom\_text**(data = roc\_data[**seq**(1, 101, 10), ],   
 **aes**(x = fpr, y = tpr, label = threshold, hjust = 1.2, vjust = **-**0.2))

A graph with a line

Description automatically generated with medium confidence

*# Calculating the AUC*  
auc <- **auc**(x = roc\_data**$**fpr, y = roc\_data**$**tpr, type = "spline")

## Warning in regularize.values(x, y, ties, missing(ties)): collapsing to unique  
## 'x' values

auc

## [1] 0.9041712

*# Creating a calibration curve*  
in\_interval <- test\_set[test\_set**$**p\_prob **>=** 0.7 **&** test\_set**$**p\_prob **<=** 0.8, ]  
**nrow**(in\_interval[in\_interval**$**booking\_status**==**1, ])**/nrow**(in\_interval)

## [1] 0.75

calibration\_data <- **data.frame**(bin\_midpoint=**seq**(0.05,0.95,0.1),  
 observed\_event\_percentage=0)  
**for** (i **in** **seq**(0.05,0.95,0.1)) {  
 in\_interval <- test\_set[test\_set**$**p\_prob **>=** (i-0.05) **&** test\_set**$**p\_prob **<=** (i+0.05), ]  
 oep <- **nrow**(in\_interval[in\_interval**$**booking\_status**==**1, ])**/nrow**(in\_interval)  
 calibration\_data[calibration\_data**$**bin\_midpoint**==**i, "observed\_event\_percentage"] <- oep  
}  
**ggplot**(data = calibration\_data, **aes**(x = bin\_midpoint, y = observed\_event\_percentage)) **+**  
 **geom\_line**(linewidth = 1) **+**  
 **geom\_abline**(intercept = 0, slope = 1, lty = 2) **+**  
 **geom\_point**(size = 2) **+**  
 **geom\_text**(**aes**(label = bin\_midpoint), hjust = 0.75, vjust = **-**0.5)

A graph with a line

Description automatically generated

*# Building another neural network model with PCA*  
*# Running PCA*  
pca\_results <- **prcomp**(training\_features)  
**summary**(pca\_results)

## Importance of components:  
## PC1 PC2 PC3 PC4 PC5 PC6 PC7  
## Standard deviation 1.76853 1.57206 1.36882 1.25127 1.22894 1.19765 1.12853  
## Proportion of Variance 0.07447 0.05884 0.04461 0.03728 0.03596 0.03415 0.03032  
## Cumulative Proportion 0.07447 0.13331 0.17792 0.21520 0.25116 0.28531 0.31563  
## PC8 PC9 PC10 PC11 PC12 PC13 PC14  
## Standard deviation 1.10616 1.09701 1.09130 1.08001 1.06595 1.05940 1.04791  
## Proportion of Variance 0.02913 0.02865 0.02836 0.02777 0.02705 0.02672 0.02615  
## Cumulative Proportion 0.34477 0.37342 0.40178 0.42955 0.45660 0.48332 0.50947  
## PC15 PC16 PC17 PC18 PC19 PC20 PC21  
## Standard deviation 1.04244 1.03552 1.0288 1.02333 1.01268 1.00460 0.99967  
## Proportion of Variance 0.02587 0.02553 0.0252 0.02493 0.02442 0.02403 0.02379  
## Cumulative Proportion 0.53534 0.56087 0.5861 0.61101 0.63542 0.65945 0.68325  
## PC22 PC23 PC24 PC25 PC26 PC27 PC28  
## Standard deviation 0.98848 0.98315 0.97693 0.9743 0.96261 0.95443 0.94294  
## Proportion of Variance 0.02326 0.02301 0.02272 0.0226 0.02206 0.02169 0.02117  
## Cumulative Proportion 0.70651 0.72952 0.75225 0.7749 0.79691 0.81860 0.83977  
## PC29 PC30 PC31 PC32 PC33 PC34 PC35  
## Standard deviation 0.92878 0.89286 0.85892 0.8250 0.81097 0.7721 0.71775  
## Proportion of Variance 0.02054 0.01898 0.01757 0.0162 0.01566 0.0142 0.01227  
## Cumulative Proportion 0.86031 0.87929 0.89685 0.9131 0.92872 0.9429 0.95518  
## PC36 PC37 PC38 PC39 PC40 PC41 PC42  
## Standard deviation 0.67507 0.64417 0.58820 0.53778 0.43749 0.42251 0.08219  
## Proportion of Variance 0.01085 0.00988 0.00824 0.00689 0.00456 0.00425 0.00016  
## Cumulative Proportion 0.96603 0.97591 0.98415 0.99103 0.99559 0.99984 1.00000

**screeplot**(pca\_results, type = "line")

A graph of a number of points

Description automatically generated

*# Reducing to 4 PCs*  
n\_components <- 4  
reduced\_training\_features <- pca\_results**$**x[, 1**:**n\_components]  
reduced\_test\_features <- **predict**(pca\_results, newdata = test\_features)[, 1**:**n\_components]  
  
pca\_model <- **keras\_model\_sequential**(**list**(  
 **layer\_dense**(units = 10, activation = "relu"),   
 **layer\_dense**(units = 5, activation = "relu"),   
 **layer\_dense**(units = 5, activation = "tanh"),   
 **layer\_dense**(units = 1, activation = "sigmoid")  
))  
**compile**(pca\_model,   
 optimizer = "rmsprop",   
 loss = "binary\_crossentropy",   
 metrics = "accuracy")  
  
*# Training the model*  
history <- **fit**(pca\_model, reduced\_training\_features, training\_labels,   
 epochs = 20, batch\_size = 512, validation\_split = 0.33)

## Epoch 1/20  
## 36/36 - 3s - loss: 0.6449 - accuracy: 0.6093 - val\_loss: 0.6228 - val\_accuracy: 0.6502 - 3s/epoch - 75ms/step  
## Epoch 2/20  
## 36/36 - 0s - loss: 0.6207 - accuracy: 0.6595 - val\_loss: 0.6040 - val\_accuracy: 0.6897 - 463ms/epoch - 13ms/step  
## Epoch 3/20  
## 36/36 - 0s - loss: 0.6025 - accuracy: 0.6908 - val\_loss: 0.5896 - val\_accuracy: 0.6915 - 462ms/epoch - 13ms/step  
## Epoch 4/20  
## 36/36 - 0s - loss: 0.5889 - accuracy: 0.6944 - val\_loss: 0.5826 - val\_accuracy: 0.6987 - 447ms/epoch - 12ms/step  
## Epoch 5/20  
## 36/36 - 0s - loss: 0.5803 - accuracy: 0.7071 - val\_loss: 0.5770 - val\_accuracy: 0.7020 - 449ms/epoch - 12ms/step  
## Epoch 6/20  
## 36/36 - 0s - loss: 0.5743 - accuracy: 0.7119 - val\_loss: 0.5711 - val\_accuracy: 0.7107 - 448ms/epoch - 12ms/step  
## Epoch 7/20  
## 36/36 - 0s - loss: 0.5693 - accuracy: 0.7156 - val\_loss: 0.5675 - val\_accuracy: 0.7143 - 444ms/epoch - 12ms/step  
## Epoch 8/20  
## 36/36 - 0s - loss: 0.5648 - accuracy: 0.7195 - val\_loss: 0.5633 - val\_accuracy: 0.7179 - 454ms/epoch - 13ms/step  
## Epoch 9/20  
## 36/36 - 0s - loss: 0.5608 - accuracy: 0.7195 - val\_loss: 0.5606 - val\_accuracy: 0.7200 - 445ms/epoch - 12ms/step  
## Epoch 10/20  
## 36/36 - 0s - loss: 0.5572 - accuracy: 0.7233 - val\_loss: 0.5585 - val\_accuracy: 0.7241 - 440ms/epoch - 12ms/step  
## Epoch 11/20  
## 36/36 - 0s - loss: 0.5540 - accuracy: 0.7250 - val\_loss: 0.5545 - val\_accuracy: 0.7213 - 447ms/epoch - 12ms/step  
## Epoch 12/20  
## 36/36 - 0s - loss: 0.5507 - accuracy: 0.7251 - val\_loss: 0.5569 - val\_accuracy: 0.7268 - 449ms/epoch - 12ms/step  
## Epoch 13/20  
## 36/36 - 0s - loss: 0.5480 - accuracy: 0.7278 - val\_loss: 0.5522 - val\_accuracy: 0.7283 - 449ms/epoch - 12ms/step  
## Epoch 14/20  
## 36/36 - 0s - loss: 0.5454 - accuracy: 0.7294 - val\_loss: 0.5492 - val\_accuracy: 0.7307 - 444ms/epoch - 12ms/step  
## Epoch 15/20  
## 36/36 - 0s - loss: 0.5429 - accuracy: 0.7327 - val\_loss: 0.5488 - val\_accuracy: 0.7320 - 449ms/epoch - 12ms/step  
## Epoch 16/20  
## 36/36 - 0s - loss: 0.5406 - accuracy: 0.7351 - val\_loss: 0.5473 - val\_accuracy: 0.7358 - 445ms/epoch - 12ms/step  
## Epoch 17/20  
## 36/36 - 0s - loss: 0.5386 - accuracy: 0.7381 - val\_loss: 0.5481 - val\_accuracy: 0.7344 - 444ms/epoch - 12ms/step  
## Epoch 18/20  
## 36/36 - 0s - loss: 0.5369 - accuracy: 0.7383 - val\_loss: 0.5502 - val\_accuracy: 0.7326 - 446ms/epoch - 12ms/step  
## Epoch 19/20  
## 36/36 - 0s - loss: 0.5353 - accuracy: 0.7383 - val\_loss: 0.5459 - val\_accuracy: 0.7369 - 451ms/epoch - 13ms/step  
## Epoch 20/20  
## 36/36 - 0s - loss: 0.5345 - accuracy: 0.7400 - val\_loss: 0.5436 - val\_accuracy: 0.7336 - 463ms/epoch - 13ms/step

**plot**(history)

A graph of data and data

Description automatically generated

*# Using the model to make predictions*  
pca\_predictions <- **predict**(pca\_model, reduced\_test\_features)

## 284/284 - 0s - 472ms/epoch - 2ms/step

test\_set**$**p\_prob <- pca\_predictions[, 1]  
**head**(pca\_predictions, 10)

## [,1]  
## [1,] 0.2031607  
## [2,] 0.1186430  
## [3,] 0.2716128  
## [4,] 0.2154604  
## [5,] 0.4540634  
## [6,] 0.2371480  
## [7,] 0.1043686  
## [8,] 0.7723917  
## [9,] 0.1244992  
## [10,] 0.1428141

pca\_predicted\_class <- (pca\_predictions[, 1] **>=** 0.5) **\*** 1  
**head**(pca\_predicted\_class, 10)

## [1] 0 0 0 0 0 0 0 1 0 0

*# Calculating accuracy*  
pca\_accuracy <- **mean**(pca\_predicted\_class **==** test\_labels)  
pca\_accuracy

## [1] 0.7280053

*# Tuning the model*  
parameterGrid <- **expand.grid**(  
 units = **c**(5, 10, 15, 20),  
 activation = **c**("relu", "tanh", "sigmoid")  
)  
  
*# Define a function to create a neural network model*  
create\_model <- **function**(units, activation, learning\_rate) {  
 model <- **keras\_model\_sequential**() **%>%**  
 **layer\_dense**(units = units, activation = activation, input\_shape = **ncol**(reduced\_training\_features)) **%>%**  
 **layer\_dense**(units = units, activation = activation) **%>%**  
 **layer\_dense**(units = units, activation = activation) **%>%**  
 **layer\_dense**(units = 1, activation = "sigmoid")  
   
 **compile**(model, optimizer = "rmsprop", loss = "binary\_crossentropy", metrics = "accuracy")  
   
 **return**(model)  
}  
  
*# Perform grid search*  
results <- **list**()  
**for** (i **in** 1**:nrow**(parameterGrid)) {  
 model <- **create\_model**(parameterGrid**$**units[i], parameterGrid**$**activation[i], parameterGrid**$**learning\_rate[i])  
   
 history <- **fit**(model,   
 x = reduced\_training\_features,   
 y = training\_labels,   
 epochs = 10,   
 batch\_size = 512,   
 validation\_split = 0.33)  
   
 results[[i]] <- **list**(model = model, history = history)  
}

## Epoch 1/10  
## 36/36 - 2s - loss: 0.7330 - accuracy: 0.5925 - val\_loss: 0.6445 - val\_accuracy: 0.6338 - 2s/epoch - 42ms/step  
## Epoch 2/10  
## 36/36 - 0s - loss: 0.6316 - accuracy: 0.6425 - val\_loss: 0.6031 - val\_accuracy: 0.6670 - 450ms/epoch - 12ms/step  
## Epoch 3/10  
## 36/36 - 0s - loss: 0.6057 - accuracy: 0.6693 - val\_loss: 0.5934 - val\_accuracy: 0.6776 - 450ms/epoch - 13ms/step  
## Epoch 4/10  
## 36/36 - 0s - loss: 0.5981 - accuracy: 0.6821 - val\_loss: 0.5901 - val\_accuracy: 0.6876 - 452ms/epoch - 13ms/step  
## Epoch 5/10  
## 36/36 - 0s - loss: 0.5958 - accuracy: 0.6893 - val\_loss: 0.5895 - val\_accuracy: 0.6844 - 448ms/epoch - 12ms/step  
## Epoch 6/10  
## 36/36 - 0s - loss: 0.5952 - accuracy: 0.6903 - val\_loss: 0.5901 - val\_accuracy: 0.6881 - 446ms/epoch - 12ms/step  
## Epoch 7/10  
## 36/36 - 0s - loss: 0.5954 - accuracy: 0.6921 - val\_loss: 0.5906 - val\_accuracy: 0.6890 - 441ms/epoch - 12ms/step  
## Epoch 8/10  
## 36/36 - 0s - loss: 0.5953 - accuracy: 0.6915 - val\_loss: 0.5913 - val\_accuracy: 0.6864 - 447ms/epoch - 12ms/step  
## Epoch 9/10  
## 36/36 - 0s - loss: 0.5952 - accuracy: 0.6925 - val\_loss: 0.5912 - val\_accuracy: 0.6873 - 443ms/epoch - 12ms/step  
## Epoch 10/10  
## 36/36 - 0s - loss: 0.5951 - accuracy: 0.6923 - val\_loss: 0.5905 - val\_accuracy: 0.6873 - 443ms/epoch - 12ms/step  
## Epoch 1/10  
## 36/36 - 2s - loss: 0.7019 - accuracy: 0.5591 - val\_loss: 0.6436 - val\_accuracy: 0.6728 - 2s/epoch - 45ms/step  
## Epoch 2/10  
## 36/36 - 0s - loss: 0.6194 - accuracy: 0.6866 - val\_loss: 0.5992 - val\_accuracy: 0.6923 - 461ms/epoch - 13ms/step  
## Epoch 3/10  
## 36/36 - 0s - loss: 0.5932 - accuracy: 0.6938 - val\_loss: 0.5833 - val\_accuracy: 0.7008 - 469ms/epoch - 13ms/step  
## Epoch 4/10  
## 36/36 - 0s - loss: 0.5829 - accuracy: 0.6994 - val\_loss: 0.5786 - val\_accuracy: 0.7000 - 450ms/epoch - 13ms/step  
## Epoch 5/10  
## 36/36 - 0s - loss: 0.5794 - accuracy: 0.7020 - val\_loss: 0.5761 - val\_accuracy: 0.7028 - 450ms/epoch - 13ms/step  
## Epoch 6/10  
## 36/36 - 0s - loss: 0.5771 - accuracy: 0.7064 - val\_loss: 0.5746 - val\_accuracy: 0.7035 - 453ms/epoch - 13ms/step  
## Epoch 7/10  
## 36/36 - 0s - loss: 0.5757 - accuracy: 0.7064 - val\_loss: 0.5750 - val\_accuracy: 0.7094 - 479ms/epoch - 13ms/step  
## Epoch 8/10  
## 36/36 - 0s - loss: 0.5746 - accuracy: 0.7090 - val\_loss: 0.5760 - val\_accuracy: 0.7091 - 462ms/epoch - 13ms/step  
## Epoch 9/10  
## 36/36 - 0s - loss: 0.5742 - accuracy: 0.7103 - val\_loss: 0.5756 - val\_accuracy: 0.6994 - 454ms/epoch - 13ms/step  
## Epoch 10/10  
## 36/36 - 0s - loss: 0.5739 - accuracy: 0.7092 - val\_loss: 0.5730 - val\_accuracy: 0.7051 - 454ms/epoch - 13ms/step  
## Epoch 1/10  
## 36/36 - 3s - loss: 0.6355 - accuracy: 0.6547 - val\_loss: 0.6055 - val\_accuracy: 0.6876 - 3s/epoch - 77ms/step  
## Epoch 2/10  
## 36/36 - 0s - loss: 0.6040 - accuracy: 0.6840 - val\_loss: 0.5908 - val\_accuracy: 0.6980 - 461ms/epoch - 13ms/step  
## Epoch 3/10  
## 36/36 - 0s - loss: 0.5918 - accuracy: 0.6981 - val\_loss: 0.5836 - val\_accuracy: 0.6989 - 457ms/epoch - 13ms/step  
## Epoch 4/10  
## 36/36 - 0s - loss: 0.5865 - accuracy: 0.6989 - val\_loss: 0.5808 - val\_accuracy: 0.6987 - 448ms/epoch - 12ms/step  
## Epoch 5/10  
## 36/36 - 0s - loss: 0.5831 - accuracy: 0.6990 - val\_loss: 0.5792 - val\_accuracy: 0.6998 - 436ms/epoch - 12ms/step  
## Epoch 6/10  
## 36/36 - 0s - loss: 0.5808 - accuracy: 0.7011 - val\_loss: 0.5806 - val\_accuracy: 0.6948 - 439ms/epoch - 12ms/step  
## Epoch 7/10  
## 36/36 - 0s - loss: 0.5799 - accuracy: 0.7016 - val\_loss: 0.5754 - val\_accuracy: 0.7071 - 441ms/epoch - 12ms/step  
## Epoch 8/10  
## 36/36 - 0s - loss: 0.5801 - accuracy: 0.7000 - val\_loss: 0.5882 - val\_accuracy: 0.6829 - 435ms/epoch - 12ms/step  
## Epoch 9/10  
## 36/36 - 0s - loss: 0.5790 - accuracy: 0.7010 - val\_loss: 0.5843 - val\_accuracy: 0.6849 - 447ms/epoch - 12ms/step  
## Epoch 10/10  
## 36/36 - 0s - loss: 0.5791 - accuracy: 0.6994 - val\_loss: 0.5750 - val\_accuracy: 0.7038 - 446ms/epoch - 12ms/step  
## Epoch 1/10  
## 36/36 - 2s - loss: 0.6619 - accuracy: 0.5869 - val\_loss: 0.6151 - val\_accuracy: 0.6581 - 2s/epoch - 47ms/step  
## Epoch 2/10  
## 36/36 - 0s - loss: 0.6034 - accuracy: 0.6724 - val\_loss: 0.5916 - val\_accuracy: 0.6776 - 477ms/epoch - 13ms/step  
## Epoch 3/10  
## 36/36 - 0s - loss: 0.5862 - accuracy: 0.6939 - val\_loss: 0.5775 - val\_accuracy: 0.7001 - 451ms/epoch - 13ms/step  
## Epoch 4/10  
## 36/36 - 0s - loss: 0.5831 - accuracy: 0.6966 - val\_loss: 0.5789 - val\_accuracy: 0.6940 - 452ms/epoch - 13ms/step  
## Epoch 5/10  
## 36/36 - 0s - loss: 0.5807 - accuracy: 0.7000 - val\_loss: 0.5801 - val\_accuracy: 0.6906 - 448ms/epoch - 12ms/step  
## Epoch 6/10  
## 36/36 - 0s - loss: 0.5801 - accuracy: 0.6988 - val\_loss: 0.5760 - val\_accuracy: 0.6994 - 437ms/epoch - 12ms/step  
## Epoch 7/10  
## 36/36 - 0s - loss: 0.5845 - accuracy: 0.6909 - val\_loss: 0.5901 - val\_accuracy: 0.6808 - 446ms/epoch - 12ms/step  
## Epoch 8/10  
## 36/36 - 0s - loss: 0.5835 - accuracy: 0.6932 - val\_loss: 0.5924 - val\_accuracy: 0.6769 - 439ms/epoch - 12ms/step  
## Epoch 9/10  
## 36/36 - 0s - loss: 0.5870 - accuracy: 0.6853 - val\_loss: 0.5937 - val\_accuracy: 0.6760 - 442ms/epoch - 12ms/step  
## Epoch 10/10  
## 36/36 - 1s - loss: 0.5886 - accuracy: 0.6850 - val\_loss: 0.5854 - val\_accuracy: 0.6858 - 529ms/epoch - 15ms/step  
## Epoch 1/10  
## 36/36 - 2s - loss: 0.7209 - accuracy: 0.4838 - val\_loss: 0.6875 - val\_accuracy: 0.5523 - 2s/epoch - 49ms/step  
## Epoch 2/10  
## 36/36 - 0s - loss: 0.6688 - accuracy: 0.6182 - val\_loss: 0.6470 - val\_accuracy: 0.6838 - 481ms/epoch - 13ms/step  
## Epoch 3/10  
## 36/36 - 0s - loss: 0.6338 - accuracy: 0.6893 - val\_loss: 0.6181 - val\_accuracy: 0.6920 - 462ms/epoch - 13ms/step  
## Epoch 4/10  
## 36/36 - 0s - loss: 0.6093 - accuracy: 0.7000 - val\_loss: 0.5989 - val\_accuracy: 0.6978 - 471ms/epoch - 13ms/step  
## Epoch 5/10  
## 36/36 - 0s - loss: 0.5938 - accuracy: 0.7001 - val\_loss: 0.5863 - val\_accuracy: 0.6979 - 486ms/epoch - 14ms/step  
## Epoch 6/10  
## 36/36 - 0s - loss: 0.5836 - accuracy: 0.6998 - val\_loss: 0.5787 - val\_accuracy: 0.7029 - 460ms/epoch - 13ms/step  
## Epoch 7/10  
## 36/36 - 0s - loss: 0.5767 - accuracy: 0.7039 - val\_loss: 0.5731 - val\_accuracy: 0.7041 - 462ms/epoch - 13ms/step  
## Epoch 8/10  
## 36/36 - 0s - loss: 0.5712 - accuracy: 0.7094 - val\_loss: 0.5686 - val\_accuracy: 0.7109 - 470ms/epoch - 13ms/step  
## Epoch 9/10  
## 36/36 - 0s - loss: 0.5661 - accuracy: 0.7150 - val\_loss: 0.5642 - val\_accuracy: 0.7232 - 463ms/epoch - 13ms/step  
## Epoch 10/10  
## 36/36 - 1s - loss: 0.5619 - accuracy: 0.7240 - val\_loss: 0.5617 - val\_accuracy: 0.7179 - 502ms/epoch - 14ms/step  
## Epoch 1/10  
## 36/36 - 2s - loss: 0.7111 - accuracy: 0.5361 - val\_loss: 0.6608 - val\_accuracy: 0.6350 - 2s/epoch - 53ms/step  
## Epoch 2/10  
## 36/36 - 1s - loss: 0.6321 - accuracy: 0.6649 - val\_loss: 0.6091 - val\_accuracy: 0.6799 - 504ms/epoch - 14ms/step  
## Epoch 3/10  
## 36/36 - 1s - loss: 0.5966 - accuracy: 0.6908 - val\_loss: 0.5852 - val\_accuracy: 0.6952 - 501ms/epoch - 14ms/step  
## Epoch 4/10  
## 36/36 - 1s - loss: 0.5792 - accuracy: 0.7078 - val\_loss: 0.5728 - val\_accuracy: 0.7115 - 522ms/epoch - 14ms/step  
## Epoch 5/10  
## 36/36 - 1s - loss: 0.5688 - accuracy: 0.7140 - val\_loss: 0.5663 - val\_accuracy: 0.7143 - 509ms/epoch - 14ms/step  
## Epoch 6/10  
## 36/36 - 0s - loss: 0.5620 - accuracy: 0.7215 - val\_loss: 0.5638 - val\_accuracy: 0.7215 - 498ms/epoch - 14ms/step  
## Epoch 7/10  
## 36/36 - 0s - loss: 0.5577 - accuracy: 0.7257 - val\_loss: 0.5601 - val\_accuracy: 0.7246 - 473ms/epoch - 13ms/step  
## Epoch 8/10  
## 36/36 - 0s - loss: 0.5542 - accuracy: 0.7287 - val\_loss: 0.5598 - val\_accuracy: 0.7205 - 472ms/epoch - 13ms/step  
## Epoch 9/10  
## 36/36 - 0s - loss: 0.5515 - accuracy: 0.7302 - val\_loss: 0.5569 - val\_accuracy: 0.7231 - 475ms/epoch - 13ms/step  
## Epoch 10/10  
## 36/36 - 0s - loss: 0.5490 - accuracy: 0.7310 - val\_loss: 0.5576 - val\_accuracy: 0.7224 - 469ms/epoch - 13ms/step  
## Epoch 1/10  
## 36/36 - 2s - loss: 0.6199 - accuracy: 0.6623 - val\_loss: 0.5875 - val\_accuracy: 0.7023 - 2s/epoch - 54ms/step  
## Epoch 2/10  
## 36/36 - 1s - loss: 0.5750 - accuracy: 0.7144 - val\_loss: 0.5743 - val\_accuracy: 0.7099 - 502ms/epoch - 14ms/step  
## Epoch 3/10  
## 36/36 - 0s - loss: 0.5634 - accuracy: 0.7232 - val\_loss: 0.5674 - val\_accuracy: 0.7162 - 467ms/epoch - 13ms/step  
## Epoch 4/10  
## 36/36 - 0s - loss: 0.5592 - accuracy: 0.7262 - val\_loss: 0.5644 - val\_accuracy: 0.7195 - 493ms/epoch - 14ms/step  
## Epoch 5/10  
## 36/36 - 0s - loss: 0.5572 - accuracy: 0.7279 - val\_loss: 0.5628 - val\_accuracy: 0.7235 - 462ms/epoch - 13ms/step  
## Epoch 6/10  
## 36/36 - 0s - loss: 0.5552 - accuracy: 0.7289 - val\_loss: 0.5609 - val\_accuracy: 0.7226 - 476ms/epoch - 13ms/step  
## Epoch 7/10  
## 36/36 - 0s - loss: 0.5536 - accuracy: 0.7298 - val\_loss: 0.5647 - val\_accuracy: 0.7134 - 475ms/epoch - 13ms/step  
## Epoch 8/10  
## 36/36 - 0s - loss: 0.5515 - accuracy: 0.7291 - val\_loss: 0.5644 - val\_accuracy: 0.7143 - 458ms/epoch - 13ms/step  
## Epoch 9/10  
## 36/36 - 0s - loss: 0.5497 - accuracy: 0.7286 - val\_loss: 0.5591 - val\_accuracy: 0.7203 - 461ms/epoch - 13ms/step  
## Epoch 10/10  
## 36/36 - 0s - loss: 0.5475 - accuracy: 0.7282 - val\_loss: 0.5587 - val\_accuracy: 0.7198 - 467ms/epoch - 13ms/step  
## Epoch 1/10  
## 36/36 - 2s - loss: 0.6159 - accuracy: 0.6608 - val\_loss: 0.5827 - val\_accuracy: 0.7061 - 2s/epoch - 54ms/step  
## Epoch 2/10  
## 36/36 - 0s - loss: 0.5700 - accuracy: 0.7165 - val\_loss: 0.5670 - val\_accuracy: 0.7156 - 490ms/epoch - 14ms/step  
## Epoch 3/10  
## 36/36 - 0s - loss: 0.5608 - accuracy: 0.7250 - val\_loss: 0.5654 - val\_accuracy: 0.7197 - 493ms/epoch - 14ms/step  
## Epoch 4/10  
## 36/36 - 0s - loss: 0.5579 - accuracy: 0.7268 - val\_loss: 0.5615 - val\_accuracy: 0.7194 - 470ms/epoch - 13ms/step  
## Epoch 5/10  
## 36/36 - 0s - loss: 0.5552 - accuracy: 0.7284 - val\_loss: 0.5605 - val\_accuracy: 0.7210 - 472ms/epoch - 13ms/step  
## Epoch 6/10  
## 36/36 - 0s - loss: 0.5526 - accuracy: 0.7308 - val\_loss: 0.5596 - val\_accuracy: 0.7196 - 462ms/epoch - 13ms/step  
## Epoch 7/10  
## 36/36 - 0s - loss: 0.5499 - accuracy: 0.7327 - val\_loss: 0.5567 - val\_accuracy: 0.7229 - 459ms/epoch - 13ms/step  
## Epoch 8/10  
## 36/36 - 0s - loss: 0.5477 - accuracy: 0.7339 - val\_loss: 0.5580 - val\_accuracy: 0.7212 - 460ms/epoch - 13ms/step  
## Epoch 9/10  
## 36/36 - 0s - loss: 0.5448 - accuracy: 0.7339 - val\_loss: 0.5566 - val\_accuracy: 0.7227 - 469ms/epoch - 13ms/step  
## Epoch 10/10  
## 36/36 - 0s - loss: 0.5414 - accuracy: 0.7366 - val\_loss: 0.5552 - val\_accuracy: 0.7202 - 456ms/epoch - 13ms/step  
## Epoch 1/10  
## 36/36 - 2s - loss: 0.6596 - accuracy: 0.6769 - val\_loss: 0.6499 - val\_accuracy: 0.6706 - 2s/epoch - 55ms/step  
## Epoch 2/10  
## 36/36 - 0s - loss: 0.6405 - accuracy: 0.6769 - val\_loss: 0.6382 - val\_accuracy: 0.6706 - 485ms/epoch - 13ms/step  
## Epoch 3/10  
## 36/36 - 0s - loss: 0.6316 - accuracy: 0.6769 - val\_loss: 0.6339 - val\_accuracy: 0.6706 - 461ms/epoch - 13ms/step  
## Epoch 4/10  
## 36/36 - 0s - loss: 0.6288 - accuracy: 0.6769 - val\_loss: 0.6331 - val\_accuracy: 0.6706 - 476ms/epoch - 13ms/step  
## Epoch 5/10  
## 36/36 - 0s - loss: 0.6280 - accuracy: 0.6769 - val\_loss: 0.6323 - val\_accuracy: 0.6706 - 457ms/epoch - 13ms/step  
## Epoch 6/10  
## 36/36 - 0s - loss: 0.6272 - accuracy: 0.6769 - val\_loss: 0.6315 - val\_accuracy: 0.6706 - 458ms/epoch - 13ms/step  
## Epoch 7/10  
## 36/36 - 0s - loss: 0.6265 - accuracy: 0.6769 - val\_loss: 0.6307 - val\_accuracy: 0.6706 - 472ms/epoch - 13ms/step  
## Epoch 8/10  
## 36/36 - 0s - loss: 0.6257 - accuracy: 0.6769 - val\_loss: 0.6300 - val\_accuracy: 0.6706 - 458ms/epoch - 13ms/step  
## Epoch 9/10  
## 36/36 - 0s - loss: 0.6249 - accuracy: 0.6769 - val\_loss: 0.6289 - val\_accuracy: 0.6706 - 458ms/epoch - 13ms/step  
## Epoch 10/10  
## 36/36 - 0s - loss: 0.6239 - accuracy: 0.6769 - val\_loss: 0.6279 - val\_accuracy: 0.6706 - 455ms/epoch - 13ms/step  
## Epoch 1/10  
## 36/36 - 2s - loss: 1.0609 - accuracy: 0.3231 - val\_loss: 0.9571 - val\_accuracy: 0.3294 - 2s/epoch - 57ms/step  
## Epoch 2/10  
## 36/36 - 0s - loss: 0.8954 - accuracy: 0.3231 - val\_loss: 0.8254 - val\_accuracy: 0.3294 - 489ms/epoch - 14ms/step  
## Epoch 3/10  
## 36/36 - 0s - loss: 0.7800 - accuracy: 0.3231 - val\_loss: 0.7325 - val\_accuracy: 0.3294 - 484ms/epoch - 13ms/step  
## Epoch 4/10  
## 36/36 - 1s - loss: 0.7017 - accuracy: 0.4577 - val\_loss: 0.6733 - val\_accuracy: 0.6706 - 509ms/epoch - 14ms/step  
## Epoch 5/10  
## 36/36 - 0s - loss: 0.6553 - accuracy: 0.6769 - val\_loss: 0.6425 - val\_accuracy: 0.6706 - 478ms/epoch - 13ms/step  
## Epoch 6/10  
## 36/36 - 0s - loss: 0.6335 - accuracy: 0.6769 - val\_loss: 0.6316 - val\_accuracy: 0.6706 - 474ms/epoch - 13ms/step  
## Epoch 7/10  
## 36/36 - 0s - loss: 0.6268 - accuracy: 0.6769 - val\_loss: 0.6296 - val\_accuracy: 0.6706 - 487ms/epoch - 14ms/step  
## Epoch 8/10  
## 36/36 - 0s - loss: 0.6253 - accuracy: 0.6769 - val\_loss: 0.6286 - val\_accuracy: 0.6706 - 480ms/epoch - 13ms/step  
## Epoch 9/10  
## 36/36 - 0s - loss: 0.6241 - accuracy: 0.6769 - val\_loss: 0.6273 - val\_accuracy: 0.6706 - 471ms/epoch - 13ms/step  
## Epoch 10/10  
## 36/36 - 0s - loss: 0.6228 - accuracy: 0.6769 - val\_loss: 0.6253 - val\_accuracy: 0.6706 - 470ms/epoch - 13ms/step  
## Epoch 1/10  
## 36/36 - 2s - loss: 0.6282 - accuracy: 0.6769 - val\_loss: 0.6317 - val\_accuracy: 0.6706 - 2s/epoch - 51ms/step  
## Epoch 2/10  
## 36/36 - 1s - loss: 0.6265 - accuracy: 0.6769 - val\_loss: 0.6298 - val\_accuracy: 0.6706 - 571ms/epoch - 16ms/step  
## Epoch 3/10  
## 36/36 - 0s - loss: 0.6241 - accuracy: 0.6769 - val\_loss: 0.6267 - val\_accuracy: 0.6706 - 463ms/epoch - 13ms/step  
## Epoch 4/10  
## 36/36 - 0s - loss: 0.6206 - accuracy: 0.6769 - val\_loss: 0.6218 - val\_accuracy: 0.6706 - 468ms/epoch - 13ms/step  
## Epoch 5/10  
## 36/36 - 0s - loss: 0.6156 - accuracy: 0.6769 - val\_loss: 0.6162 - val\_accuracy: 0.6706 - 469ms/epoch - 13ms/step  
## Epoch 6/10  
## 36/36 - 0s - loss: 0.6098 - accuracy: 0.6769 - val\_loss: 0.6094 - val\_accuracy: 0.6706 - 455ms/epoch - 13ms/step  
## Epoch 7/10  
## 36/36 - 0s - loss: 0.6042 - accuracy: 0.6769 - val\_loss: 0.6030 - val\_accuracy: 0.6706 - 469ms/epoch - 13ms/step  
## Epoch 8/10  
## 36/36 - 0s - loss: 0.5991 - accuracy: 0.6769 - val\_loss: 0.5981 - val\_accuracy: 0.6706 - 456ms/epoch - 13ms/step  
## Epoch 9/10  
## 36/36 - 0s - loss: 0.5950 - accuracy: 0.6770 - val\_loss: 0.5927 - val\_accuracy: 0.6728 - 463ms/epoch - 13ms/step  
## Epoch 10/10  
## 36/36 - 0s - loss: 0.5913 - accuracy: 0.6876 - val\_loss: 0.5888 - val\_accuracy: 0.6877 - 465ms/epoch - 13ms/step  
## Epoch 1/10  
## 36/36 - 2s - loss: 0.6462 - accuracy: 0.6578 - val\_loss: 0.6329 - val\_accuracy: 0.6706 - 2s/epoch - 53ms/step  
## Epoch 2/10  
## 36/36 - 0s - loss: 0.6272 - accuracy: 0.6769 - val\_loss: 0.6299 - val\_accuracy: 0.6706 - 495ms/epoch - 14ms/step  
## Epoch 3/10  
## 36/36 - 0s - loss: 0.6236 - accuracy: 0.6769 - val\_loss: 0.6249 - val\_accuracy: 0.6706 - 475ms/epoch - 13ms/step  
## Epoch 4/10  
## 36/36 - 0s - loss: 0.6183 - accuracy: 0.6769 - val\_loss: 0.6185 - val\_accuracy: 0.6706 - 473ms/epoch - 13ms/step  
## Epoch 5/10  
## 36/36 - 0s - loss: 0.6118 - accuracy: 0.6769 - val\_loss: 0.6110 - val\_accuracy: 0.6706 - 463ms/epoch - 13ms/step  
## Epoch 6/10  
## 36/36 - 0s - loss: 0.6048 - accuracy: 0.6769 - val\_loss: 0.6031 - val\_accuracy: 0.6706 - 482ms/epoch - 13ms/step  
## Epoch 7/10  
## 36/36 - 0s - loss: 0.5986 - accuracy: 0.6770 - val\_loss: 0.5963 - val\_accuracy: 0.6721 - 458ms/epoch - 13ms/step  
## Epoch 8/10  
## 36/36 - 0s - loss: 0.5937 - accuracy: 0.6824 - val\_loss: 0.5909 - val\_accuracy: 0.6806 - 456ms/epoch - 13ms/step  
## Epoch 9/10  
## 36/36 - 0s - loss: 0.5899 - accuracy: 0.6966 - val\_loss: 0.5868 - val\_accuracy: 0.6916 - 469ms/epoch - 13ms/step  
## Epoch 10/10  
## 36/36 - 0s - loss: 0.5869 - accuracy: 0.7006 - val\_loss: 0.5839 - val\_accuracy: 0.6924 - 464ms/epoch - 13ms/step

*# Evaluate results and choose the best model*  
best\_accuracy <- 0  
best\_model <- NULL  
**for** (i **in** 1**:length**(results)) {  
 accuracy <- **max**(results[[i]]**$**history**$**metrics**$**val\_accuracy)  
 **if** (accuracy **>** best\_accuracy) {  
 best\_accuracy <- accuracy  
 best\_model <- results[[i]]**$**model  
 }  
}  
**summary**(best\_model)

## Model: "sequential\_8"  
## \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
## Layer (type) Output Shape Param #   
## ================================================================================  
## dense\_34 (Dense) (None, 10) 50   
## dense\_33 (Dense) (None, 10) 110   
## dense\_32 (Dense) (None, 10) 110   
## dense\_31 (Dense) (None, 1) 11   
## ================================================================================  
## Total params: 281 (1.10 KB)  
## Trainable params: 281 (1.10 KB)  
## Non-trainable params: 0 (0.00 Byte)  
## \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**str**(best\_model)

## Model: "sequential\_8"  
## \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
## Layer (type) Output Shape Param #   
## ================================================================================  
## dense\_34 (Dense) (None, 10) 50   
## dense\_33 (Dense) (None, 10) 110   
## dense\_32 (Dense) (None, 10) 110   
## dense\_31 (Dense) (None, 1) 11   
## ================================================================================  
## Total params: 281 (1.10 KB)  
## Trainable params: 281 (1.10 KB)  
## Non-trainable params: 0 (0.00 Byte)  
## \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

activation\_functions <- **lapply**(best\_model**$**layers, `[[`, "activation")  
**print**(activation\_functions)

## [[1]]  
## <function tanh at 0x2b3f0e430>  
##   
## [[2]]  
## <function tanh at 0x2b3f0e430>  
##   
## [[3]]  
## <function tanh at 0x2b3f0e430>  
##   
## [[4]]  
## <function sigmoid at 0x2b3f0e5e0>

*# Use the best model for predictions*  
predictions <- **predict**(best\_model, reduced\_test\_features)

## 284/284 - 1s - 526ms/epoch - 2ms/step

test\_set**$**p\_prob <- predictions[, 1]  
pca\_predicted\_class <- **ifelse**(predictions[, 1] **>=** 0.5, 1, 0)  
pca\_accuracy <- **mean**(pca\_predicted\_class **==** test\_labels)  
pca\_accuracy

## [1] 0.7210509

*# Making predictions and calculating fpr and tpr rates at 0.5 threshold*  
over\_threshold <- test\_set[test\_set**$**p\_prob **>=** 0.5, ]  
fpr <- **sum**(over\_threshold**$**booking\_status**==**0)**/sum**(test\_set**$**booking\_status**==**0)  
fpr

## [1] 0.07774086

tpr <- **sum**(over\_threshold**$**booking\_status**==**1)**/sum**(test\_set**$**booking\_status**==**1)  
tpr

## [1] 0.3224745

*# Plotting ROC curve*  
roc\_data <- **data.frame**(threshold = **seq**(1, 0, **-**0.01), fpr = 0, tpr = 0)  
**for** (i **in** roc\_data**$**threshold) {  
 over\_threshold <- test\_set[test\_set**$**p\_prob **>=** i, ]  
 fpr <- **sum**(over\_threshold**$**booking\_status**==**0)**/sum**(test\_set**$**booking\_status**==**0)  
 roc\_data[roc\_data**$**threshold**==**i, "fpr"] <- fpr  
 tpr <- **sum**(over\_threshold**$**booking\_status**==**1)**/sum**(test\_set**$**booking\_status**==**1)  
 roc\_data[roc\_data**$**threshold**==**i, "tpr"] <- tpr  
}  
**ggplot**() **+**   
 **geom\_line**(data = roc\_data,   
 **aes**(x = fpr, y = tpr, color = threshold), linewidth = 2) **+**   
 **scale\_color\_gradientn**(colors = **rainbow**(3)) **+**   
 **geom\_abline**(intercept = 0, slope = 1, lty = 2) **+**   
 **geom\_point**(data = roc\_data[**seq**(1, 101, 10), ], **aes**(x = fpr, y = tpr)) **+**   
 **geom\_text**(data = roc\_data[**seq**(1, 101, 10), ],   
 **aes**(x = fpr, y = tpr, label = threshold, hjust = 1.2, vjust = **-**0.2))

A graph with a line graph

Description automatically generated with medium confidence

*# Calculating the AUC*  
pca\_auc <- **auc**(x = roc\_data**$**fpr, y = roc\_data**$**tpr, type = "spline")

## Warning in regularize.values(x, y, ties, missing(ties)): collapsing to unique  
## 'x' values

pca\_auc

## [1] 0.7334001

*# Creating a calibration curve*  
in\_interval <- test\_set[test\_set**$**p\_prob **>=** 0.7 **&** test\_set**$**p\_prob **<=** 0.8, ]  
**nrow**(in\_interval[in\_interval**$**booking\_status**==**1, ])**/nrow**(in\_interval)

## [1] 0.8860759

calibration\_data <- **data.frame**(bin\_midpoint=**seq**(0.05,0.95,0.1),  
 observed\_event\_percentage=0)  
**for** (i **in** **seq**(0.05,0.95,0.1)) {  
 in\_interval <- test\_set[test\_set**$**p\_prob **>=** (i-0.05) **&** test\_set**$**p\_prob **<=** (i+0.05), ]  
 oep <- **nrow**(in\_interval[in\_interval**$**booking\_status**==**1, ])**/nrow**(in\_interval)  
 calibration\_data[calibration\_data**$**bin\_midpoint**==**i, "observed\_event\_percentage"] <- oep  
}  
**ggplot**(data = calibration\_data, **aes**(x = bin\_midpoint, y = observed\_event\_percentage)) **+**  
 **geom\_line**(linewidth = 1) **+**  
 **geom\_abline**(intercept = 0, slope = 1, lty = 2) **+**  
 **geom\_point**(size = 2) **+**  
 **geom\_text**(**aes**(label = bin\_midpoint), hjust = 0.75, vjust = **-**0.5)

## Warning: Removed 1 row containing missing values (`geom\_line()`).

## Warning: Removed 1 rows containing missing values (`geom\_point()`).

## Warning: Removed 1 rows containing missing values (`geom\_text()`).

A graph with a line graph

Description automatically generated

*# Table with models and relative accuracies*  
classification\_overview <- **data.frame**(  
 Method = **c**("Logistic Regression", "kNN (k = 3)", "Random Forest", "Simple Neural Network", "Complex Neural Network", "Neural Network with PCA"),  
 Accuracy = **c**("80.38%", "84.23%", "88.37%", "80.02%", "84.10%", "72.11%")  
)  
classification\_table <- **kable**(classification\_overview, "markdown") **%>%**  
 **kable\_styling**(full\_width = FALSE) **%>%**  
 **column\_spec**(1, bold = TRUE)

## Warning in kable\_styling(., full\_width = FALSE): Please specify format in  
## kable. kableExtra can customize either HTML or LaTeX outputs. See  
## https://haozhu233.github.io/kableExtra/ for details.

## Warning in column\_spec(., 1, bold = TRUE): Please specify format in kable.  
## kableExtra can customize either HTML or LaTeX outputs. See  
## https://haozhu233.github.io/kableExtra/ for details.

classification\_table

| Method | Accuracy |
| --- | --- |
| Logistic Regression | 80.38% |
| kNN (k = 3) | 84.23% |
| Random Forest | 88.37% |
| Simple Neural Network | 80.02% |
| Complex Neural Network | 84.10% |
| Neural Network with PCA | 72.11% |