
# Business Case:

# Prediction of Charged Off Loans

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# The Problem and Solution Proposal

- Objective: design a model that predicts Charged Off Loans using LC's database
- Solution Structure
  - Exploratory Data Analysis
  - Analysis and data cleaning (missing values, "o.h.e." on categorical variables)
  - Feature Selection (Forward Selection, Gradient Boosted Weights and Regularization)
  - Model Training
    - three models: Logistic Regression, Gradient Boosting, K-Nearest Neighbors
    - GridSearch for HyperParameters and Cross Validation for overfitting analysis
    - Performance analysis: Confusion Matrices and ROC Curves
  - Model Testing
    - Performance analysis: Confusion Matrices and ROC Curve

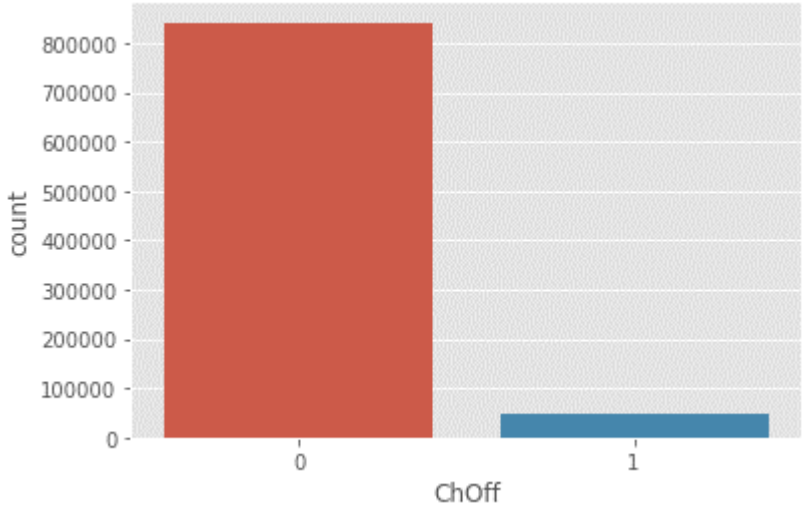
# Dataset

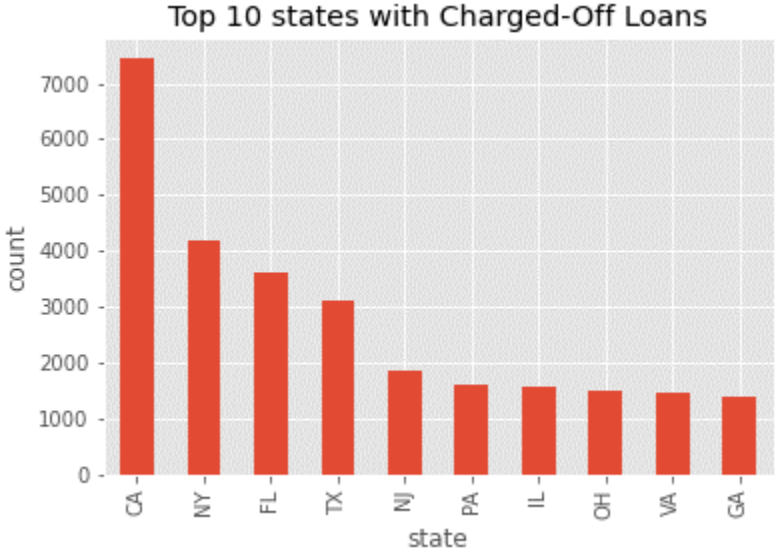
- Train set: 887379 observations by 74 variables
- Test set: 759338 observations by 72 variables
- Columns with more than half of observations with missing values:

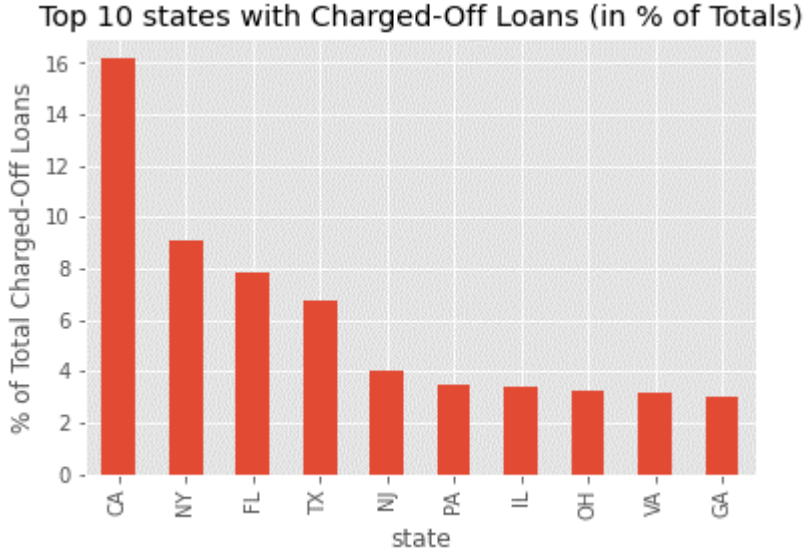
| | |
|---|---|
| desc | 761351 |
| mths_since_last_delinq | 454312 |
| mths_since_last_record | 750326 |
| mths_since_last_major_derog | 665676 |
| annual_inc_joint | 886868 |
| dti_joint | 886870 |
| verification_status_joint | 886868 |
| open_acc_6m | 866007 |
| open_il_6m | 866007 |
| open_il_12m | 866007 |
| open_il_24m | 866007 |
| mths_since_rcnt_il | 866569 |
| total_bal_il | 866007 |
| il_util | 868762 |
| open_rv_12m | 866007 |
| open_rv_24m | 866007 |
| max_bal_bc | 866007 |
| all_util | 866007 |
| inq_fi | 866007 |
| total_cu_tl | 866007 |
| inq_last_12m | 866007 |

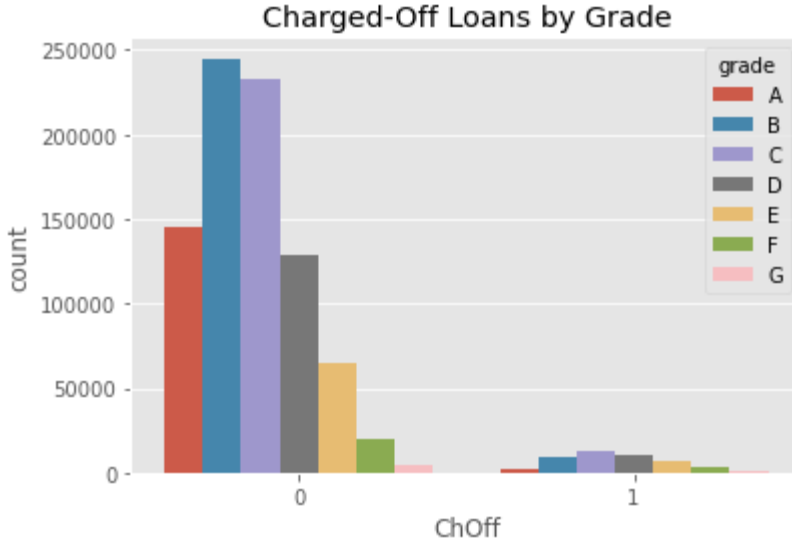
# Exploratory Data Analysis

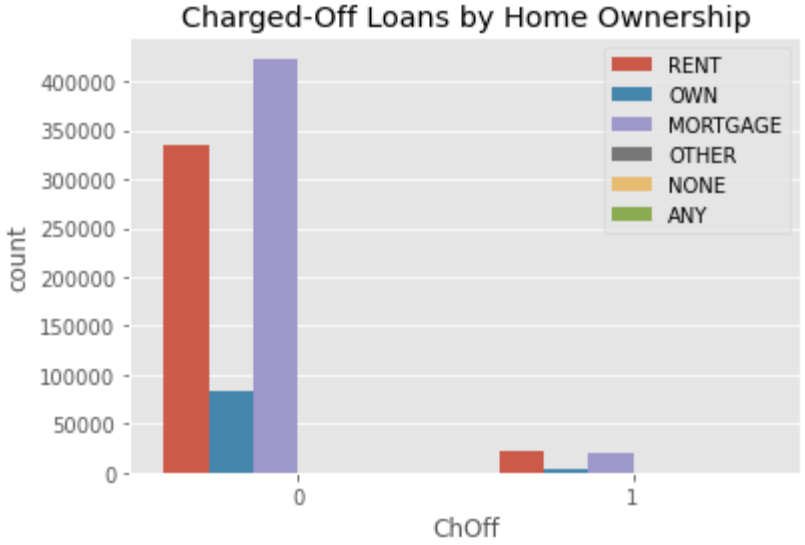
Number of Non Charged-Off vs Charged-Off Loans

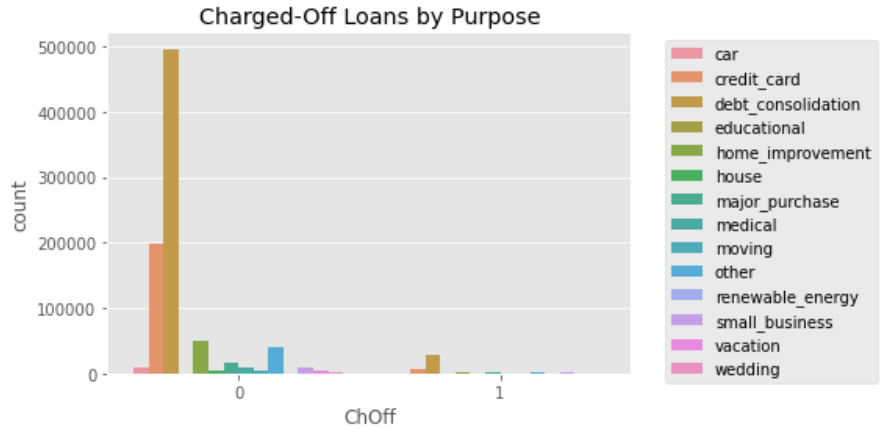


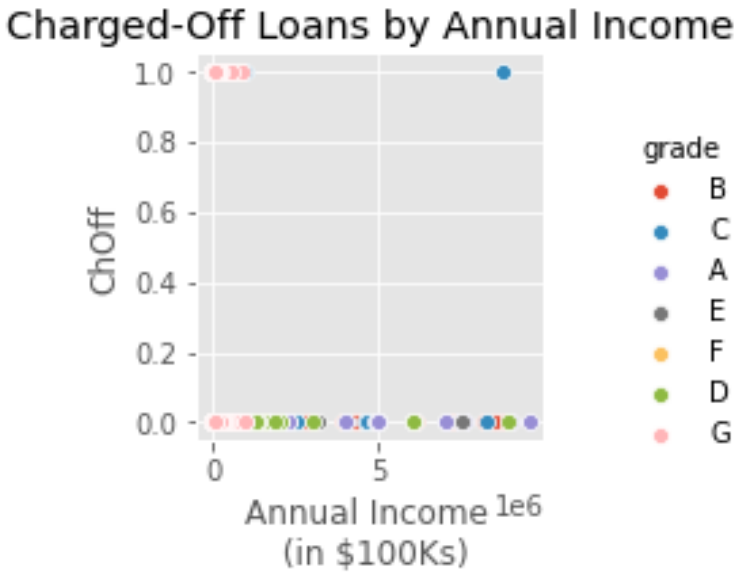



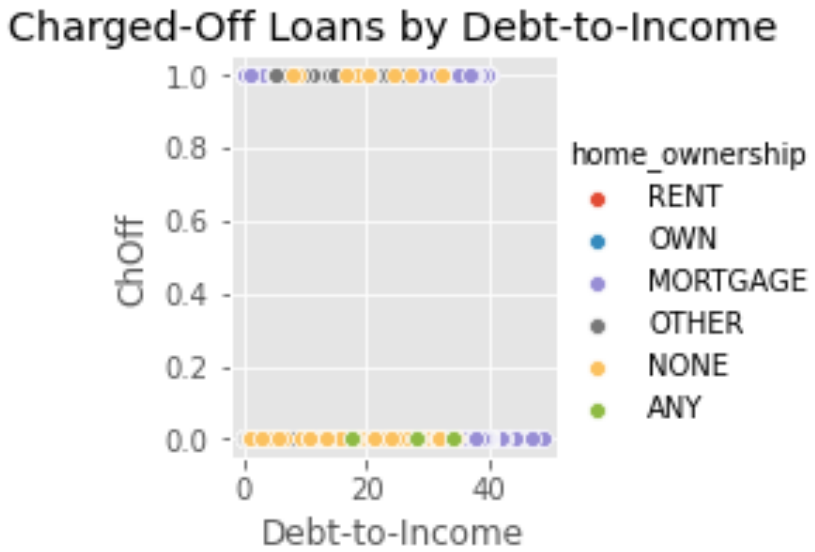



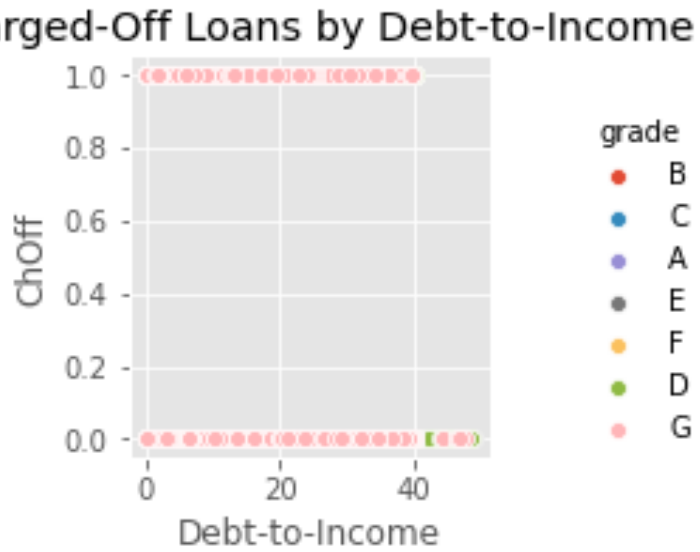



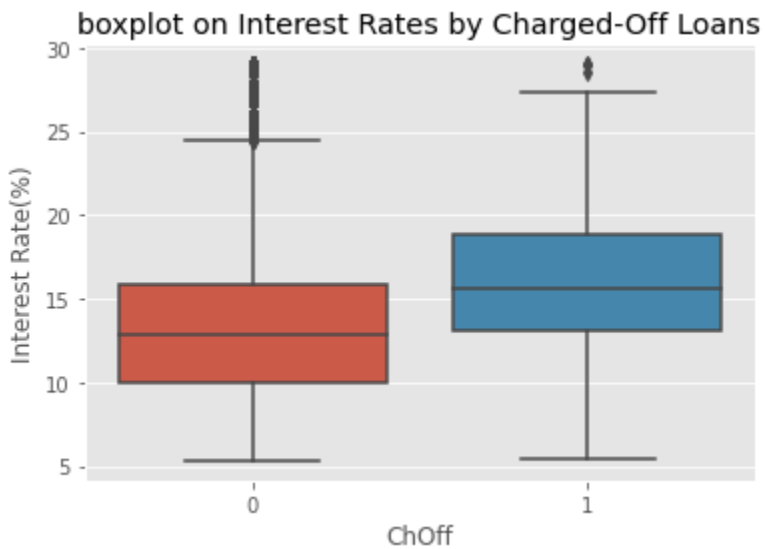



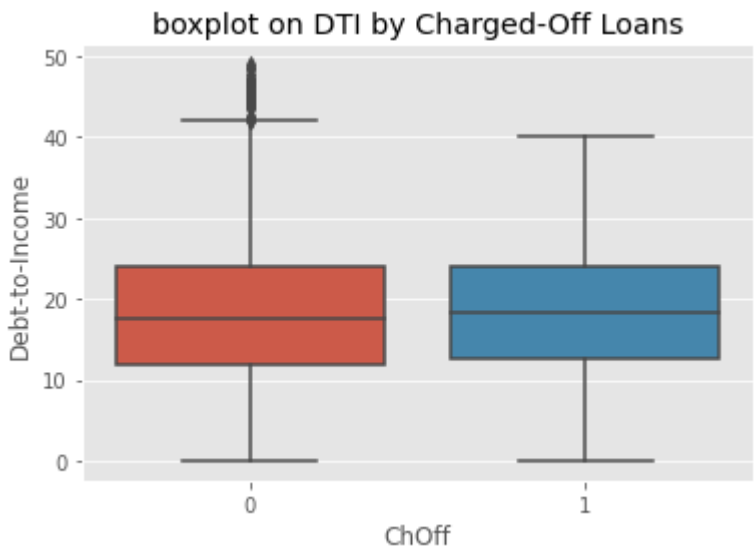
# Exploratory Data Analysis (2)

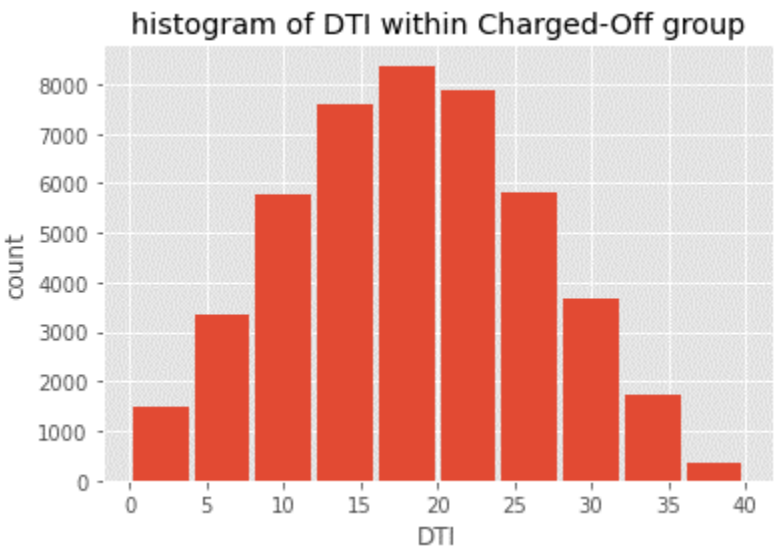


# Exploratory Data Analysis (conclusion)

- Average Loan Rate for Charged-Off borrowers may show common higher cost:

Avg Loan Rate per Home Ownership
(for Charged-Off and none's)

| ChOff | 0 | 1 |
|---|---|---|
| home_ownership | | |
| ANY | 14.2 | NaN |
| MORTGAGE | 12.8 | 15.9 |
| NONE | 14.3 | 15.3 |
| OTHER | 13.2 | 14.3 |
| OWN | 13.1 | 16.1 |
| RENT | 13.4 | 16.1 |

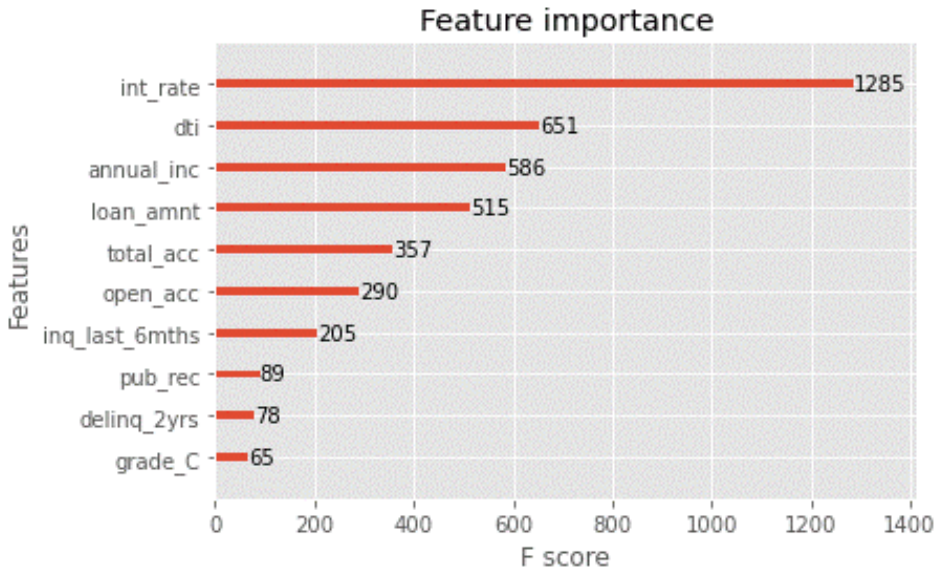
- In summary, a preliminary analysis shows no noticeable common characteristics among Charged-Off Loan borrowers compared to others.

# Feature Selection

## Several selection techniques were performed

- Regularization (for Logistic Regression): loan amount, interest rate, annual income, Debe-to-Income, delinquencies in the last 2 years, inquiries last 6 months, employment length, number of derogatory public records, number of open credit lines in the borrower's credit file.

- Gradient Boosted Weights (for Gradient Boosting):



# Logistic Regression

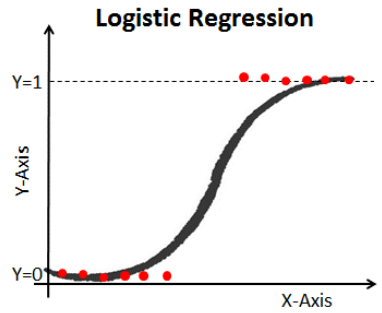
- Called logistic since it uses the Logit function $log_e\left(\frac{p}{1-p}\right)$
- The regression is in the form of

$$p = \left(\frac{1}{1 + e^{-\beta \cdot X}}\right)$$

where β is the coefficients matrix representing the log-odds for p =1

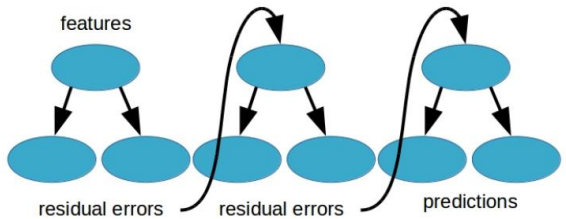
X is the feature or explanatory variables matrix

p is the probability of the target variable being 1

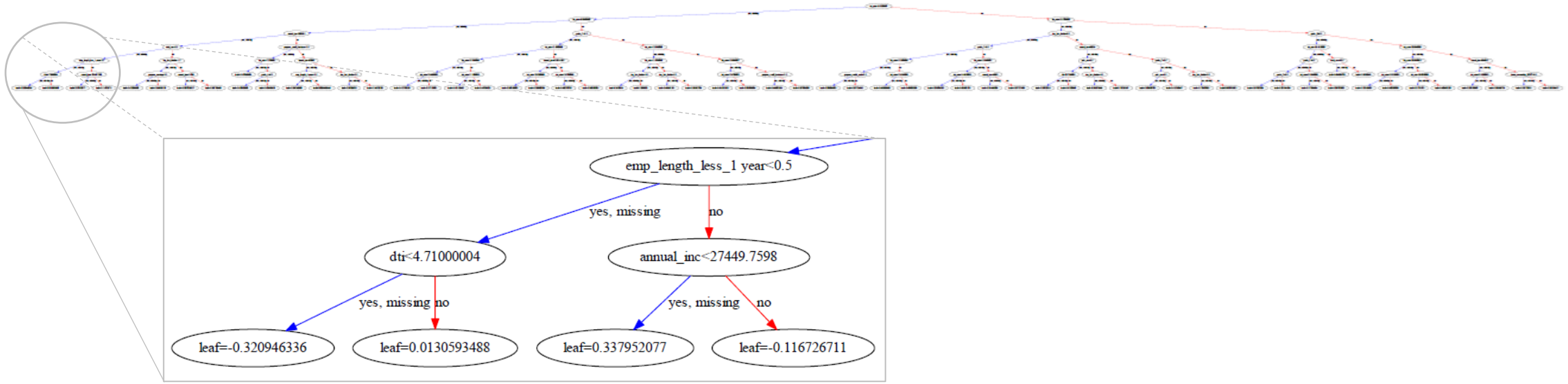


# Gradient Boosting

A gradient boosting tress is an ensemble learning technique which predicts in the form of an ensemble of decision trees where the results of the each base-learner are combined to generate the final estimate.

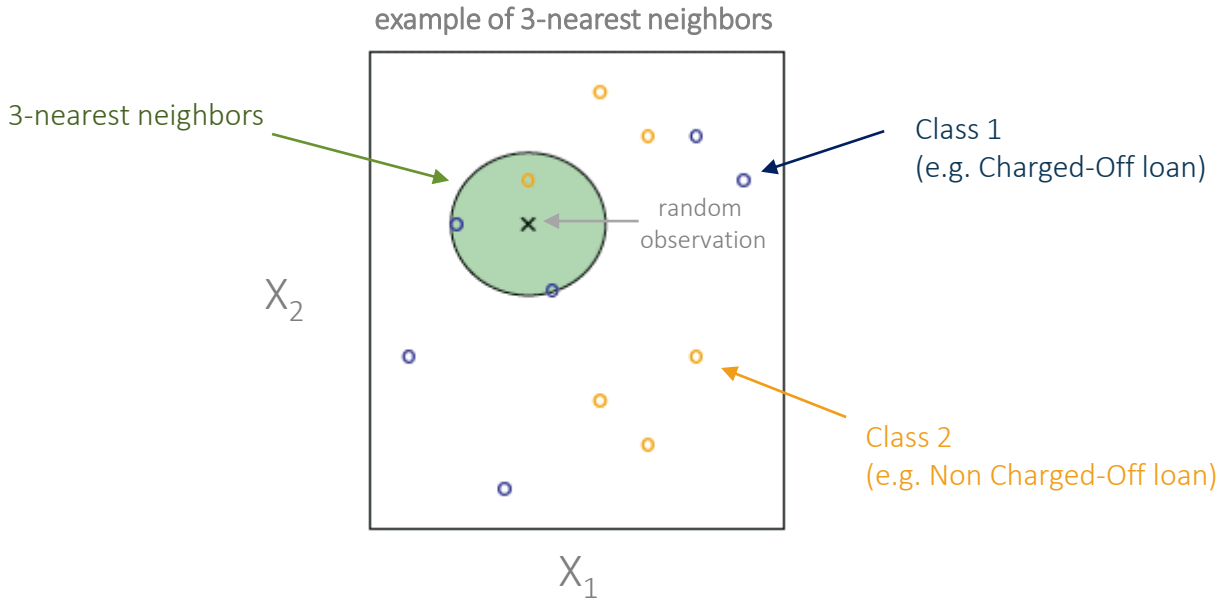



XGBoost Plot from Charged-Off Model:

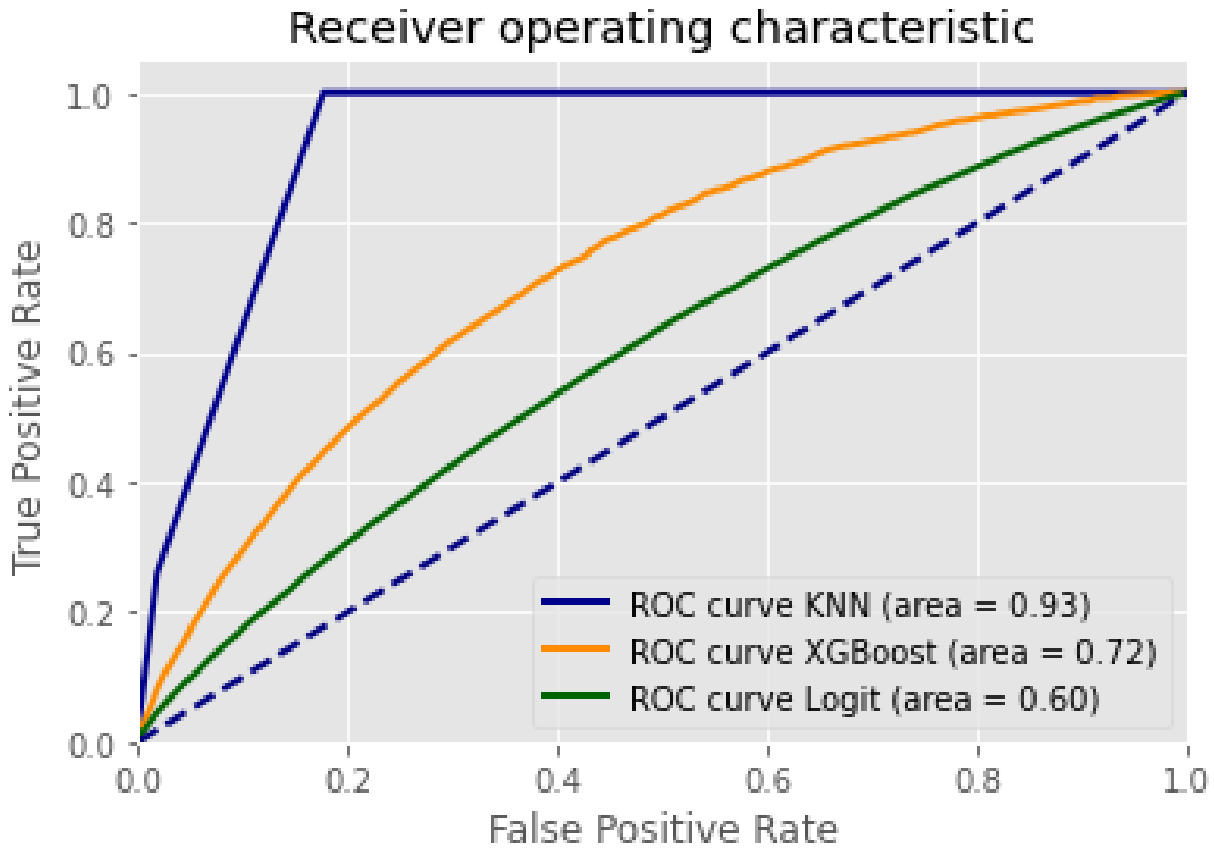


# K-Nearest Neighbor

Given a defined ‘number of neighbors’ (K), for every pair combination of features (e.g. $X_1$ and $X_2$), this model analyzes for each random observation the K-nearest points and identifies their class to then estimate the very class of it based on the distribution of their neighbors (i.e. conditional probability).



# Model Training and Performance Comparison



# Confusion Matrix

| | Predicted Negative | Predicted Positive |
|---|---|---|
| **Actual Negative** | TRUE NEGATIVE | FALSE POSITIVE |
| **Actual Positive** | FALSE NEGATIVE | TRUE POSITIVE |

| | Predicted Negative | Predicted Positive |
|---|---|---|
| **Actual Negative** | $1 - \alpha$ | $\alpha$ |
| **Actual Positive** | $\beta$ | $1 - \beta$ |

# Results – Train set

| Regularized Logistic Regression | Predicted *No Charged-Off* | Predicted *Charged-Off* |
|---|---|---|
| Actual *No Charged-Off* | 841,201 | 143 |
| Actual *Charged-Off* | 45,935 | 71 |

| Gradian Boosting | Predicted *No Charged-Off* | Predicted *Charged-Off* |
|---|---|---|
| Actual *No Charged-Off* | 840,904 | 440 |
| Actual *Charged-Off* | 45,773 | 233 |

| K-Nearest Neighbors | Predicted *No Charged-Off* | Predicted *Charged-Off* |
|---|---|---|
| Actual *No Charged-Off* | 840,323 | 1,021 |
| Actual *Charged-Off* | 44,218 | 1,788 |

# Results – Test set

| Regularized Logistic Regression | Predicted *No Charged-Off* | Predicted *Charged-Off* |
|---|---|---|
| Actual *No Charged-Off* | 715,350 | 14 |
| Actual *Charged-Off* | 43,618 | 0 |

| Gradian Boosting | Predicted *No Charged-Off* | Predicted *Charged-Off* |
|---|---|---|
| Actual *No Charged-Off* | 715,054 | 310 |
| Actual *Charged-Off* | 43,587 | 31 |

| K-Nearest Neighbors | Predicted *No Charged-Off* | Predicted *Charged-Off* |
|---|---|---|
| Actual *No Charged-Off* | 713,791 | 1,573 |
| Actual *Charged-Off* | 43,520 | 98 |

# Classification Report

- Precision: $\frac{TP}{(TP + FP)}$
- Recall: $\frac{TP}{(TP + FN)}$
- F1score: $2 \cdot \frac{precision \cdot recall}{(precision + recall)}$
- High precision: Predicted most of *Non-Charged Off Loans* correctly
- High recall: Not many actual *Charged Off Loans* predicted as *Non-Charged Off*

# Classification Report: Train and Test sets

TRAIN

REGULARIZED LOGISTIC REGRESSION

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| No Charged-Off | 0.95 | 1.00 | 0.97 | 841,344 |
| Charged-Off | 0.33 | 0.00 | 0.00 | 46,006 |
| accuracy | | | 0.9481 | 887,350 |
| macro avg | 0.64 | 0.50 | 0.49 | 887,350 |
| weighted avg | 0.92 | 0.95 | 0.92 | 887,350 |

GRADIENT BOOSTING

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| No Charged-Off | 0.95 | 1.00 | 0.97 | 841,344 |
| Charged-Off | 0.35 | 0.01 | 0.01 | 46,006 |
| accuracy | | | 0.9479 | 887,350 |
| macro avg | 0.65 | 0.50 | 0.49 | 887,350 |
| weighted avg | 0.92 | 0.95 | 0.92 | 887,350 |

KNN

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| No Charged-Off | 0.95 | 1.00 | 0.97 | 841,344 |
| Charged-Off | 0.64 | 0.04 | 0.07 | 46,006 |
| accuracy | | | 0.9490 | 887,350 |
| macro avg | 0.79 | 0.52 | 0.52 | 887,350 |
| weighted avg | 0.93 | 0.95 | 0.93 | 887,350 |

TEST

REGULARIZED LOGISTIC REGRESSION

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| No Charged-Off | 0.94 | 1.00 | 0.97 | 715,364 |
| Charged-Off | 0.00 | 0.00 | 0.00 | 43,618 |
| accuracy | | | 0.9425 | 758,982 |
| macro avg | 0.47 | 0.50 | 0.49 | 758,982 |
| weighted avg | 0.89 | 0.94 | 0.91 | 758,982 |

GRADIENT BOOSTING

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| No Charged-Off | 0.94 | 1.00 | 0.97 | 715,364 |
| Charged-Off | 0.09 | 0.00 | 0.00 | 43,618 |
| accuracy | | | 0.9422 | 758,982 |
| macro avg | 0.52 | 0.50 | 0.49 | 758,982 |
| weighted avg | 0.89 | 0.94 | 0.91 | 758,982 |

KNN

| | precision | recall | f1-score | support |
|---|---|---|---|---|
| No Charged-Off | 0.94 | 1.00 | 0.97 | 715,364 |
| Charged-Off | 0.06 | 0.00 | 0.00 | 43,618 |
| accuracy | | | 0.9406 | 758,982 |
| macro avg | 0.50 | 0.50 | 0.49 | 758,982 |
| weighted avg | 0.89 | 0.94 | 0.91 | 758,982 |

conclusion 1: in terms of **Accuracy**, KNN model performs better in the Train set

conclusion 2: in terms of **Accuracy**, Regularized Logistic Regression model performs better in the Test set

# Further Improvement

- Feature Engineering:
  - Standardization
  - Normalization
  - log-changes
- Outlier Analysis
- Other Classifying Models


# Business Case:

# Prediction of Charged Off Loans

Applicant: Pedro Martinez