Loan Prediction

By Adriana Caetano and Torsha Mazumdar

Motivation

Dream Housing Finance company deals in all home loans

Automate loan eligibility

Online application form

Problem Category

Supervised Learning - learning from the data based on sample input-output pairs.

- **Input** - Customer Attributes, Loan Amount, Term
- **Output/Label** - Loan Status

Binary Classification - Loan Status is either Y(Yes) or N(No).

Dataset

The Loan Eligible dataset can be downloaded from Kaggle

It’s a short dataset with 13 columns and 614 rows

This dataset has some missing values and some of the features have a wide range of values, so we’ll need to preprocess it.

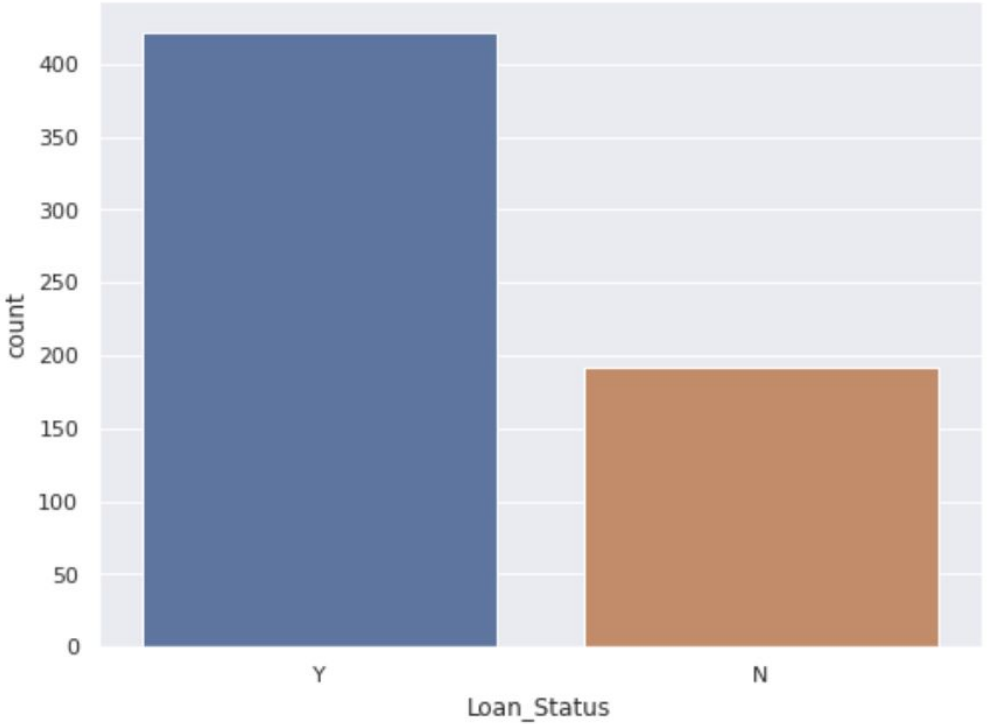
Dataset Features

Features	Values	Datatype	Non-null Count	Missing Values
Loan_ID	Unique ID	categorical	614	0
Gender	Male / Female	categorical	601	13
Married	Yes / No	categorical	611	3
Dependents	0 / 1 / 2 / 3+	categorical	599	15
Education	Graduate / Not Graduate	categorical	614	0
Self_Employed	Yes / No	categorical	582	32
ApplicantIncome	$150 - $81000 per month	numerical	614	0
CoapplicantIncome	$0 - $41667 per month	numerical	614	0
LoanAmount	$9000 - $700000	numerical	592	22
Loan_Amount_Term	12 months - 480 months	numerical	600	14
Credit_History	1 / 0	numerical	564	50
Property_Area	Rural / Urban / Semiurban	categorical	614	0
Loan_Status	Y / N	categorical	614	0

Dataset Visualization

Loan Status

- Yes: 422 (69%)
- No: 192 (31%)

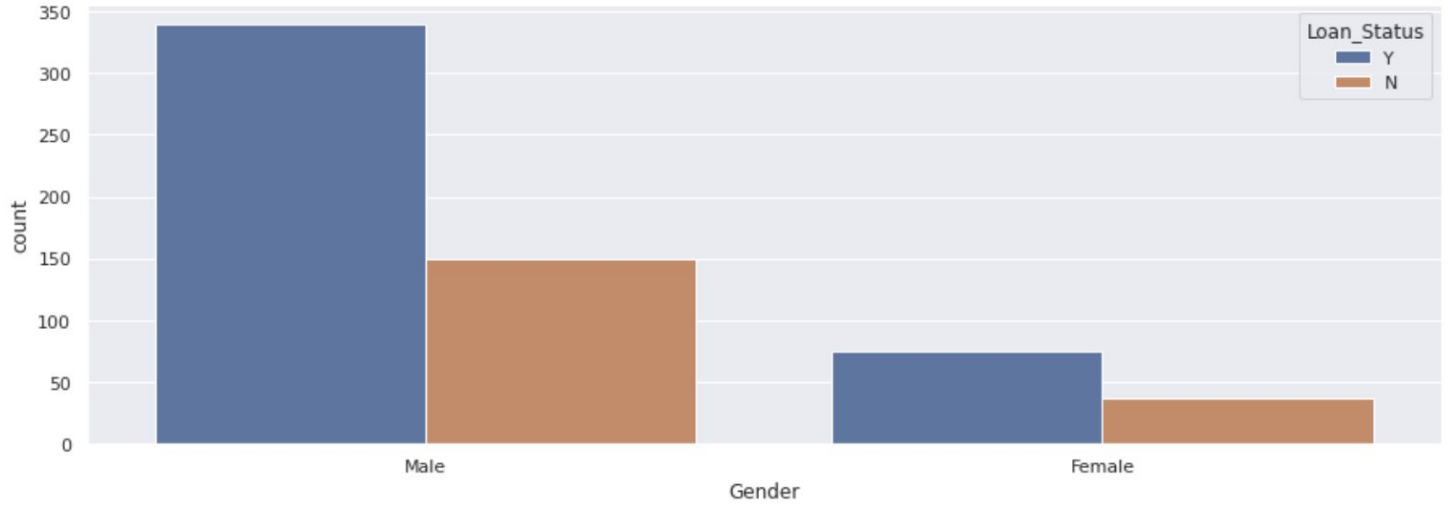


Dataset Visualization

Gender

Male: 489 (Y 69%, N 31%)

Female: 112 (Y 67%, N 33%)

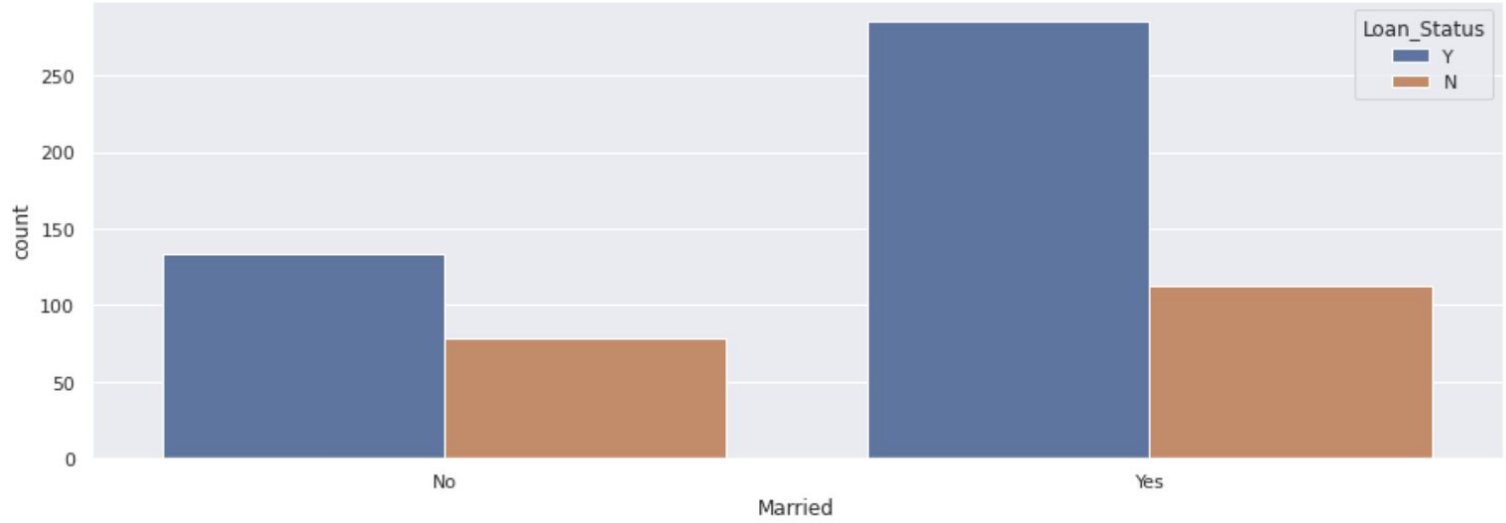


Dataset Visualization

Married

No: 213 (Y 63%, N 37%)

Yes: 398 (Y 72%, N 28%)

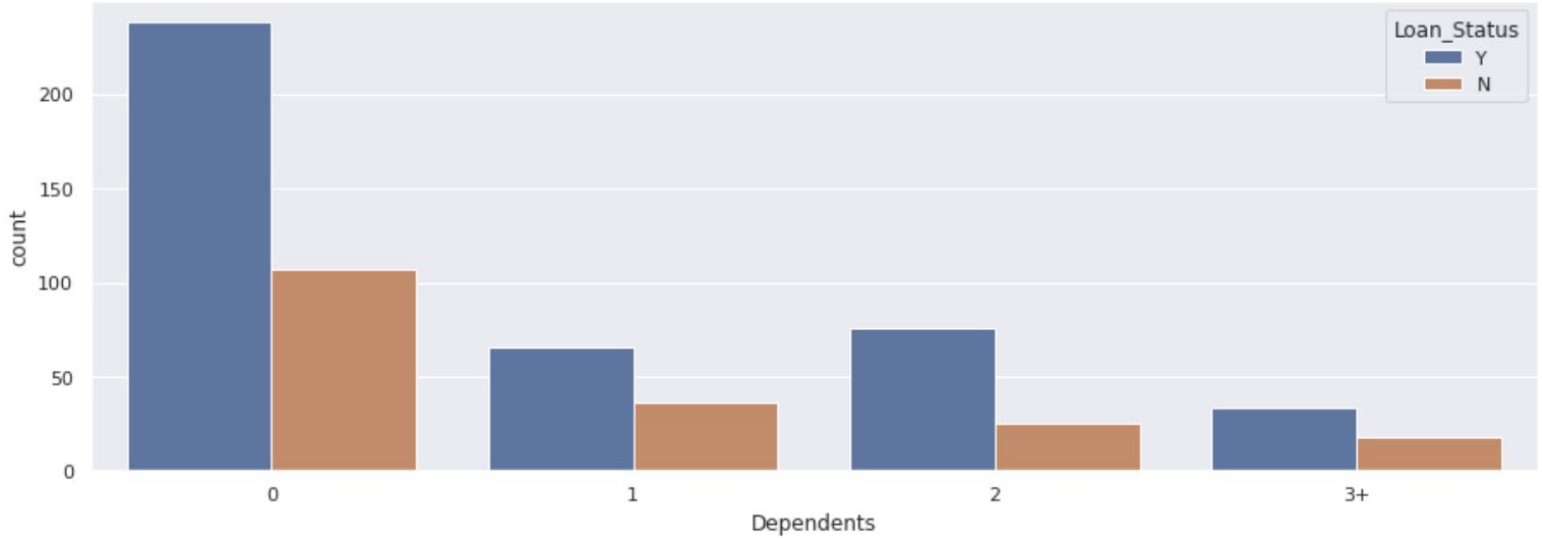


Dataset Visualization

Dependents

0: 345 (Y 69%, N 31%) 1: 102 (Y 65%, N 35%)

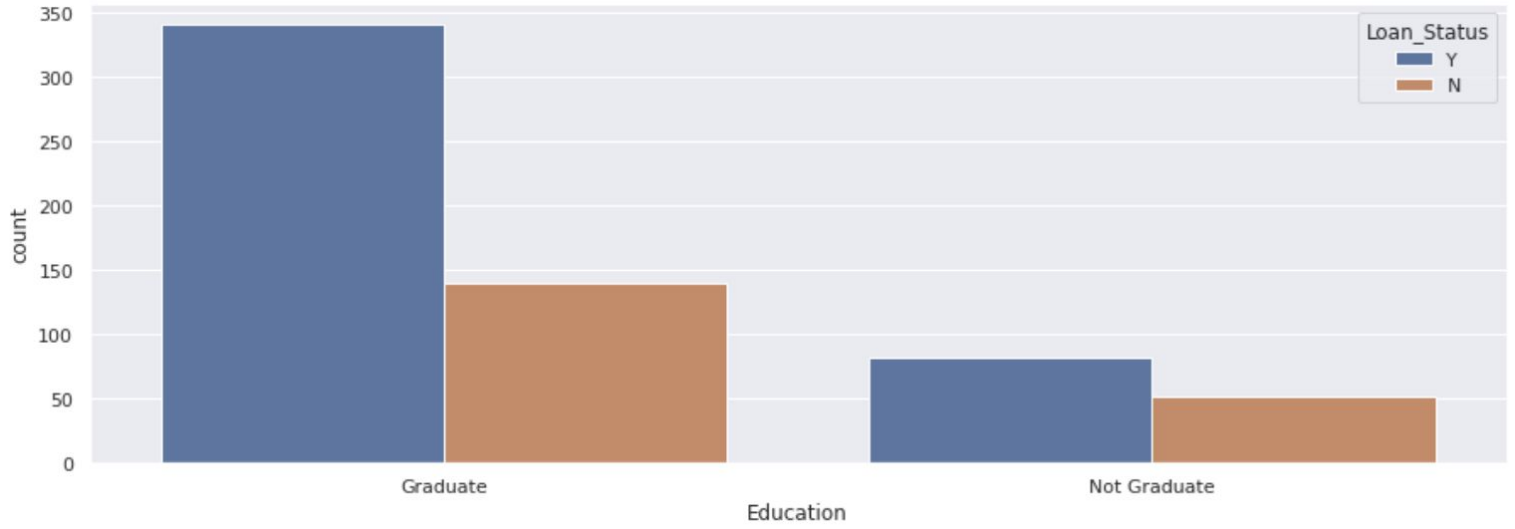
2: 101 (Y 76%, N 24%) 3+: 51 (Y 64%, N 36%)



Dataset Visualization

Education

Graduate: 480 (Y 71%, N 29%) Not Graduate: 134 (Y 61%, N 39%)

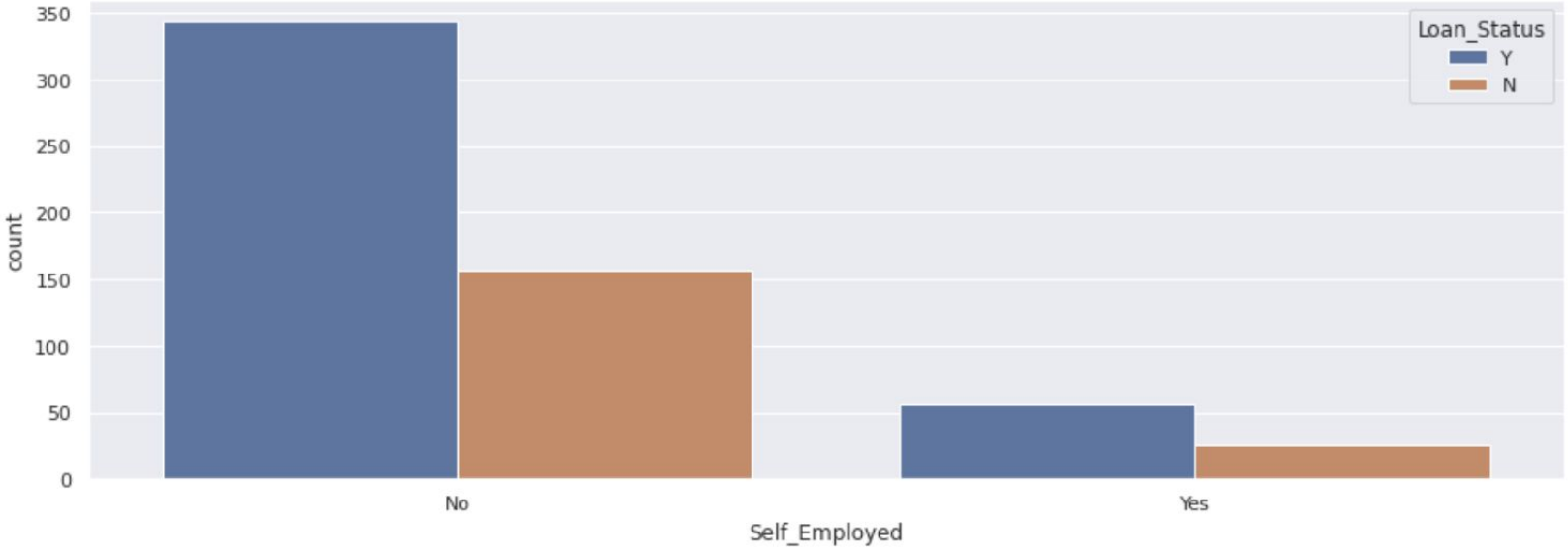


Dataset Visualization

Self-Employed

No: 500 (Y 69%, N 21%)

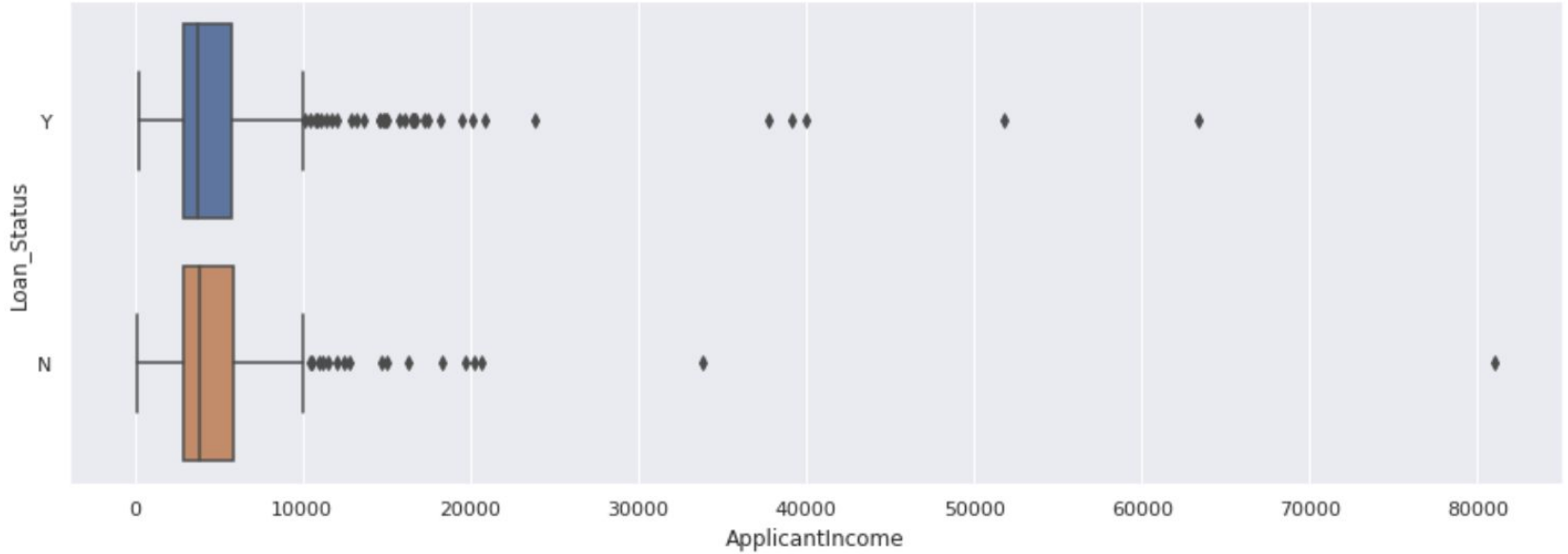
Yes: 82 (Y 68%, N 22%)



Dataset Visualization

Applicant Income

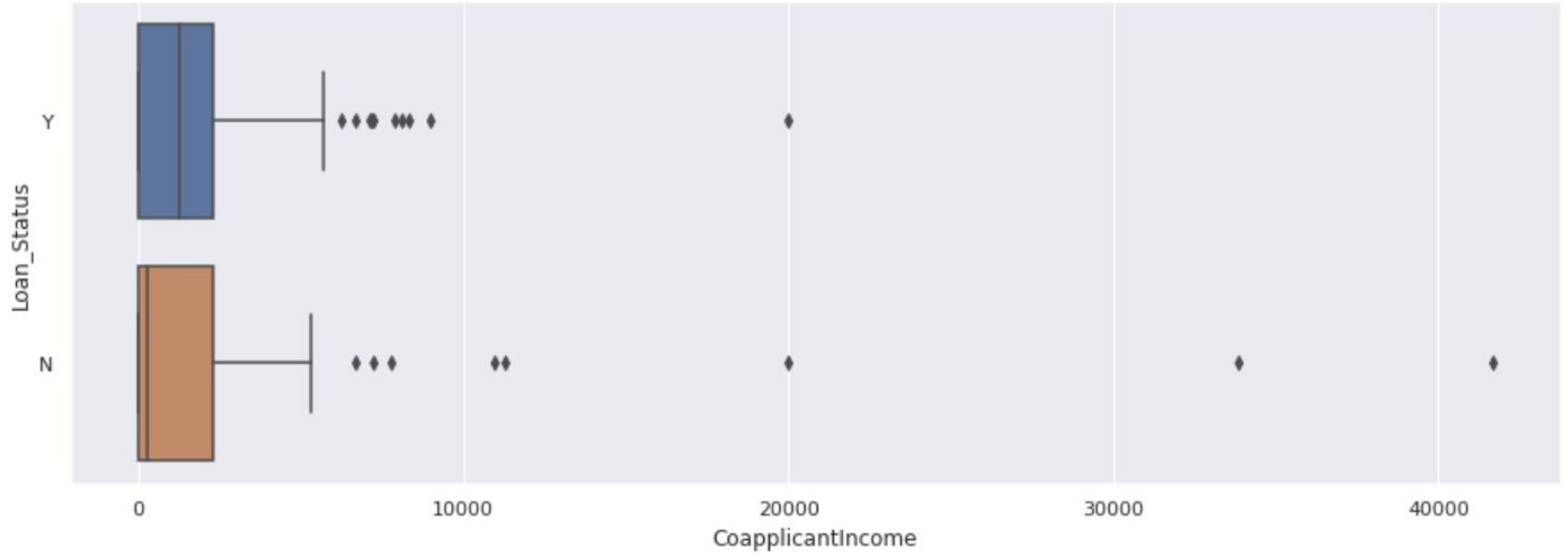
Min: 150 Max: 81000 25%: 2877 50%: 3812 75%: 5795 Mean: 5403



Dataset Visualization

Co-Applicant Income

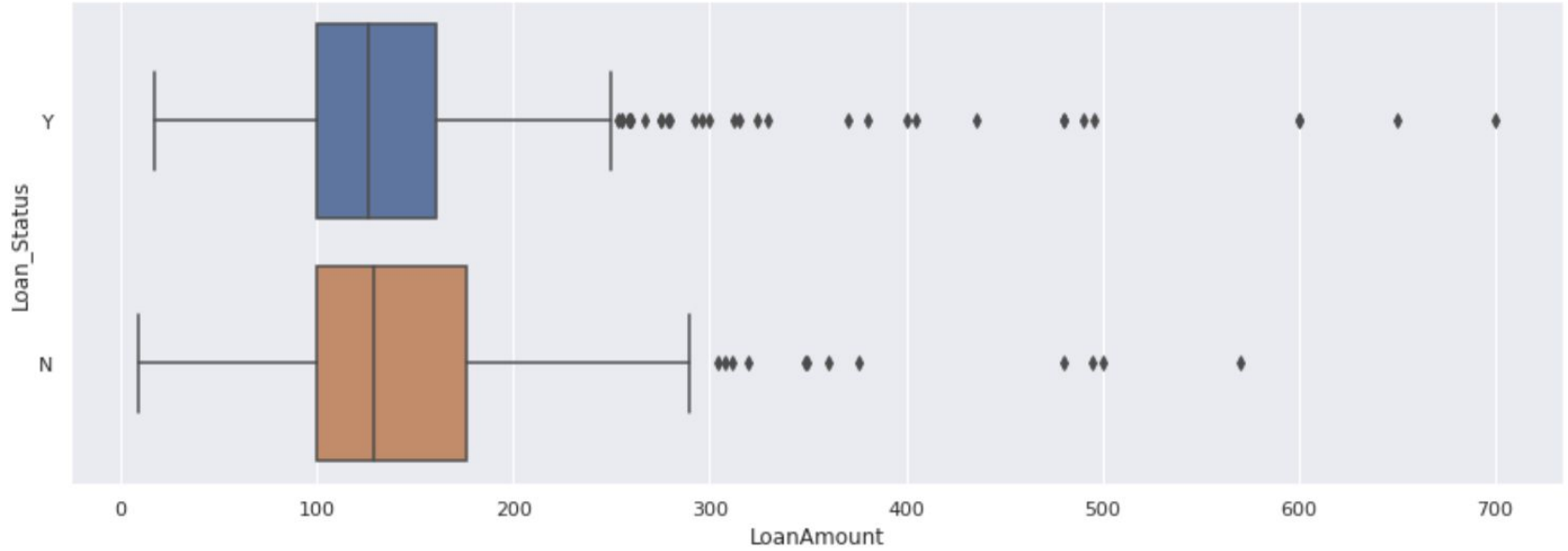
Min: 0 Max: 41667 25%: 0 50%: 1188 75%: 2297 Mean: 1621



Dataset Visualization

Loan Amount

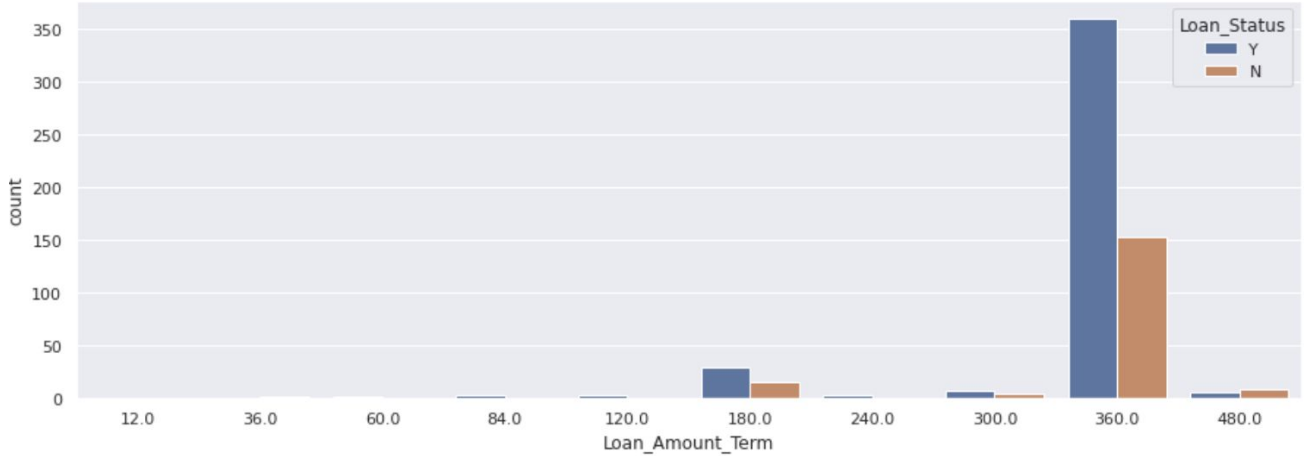
Min: 9k Max: 700k 25%: 100k 50%: 128k 75%: 168k Mean: 146k



Dataset Visualization

Loan Amount Term

0-7 years: 9 (Y 66%, N 34%) 10 years: 3 (Y 100%) 15 years: 44 (Y 66%, N 34%)
20 years: 4 (Y 75%, N 25%) 25 years: 13 (Y 62%, N 38%)
30 years: 512 (Y 70%, N 30%) 40 years: 15 (Y 40%, N 60%)

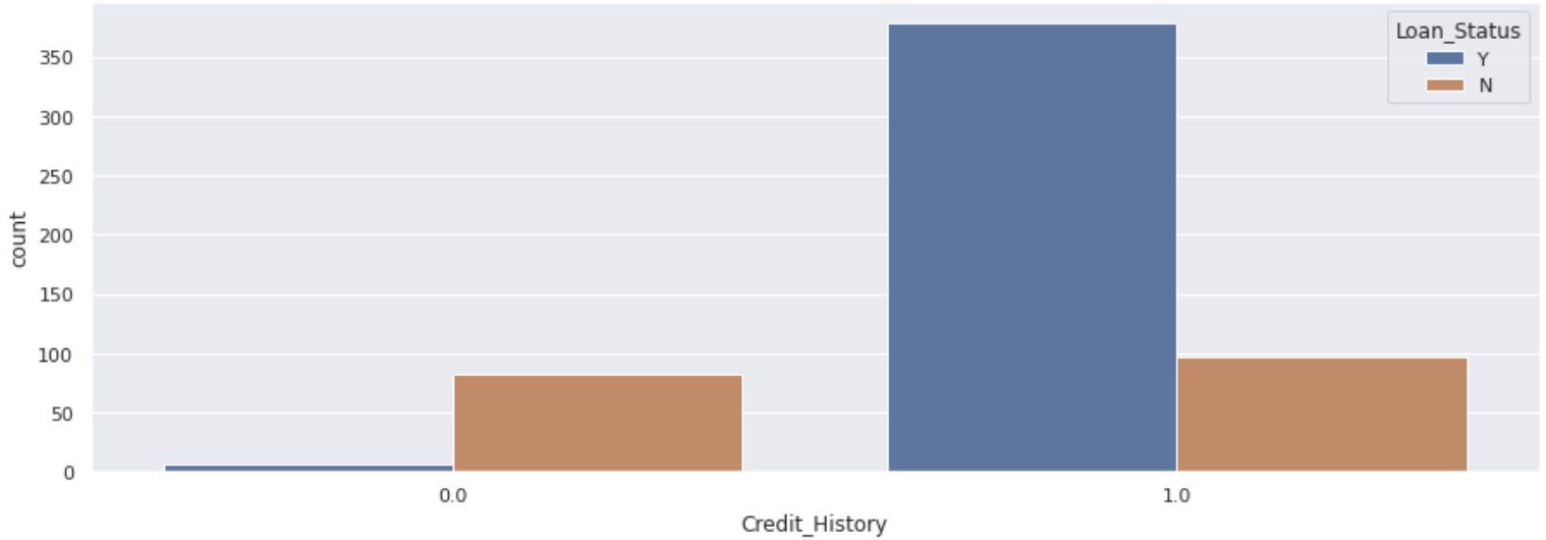


Dataset Visualization

Credit History

0: 89 (Y 8% , N 92%)

1: 475 (Y 80% , N 20%)



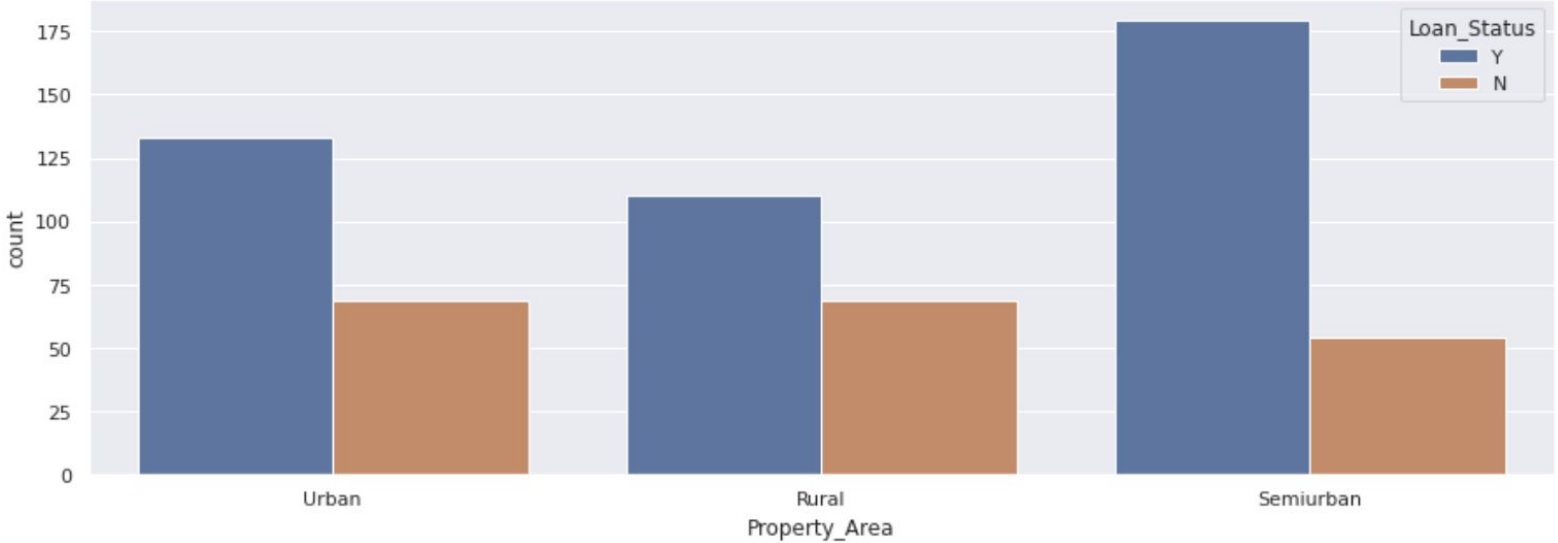
Dataset Visualization

Property Area

Urban: 202 (Y 66% , N 34%)

Rural: 179 (Y 61% , N 39%)

Semi-Urban: 233 (Y 77%, N 23%)



Preprocessing the Dataset

Fill up the missing values

- Mode for categorical features
- Mean or median for numerical features
- Zero for dependents: dependents can be categorized as missing not at random (if a person "forgot" to fill up the number of dependents, most likely they don't have dependents)
- Zero for credit history: credit history can be categorized as missing not at random (if a person "forgot" to fill up the credit history, most likely they don't have history)

Preprocessing the Dataset

Fill up the missing values

- Gender 13 → mode
- Married 3 → mode
- Dependents 15 → 0
- Self_Employed 32 → mode
- LoanAmount 22 → mean
- Loan_Amount_Term 14 → median
- Credit_History 50 → 0

Preprocessing the Dataset

Upsampling the dataset

Imbalanced Initial Dataset -

- 422 labels for Y (69%)
- 192 labels for N (31%)

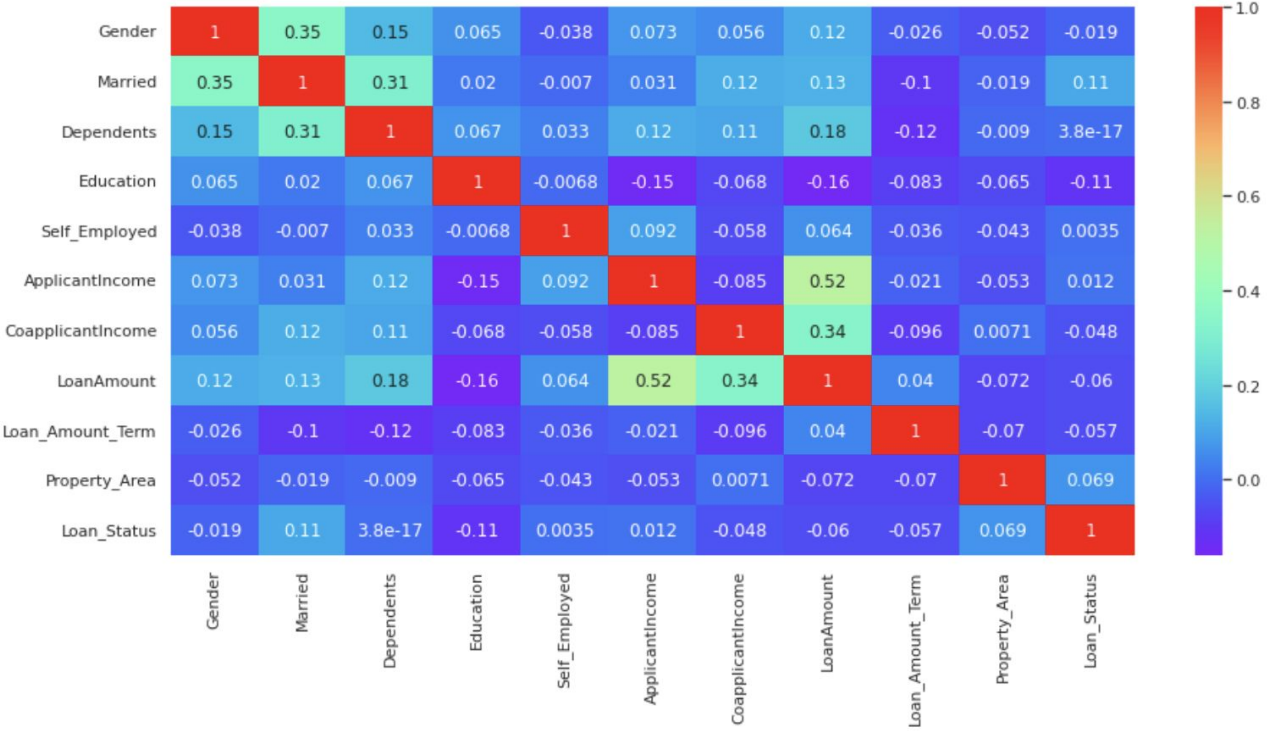
Upsampled Dataset -

- 422 labels for Y
- 422 labels for N

Total Count of Upsampled dataset = 844

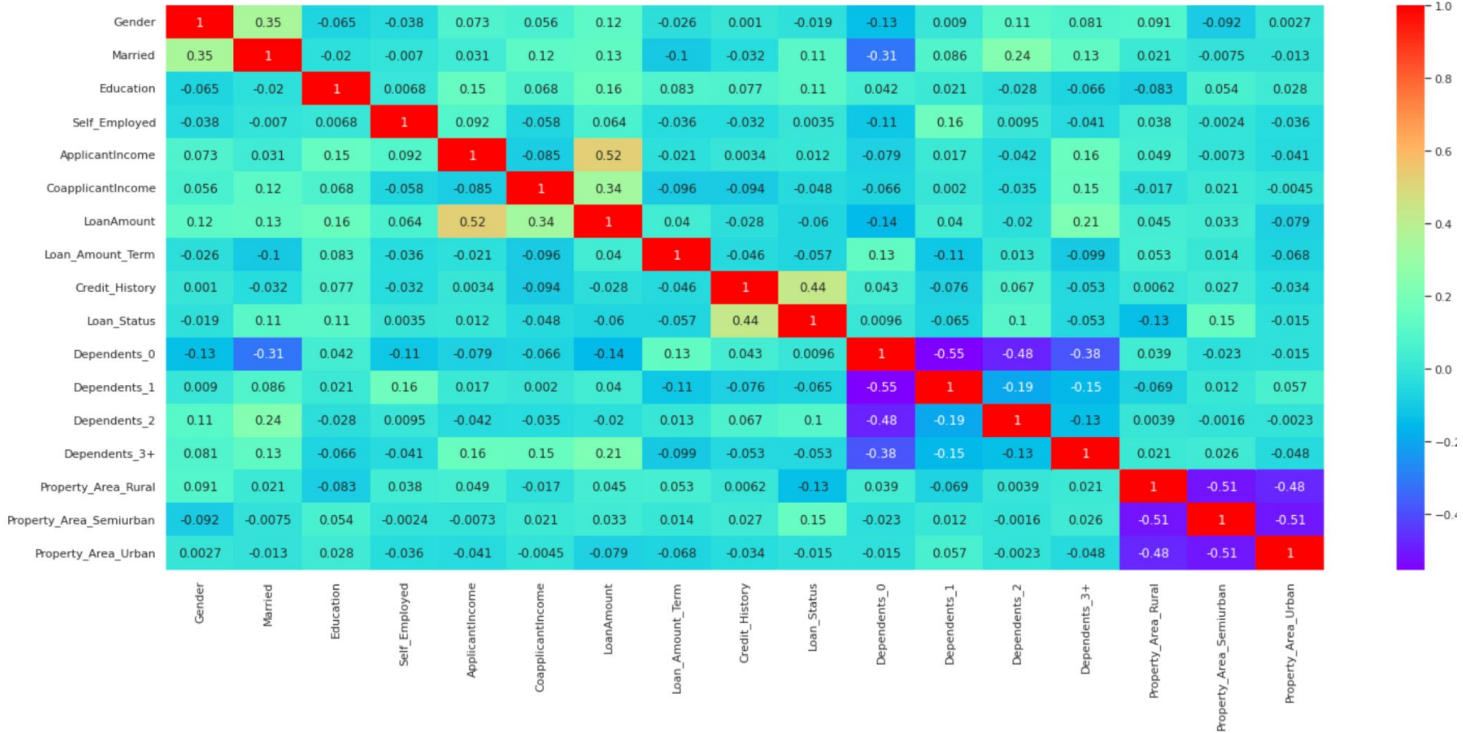
Preprocessing the Dataset

Categorical values into numerical with LabelEncoder



Preprocessing the Dataset

Categorical values into numerical with get_dummies



Preprocessing the Dataset

Splitting the Dataset

Training -

- 70% of dataset
- 590 rows

Test -

- 30% of dataset
- 254 rows

No Validation dataset, since data available is less.

Use of k- fold cross validation to tune hyperparameters

Methods

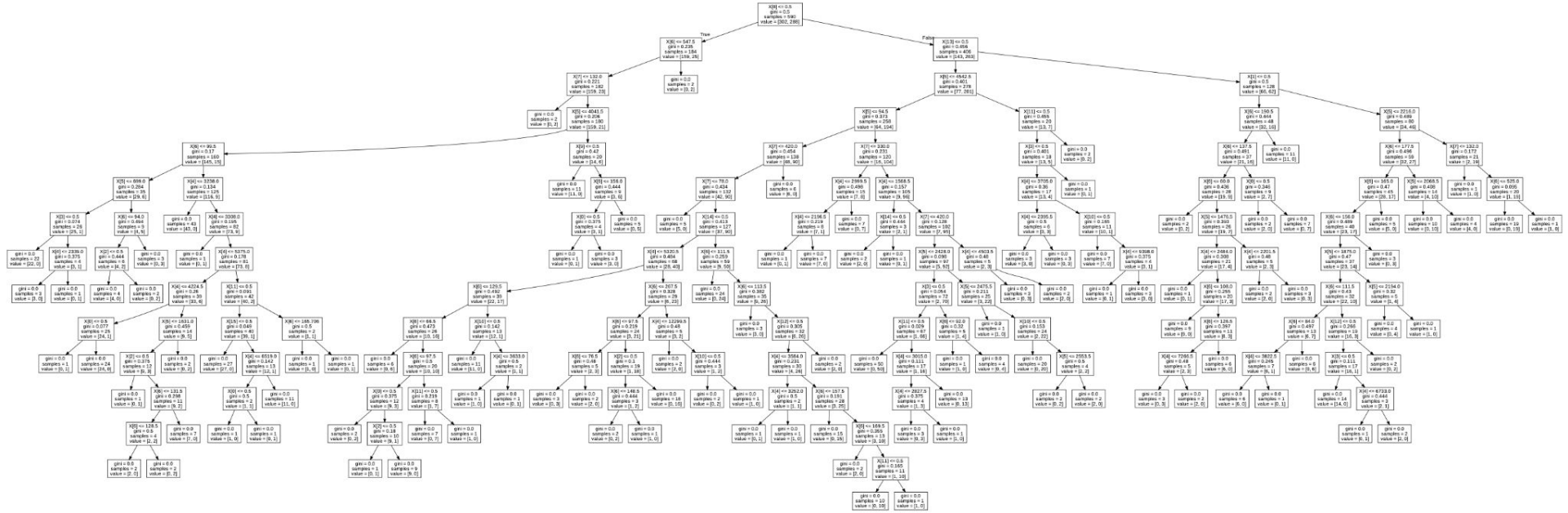
1. **Decision Tree Classifier**
    i. simple and easy to interpret
    ii. trees can be visualized
2. **Random Forest Classifier**
    i. have much higher accuracy than the single decision tree
    ii. doesn't overfit the model, thus gives a good prediction on unseen datasets
    iii. low bias and low variance
3. **Logistic Regression**
    i. efficient for linear dataset
    ii. it can handle both dense and sparse input

Decision Tree Classifier

Default

Depth = 14

Number of leaves = 106



Decision Tree Classifier

Experiments: Gini vs Entropy, k-fold Cross Validation

```
Accuracy without cross-validation using Gini:  1.0
Accuracy without cross-validation using Entropy:  1.0
```

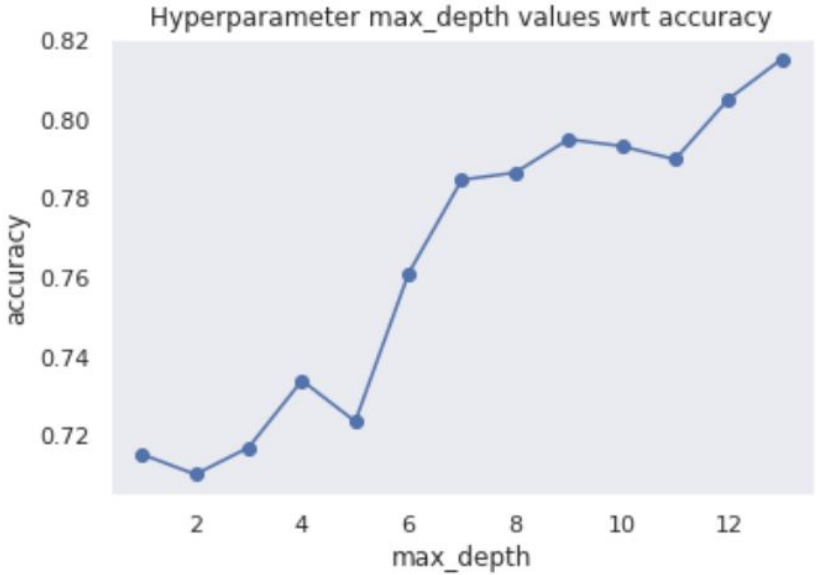
Overfitting??

cv	Gini	Entropy
2	0.735593220338983	0.7508474576271187
3	0.7812856106909769	0.7948565212887185
4	0.7931605074462218	0.7728097995955138
5	0.7983050847457628	0.7932203389830509
6	0.789716896859754	0.8134920634920636
7	0.8219887955182071	0.798219287715086
8	0.803336727138097	0.7897769344687152
9	0.8134421134421135	0.8134421134421134
10	0.8101694915254237	0.8186440677966103

We select **k=7** and **Gini**

Decision Tree Classifier

Experiments: max_depth

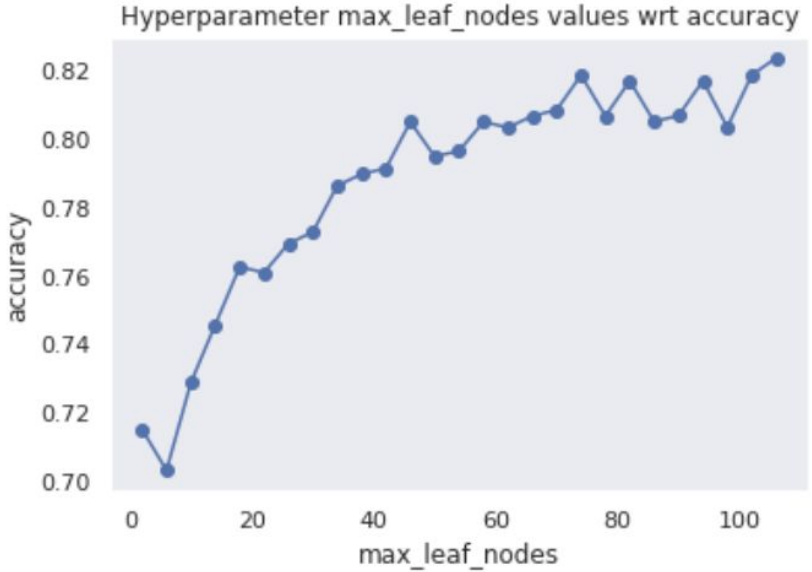


max_depth	Accuracy	std
1	0.715244353942984	0.04025996640440447
2	0.7101767863754165	0.04122461768209515
3	0.7169798222880415	0.03655062424595303
4	0.7339179933358015	0.027785989381750382
5	0.7235514624213255	0.04399791622469432
6	0.7609681599407627	0.0376125991994625
7	0.7846630877452796	0.04043810566534662
8	0.7864448352462051	0.04405493069093531
9	0.7948907811921511	0.03986083632243769
10	0.7931784524250278	0.051813540235849026
11	0.7898000740466494	0.036073407152003224
12	0.8050259163272862	0.038094548776207986
13	0.8151610514624213	0.04170920315879154

We select **max_depth=9**

Decision Tree Classifier

Experiments: max_leaf_nodes



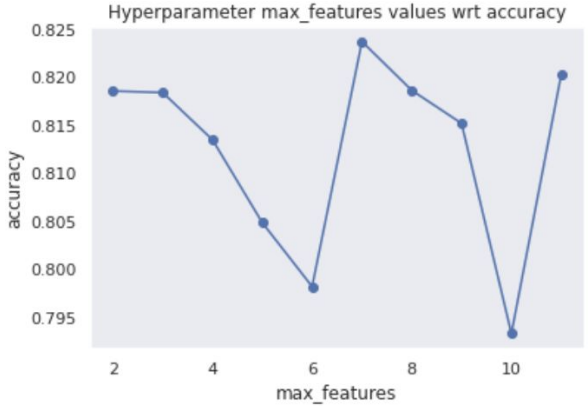
We select **max_leaf_nodes=46**

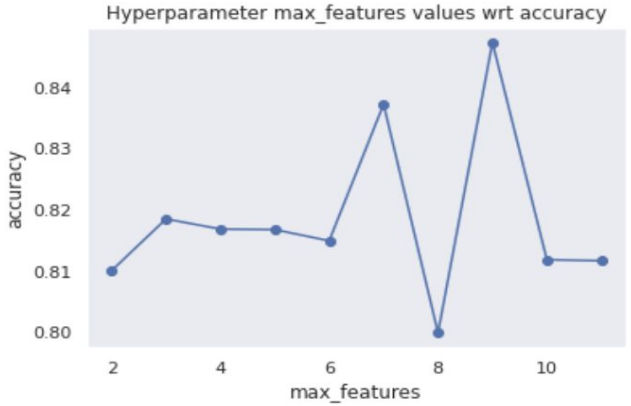
max_leaf_nodes	Accuracy	std
2	0.715244353942984	0.04025996640440447
6	0.7032349129951869	0.04091375119836036
10	0.7288735653461681	0.03908437741627181
14	0.7457654572380601	0.030970256955392652
18	0.7626573491299519	0.034381823340946846
22	0.7609681599407626	0.046806212945815585
26	0.7694372454646428	0.0336395668095371
30	0.772815623843021	0.03071189530409793
34	0.7863291373565346	0.03520876692424234
38	0.789730655312847	0.029586889068732247
42	0.7914198445020363	0.027999271770009413
46	0.8050027767493522	0.026854345046490008
50	0.7948445020362829	0.031161615211186936
54	0.7965105516475379	0.038353415901820696
58	0.8050027767493521	0.029229079157122778
62	0.8033135875601629	0.03075708660190856
66	0.8066688263606072	0.03432827161550478
70	0.8084505738615327	0.03442232911638383
74	0.8186088485746019	0.0378107713225851
78	0.8067151055164754	0.04515038064252705
82	0.8169427989633469	0.047578432914136076
86	0.8050490559052204	0.03131104693455119
90	0.8068076638282118	0.02919564664481759
94	0.8169659385412811	0.027822780637790888
98	0.8034061458718993	0.030923619750637576
102	0.8186319881525361	0.02959258009311779
106	0.8236301369863013	0.02863774956265964

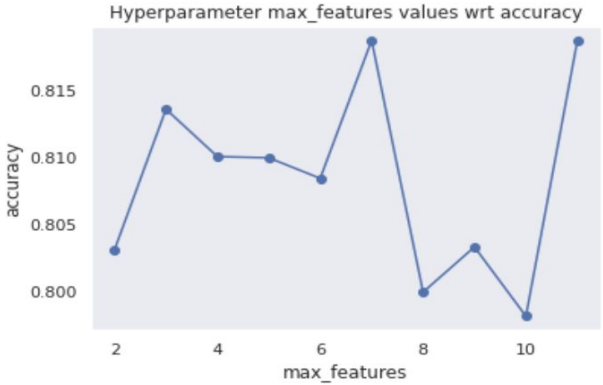
Decision Tree Classifier

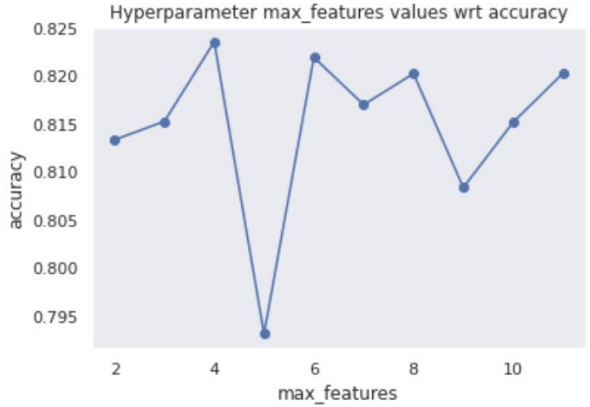
Experiments: max_features

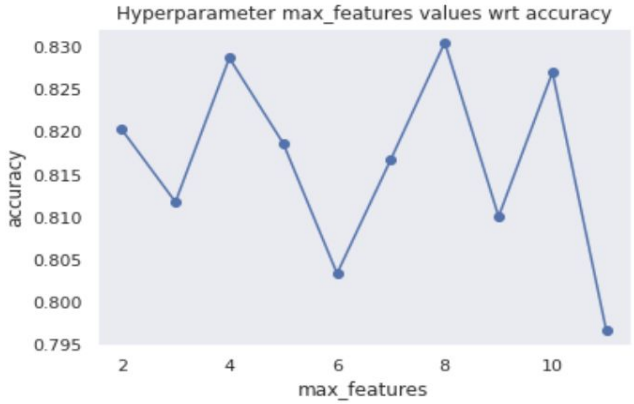
Random choices





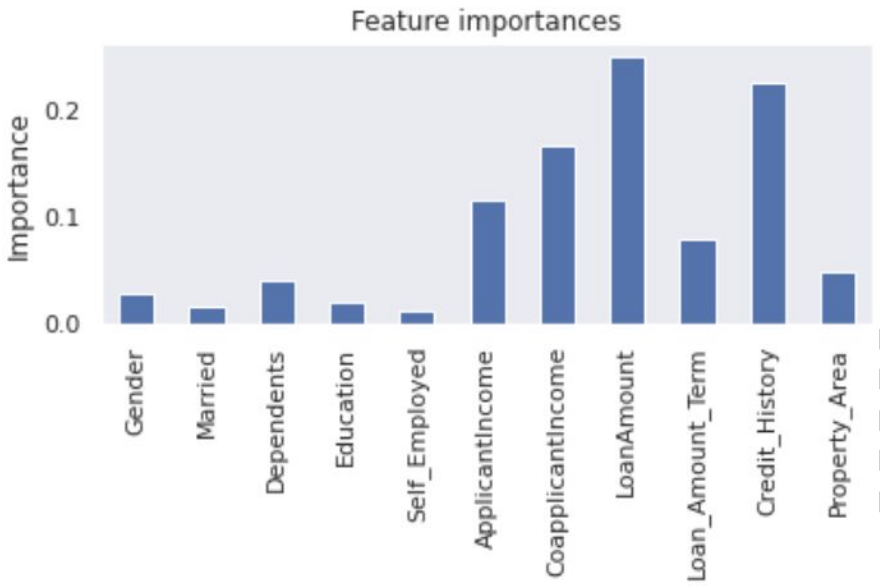






Decision Tree Classifier

Experiments: feature_importances_



Feature	Importance
Gender	0.02758441468085508
Married	0.01640754346026491
Dependents	0.040980477806997484
Education	0.01912663814767481
Self_Employed	0.012518357581320081
ApplicantIncome	0.11613221977809644
CoapplicantIncome	0.16560124306634597
LoanAmount	0.2494030680754342
Loan_Amount_Term	0.07856211236290246
Credit_History	0.2250805185402017
Property_Area	0.048603406499906916

Decision Tree Classifier

Experiments: feature_importances_

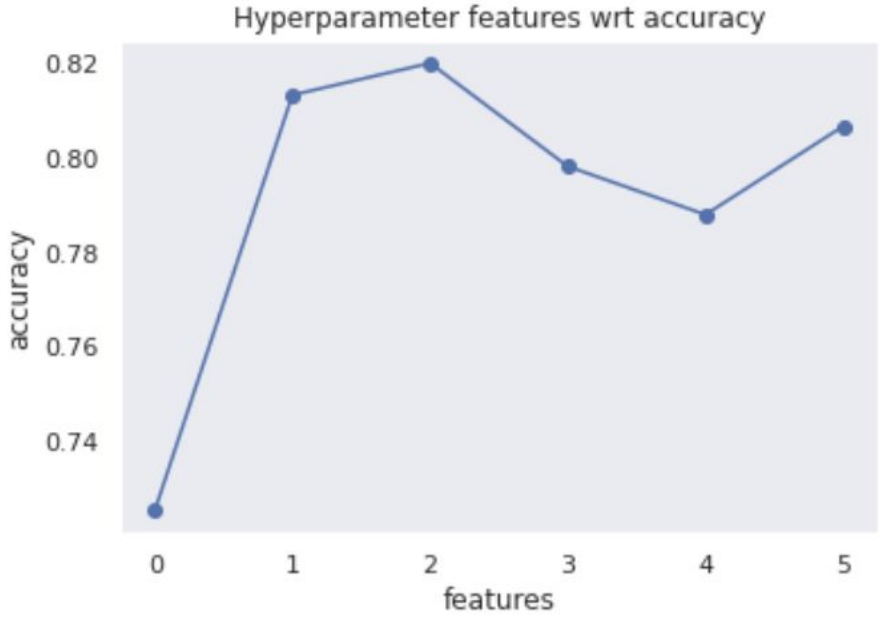
LoanAmount

Credit_History

ApplicantIncome

CoapplicantIncome

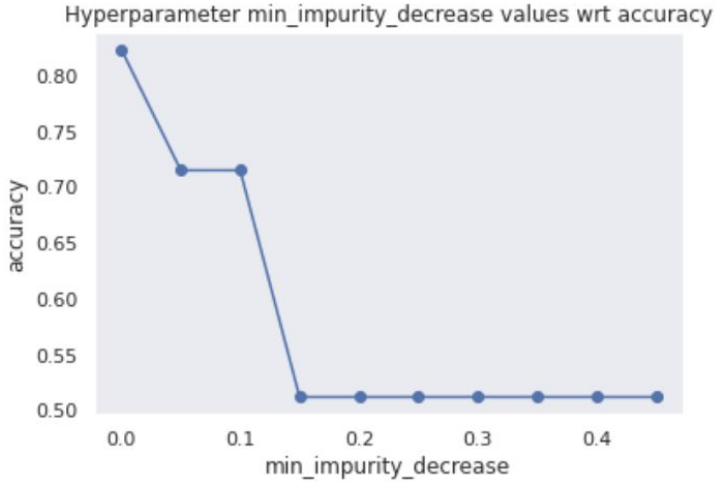
Loan_Amount_Term



Features	Accuracy	std
['LoanAmount', 'Credit_History']	0.7252637911884487	0.028608370851260723
['LoanAmount', 'Credit_History', 'ApplicantIncome', 'CoapplicantIncome']	0.8133793039614958	0.049951178084086036
['LoanAmount', 'Credit_History', 'ApplicantIncome', 'CoapplicantIncome', 'Loan_Amount_Term']	0.8201360607182525	0.039304158528231437
['LoanAmount', 'Credit_History', 'ApplicantIncome', 'CoapplicantIncome', 'Loan_Amount_Term', 'Property_Area_Rural']	0.7982460199925954	0.037140622857010225
['LoanAmount', 'Credit_History', 'ApplicantIncome', 'CoapplicantIncome', 'Loan_Amount_Term', 'Property_Area_Rural', 'Gender']	0.7880183265457238	0.04132274483100086
['LoanAmount', 'Credit_History', 'ApplicantIncome', 'CoapplicantIncome', 'Loan_Amount_Term', 'Property_Area_Rural', 'Gender', 'Married']	0.8067613846723436	0.05868295050989534

Decision Tree Classifier

Experiments: min_impurity

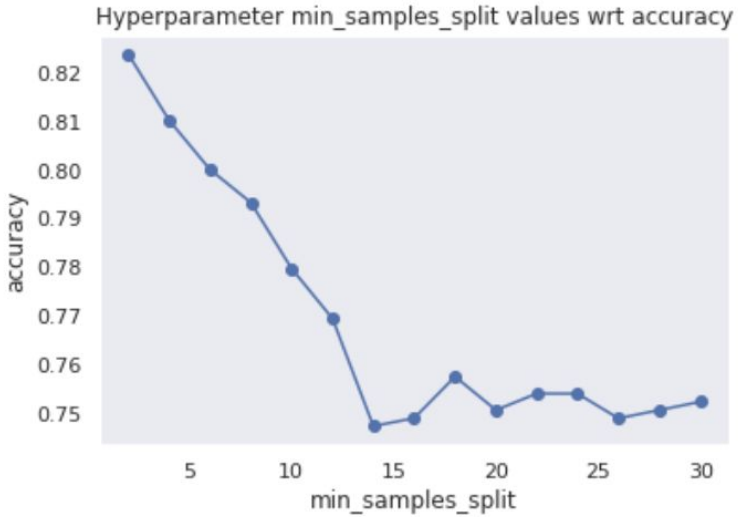


min_impurity	Accuracy	std
0.0	0.8236764161421696	0.024769510417746714
0.05	0.715244353942984	0.04025996640440447
0.1	0.715244353942984	0.04025996640440447
0.15000000000000002	0.5117780451684562	0.045727359939571666
0.2	0.5117780451684562	0.045727359939571666
0.25	0.5117780451684562	0.045727359939571666
0.30000000000000004	0.5117780451684562	0.045727359939571666
0.35000000000000003	0.5117780451684562	0.045727359939571666
0.4	0.5117780451684562	0.045727359939571666
0.45	0.5117780451684562	0.045727359939571666

No improvement

Decision Tree Classifier

Experiments: min_smaples_split



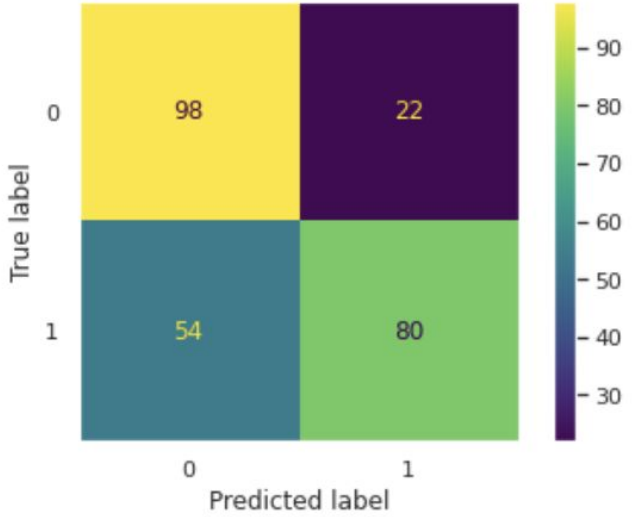
min_samples_split	Accuracy	std
2	0.8236532765642355	0.024067285793907368
4	0.8101166234727878	0.037280294583422
6	0.800050907071455	0.028387415035331633
8	0.7932941503146983	0.04023891433763866
10	0.7797574972232506	0.044902110999025656
12	0.7695529433543131	0.05498824079836616
14	0.7475472047389856	0.051614331517467193
16	0.7491901147723065	0.0541056526760061
18	0.7576823398741206	0.04974008233845239
20	0.7508330248056275	0.04890460976153757
22	0.7542114031840059	0.04818100224550936
24	0.7541882636060718	0.048278493258157314
26	0.7491438356164384	0.03768685737971202
28	0.7508330248056276	0.038879889789241937
30	0.7525222139948167	0.030207272180801516

No improvement

Decision Tree Classifier

Evaluation: criterion (Gini), cv (8-fold), max depth (9), max_leaf_nodes (46), features ['LoanAmount', 'Credit_History', 'ApplicantIncome', 'CoapplicantIncome', 'Loan_Amount_Term']

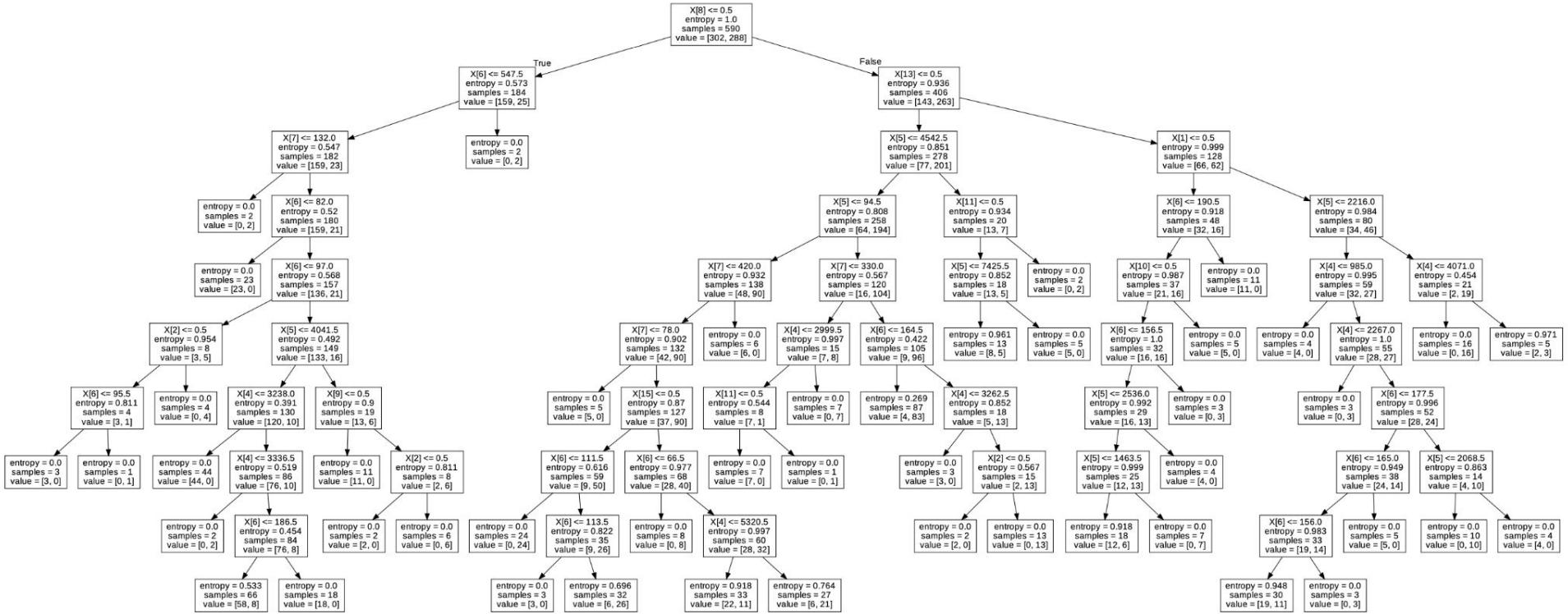
Confusion Matrix:



	precision	recall	f1-score	support
0	0.82	0.64	0.72	152
1	0.60	0.78	0.68	102
accuracy			0.70	254
macro avg	0.71	0.71	0.70	254
weighted avg	0.73	0.70	0.70	254

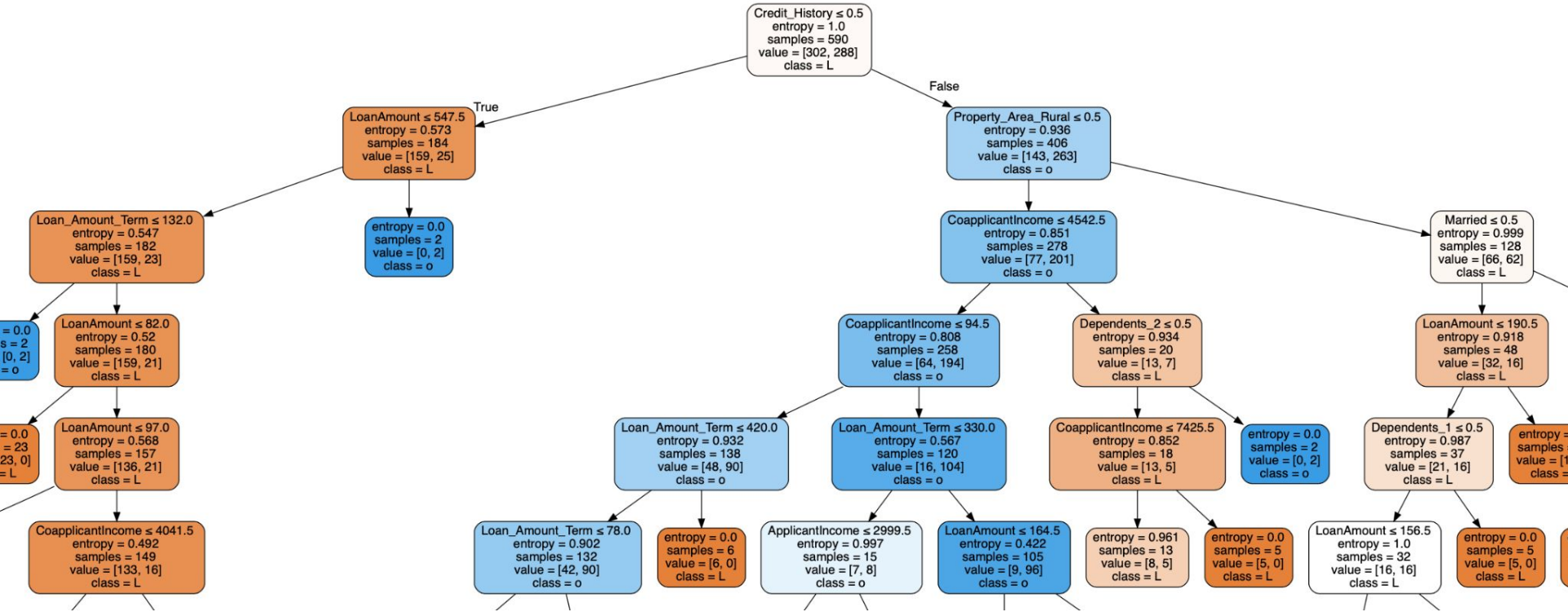
Decision Tree Classifier

Final Tree



Decision Tree Classifier

Final Tree



Random Forest Classifier

Experiment : Gini vs Entropy, k-fold Cross Validation

```
Accuracy without cross-validation using Gini:  1.0
Accuracy without cross-validation using Entropy:  1.0
```

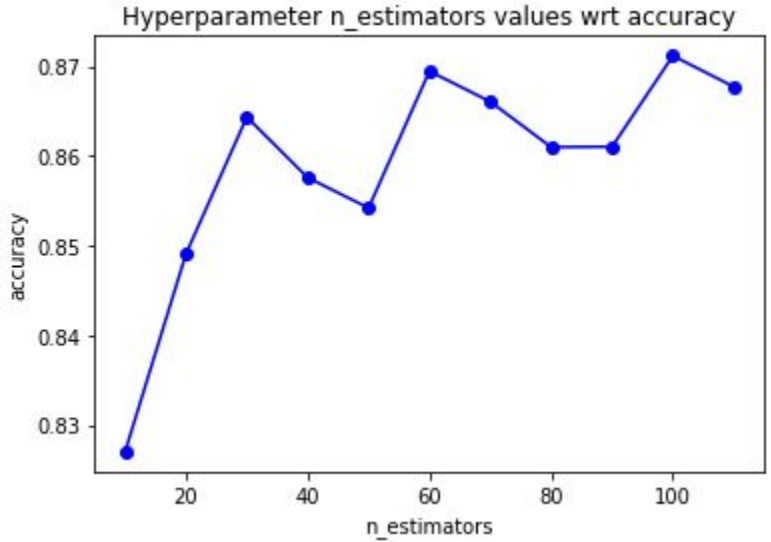
Overfitting??

cv	Gini	Entropy
2	0.7915254237288136	0.7983050847457627
3	0.8474481163023585	0.8406799267930523
4	0.8643477661334804	0.8541896488325059
5	0.8728813559322033	0.8661016949152543
6	0.8627258984401841	0.8779804851233423
7	0.8830532212885155	0.8661264505802321
8	0.8830757126990003	0.8763189559422436
9	0.866070966070966	0.8677544677544677
10	0.8745762711864407	0.8677966101694915

We select **k=8** and **Gini**

Random Forest Classifier

Experiment : tune n_estimators



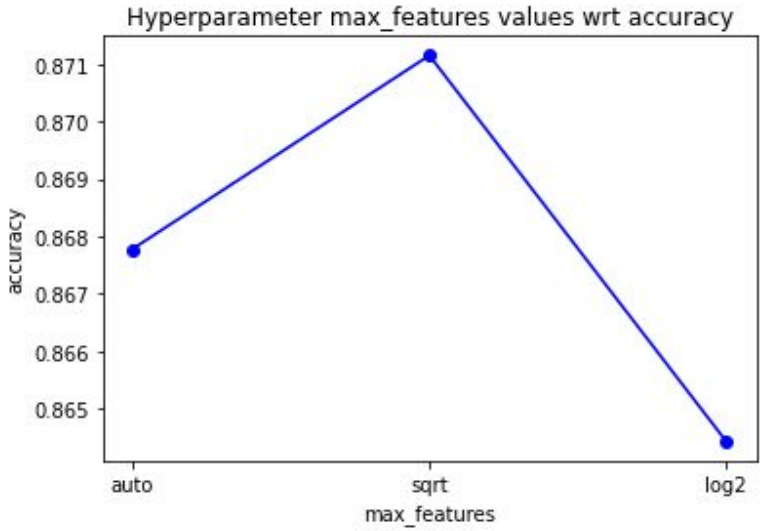
Model 1:

n_estimators	Accuracy	std
10	0.8270316549426139	0.02982302021124012
20	0.8490836727138097	0.021299626410377144
30	0.8643557941503146	0.029697771001670082
40	0.857599037393558	0.027260858442597364
50	0.8542206590151795	0.030867329651380546
60	0.8694696408737504	0.03108449842557713
70	0.8660681229174381	0.018743000991772358
80	0.8610005553498705	0.02426748273669653
90	0.8610468345057387	0.02304198923540557
100	0.8711819696408737	0.022485657895571602
110	0.8677341725286931	0.024496147814921383

We select **n_estimators=100**

Random Forest Classifier

Experiment : tune max_features



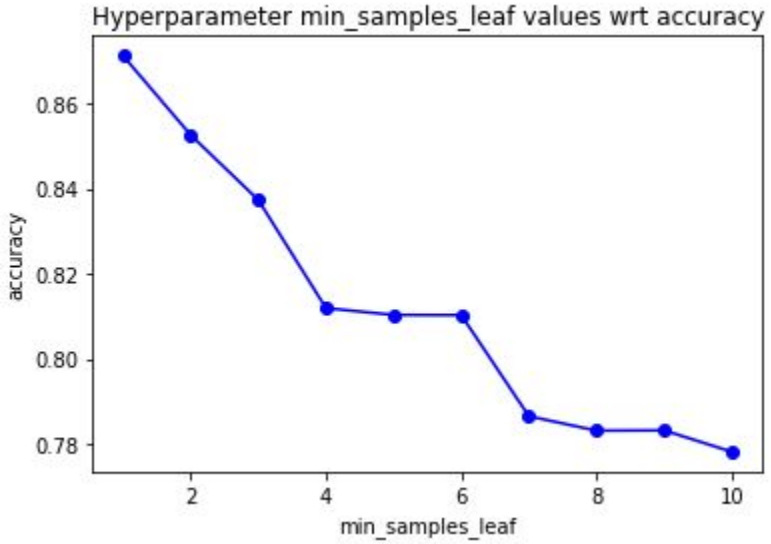
Model 2:

max_features	Accuracy	std
auto	0.8677804516845613	0.023350345183609934
sqrt	0.8711588300629396	0.028808393512302383
log2	0.864425212884117	0.021307505863981932

We select **max_features=sqrt**

Random Forest Classifier

Experiment : tune min_samples_leaf



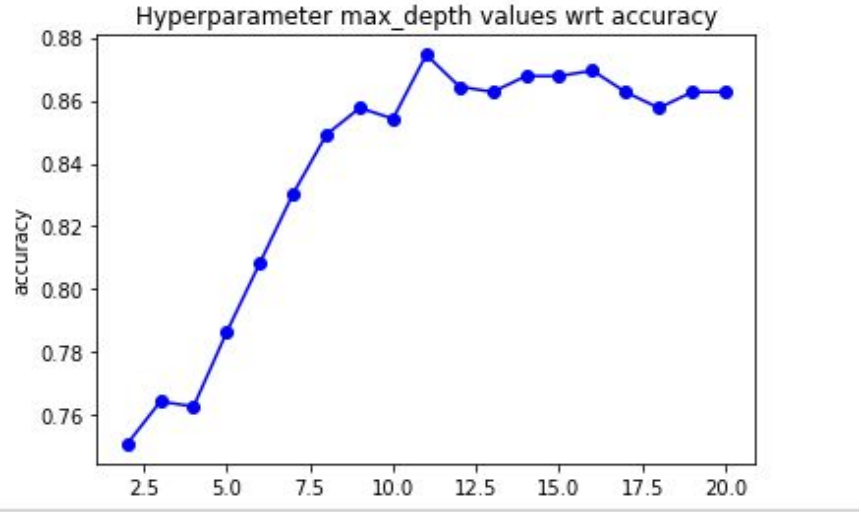
Model 3:

min_samples_leaf	Accuracy	std
1	0.8712051092188078	0.01787472111673374
2	0.8525777489818586	0.02265220495971451
3	0.8373056275453536	0.02619799819529852
4	0.8118752313957793	0.024670349755966187
5	0.8102786005183266	0.03776406767136412
6	0.8102323213624583	0.02832230459701961
7	0.7864679748241392	0.03557527807973347
8	0.7830664568678267	0.03302081011202703
9	0.7831358756016289	0.03329925964528661
10	0.7780914476119956	0.04536204860013788

We select **min_samples_leaf=1**

Random Forest Classifier

Experiment : tune max_depth



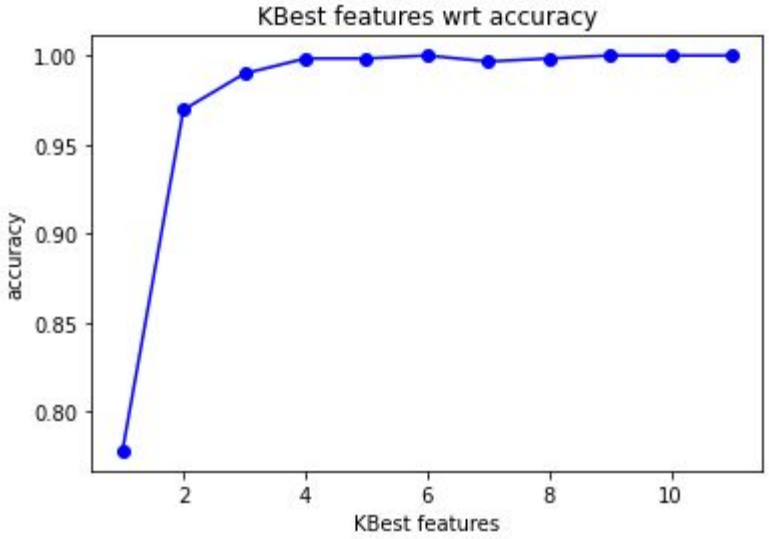
Model 4:

max_depth	Accuracy	std
2	0.7508330248056275	0.03459923289733157
3	0.764346538319141	0.02679655042068158
4	0.7627730470196223	0.03910103941969463
5	0.7864911144020734	0.03597303970266889
6	0.8084968530174009	0.028188223166753363
7	0.8305025916327287	0.03640436626442366
8	0.8491762310255462	0.03260099651190076
9	0.8576221769714921	0.02535142209468115
10	0.8541975194372455	0.03310935627623877
11	0.874537208441318	0.02340330094374288
12	0.8643789337282488	0.023621043911394555
13	0.8627128841169938	0.022940823102555106
14	0.8677573121066271	0.027894307713888046
15	0.8677573121066271	0.0253205670794937
16	0.8694696408737503	0.0214540578140225
17	0.8626666049611256	0.030754919145733892
18	0.857599037393558	0.031106995150041335
19	0.8626897445390597	0.024938711652906183
20	0.8626897445390596	0.022980711588021473

We select **max_depth=14**

Random Forest Classifier

Experiment : select k Best Features



KBest features	Accuracy
1	0.7779661016949152
2	0.9694915254237289
3	0.9898305084745763
4	0.9983050847457627
5	0.9983050847457627
6	1.0
7	0.9966101694915255
8	0.9983050847457627
9	1.0
10	1.0
11	1.0

We select **k=8**

Random Forest Classifier

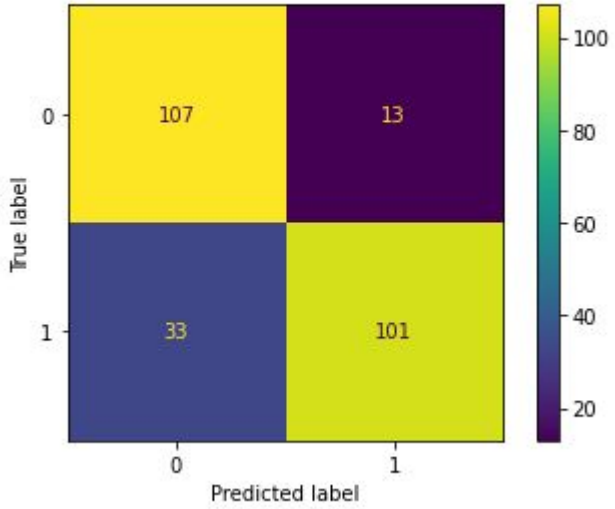
Test: select k Best Features

```
Accuracy: 0.709

F1 score: [0.68376068 0.72992701]

precision_score: 0.714

recall_score: 0.746

              precision    recall  f1-score   support

           0       0.67      0.70      0.68       114
           1       0.75      0.71      0.73       140

    accuracy                           0.71       254
   macro avg       0.71      0.71      0.71       254
weighted avg       0.71      0.71      0.71       254
```

Random Forest Classifier

Evaluation : criterion(Gini), n_estimators(100), min_samples_leaf(1), max_depth(14), max_features(sqrt)

Confusion Matrix:



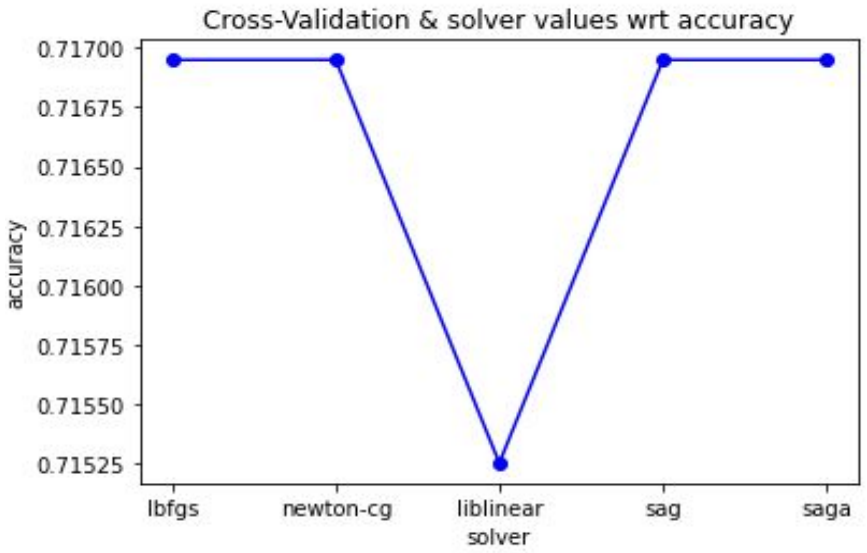
Accuracy: 0.819

F1 score: [0.82307692 0.81451613]

	precision	recall	f1-score	support
0	0.89	0.76	0.82	140
1	0.75	0.89	0.81	114
accuracy			0.82	254
macro avg	0.82	0.83	0.82	254
weighted avg	0.83	0.82	0.82	254

Logistic Regression

Experiment - different solvers



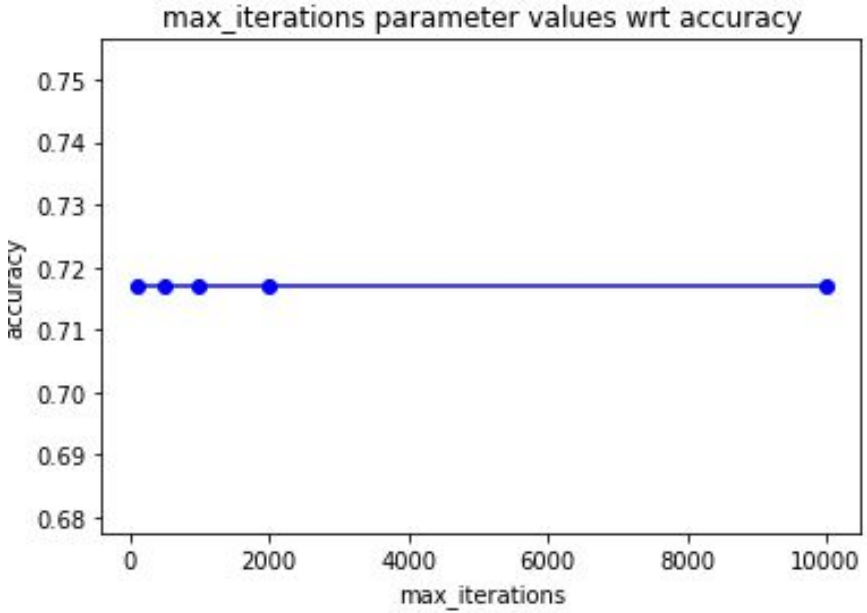
Model 1:

solver	LR acc	LRCV acc
lbfgs	0.7508474576271187	0.7508474576271187
newton-cg	0.7508474576271187	0.7508474576271187
liblinear	0.7508474576271187	0.7389830508474576
sag	0.7508474576271187	0.7508474576271187
saga	0.7508474576271187	0.7508474576271187

Since our data set is small, ‘newton-cg’ and 'lbfgs' are appropriate to use. We decided to choose **'lbfgs'**, the default solver, because it only stores the last few updates and saves memory.

Logistic Regression

Experiment - max_iterations parameter



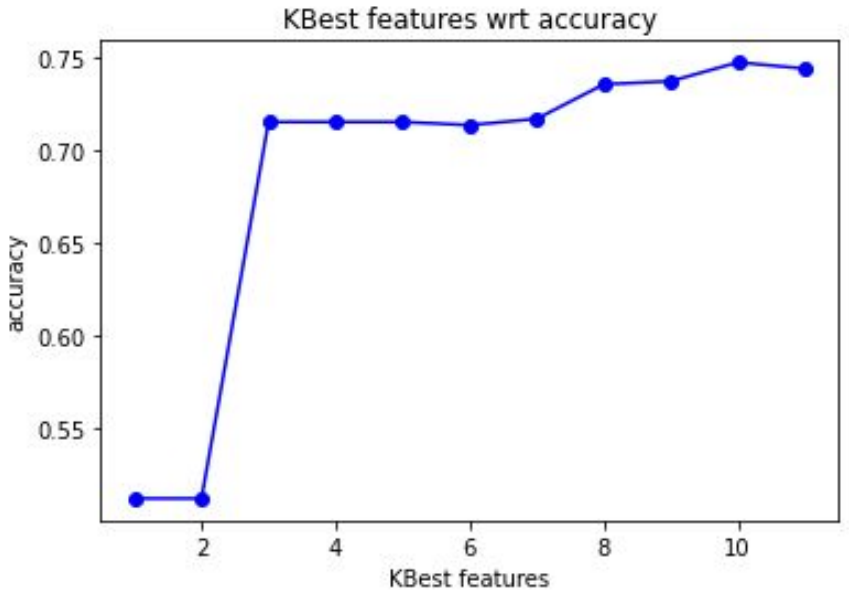
Model 2:

max_iterations	Accuracy
100	0.7508474576271187
500	0.7508474576271187
1000	0.7508474576271187
2000	0.7508474576271187
10000	0.7508474576271187

No difference was found.

Logistic Regression

Experiment : k-best features



KBest features	Accuracy
1	0.511864406779661
2	0.511864406779661
3	0.7152542372881356
4	0.7152542372881356
5	0.7152542372881356
6	0.7135593220338983
7	0.7169491525423729
8	0.735593220338983
9	0.7372881355932204
10	0.747457627118644
11	0.7440677966101695

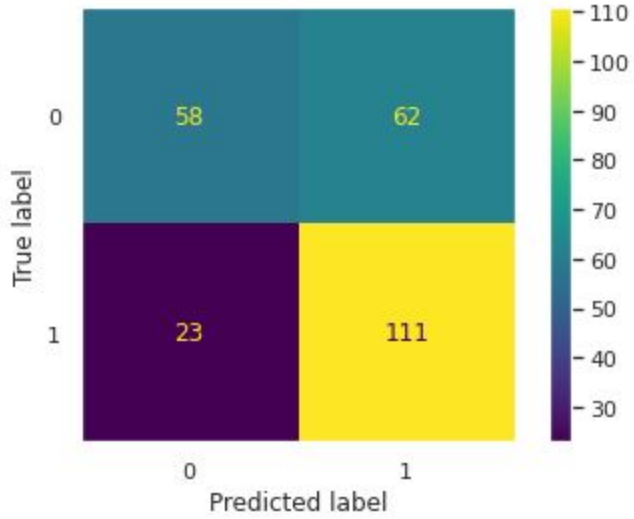
No improvement was found

Logistic Regression

Evaluation

Since no improvement was found, we keep the default model.

Confusion Matrix:




```
Accuracy: 0.665

F1 score: [0.57711443 0.72312704]

precision_score: 0.6416184971098265

recall_score: 0.8283582089552238
```

Best Model

Model	Accuracy	Recall
Decision Tree	0.7	0.7
Random Forest	0.82	0.82
Logistic Regression	0.67	0.82