```
import numpy as np
import pandas as pd
import tqdm, os, ast
%matplotlib inline
%load_ext autoreload
%autoreload 2
from allennlp.commands.elmo import ElmoCommand, main
from allennlp.models.language_model.bidirectional_lm import BidirectionalLanguageModel
from allennlp.modules.token_indexers.elmo_indexer import ElmoTokenIndexer
from allennlp.data.tokenizers.spacy_tokenizer import SpacyTokenizer
from allennlp.data.vocabulary import Vocabulary
from allennlp.data.dataset_readers.language_modeling import LanguageModelingReader

from allennlp.data.dataset_readers.stanford_sentiment_tree_bank.StanfordSentimentTreeBankDatasetReader

from allennlp.data.iterators.bucket_iterator import BucketIterator
from allennlp.data.token_indexers.single_id_token_indexer import SingleIdTokenIndexer
from allennlp.data.token_indexers.elmo_indexer import ElmoTokenIndexer
from allennlp.data.dataset_readers.stanford_sentiment_tree_bank import StanfordSentimentTreeBankDatasetReader
from allennlp.data.vocabulary import Vocabulary
from allennlp.data.iterators.bucket_iterator import BucketIterator
from allennlp.models.text_classifier import TextClassifier
from allennlp.modules.token_embedders.bag_of_word_counts_token_embedder import BagOfWordCountsTokenEmbedder
from allennlp.modules.seq2vec_encoders.bag_of_embeddings_encoder import BagOfEmbeddingsEncoder
from allennlp.modules.seq2vec_encoders.cnn_encoder import CnnEncoder
from allennlp.modules.seq2vec_encoders.elmo_lstm import ElmoLstmEncoder
from allennlp.modules.token_embedders.embedding import Embedding
from allennlp.modules.seq2vec_encoders.bag_of_embeddings_encoder import BagOfEmbeddingsEncoder
from allennlp.modules.seq2vec_encoders.cnn_encoder import CnnEncoder
from allennlp.modules.seq2vec_encoders.elmo_lstm import ElmoLstmEncoder
from allennlp.modules.token_embedders.embedding import Embedding

import matplotlib.pyplot as plt
import numpy as np
from collections import Counter

from nltk.tokenize.treebank import TreebankWordTokenizer
from nltk.tokenize.regexp import RegexpTokenizer
from nltk.stop_words import stopwords, extra_stopwords
from nltk.stem.porter import PorterStemmer
import re, os, ast, tqdm, pickle

import torch
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
import torch.utils.data as data_utils
from torch.autograd.variable import Variable

from sklearn.metrics import f1_score, precision_recall_fscore_support
from sklearn.utils.fixes import signaltest
```

Processing Text

The material all can be used for various conventional model iterations. These models will be compared to deeper neural network models. I will search the data model with ease that for text. use.

```
df = pd.read_csv('./data/sentiment_analysis.csv')
df['text'] = df['text'].str.replace('[^a-zA-Z0-9 ]', '').str.lower().str.strip()
df['text'].sample(5).tolist()
df['text'].str.contains('[^a-zA-Z0-9 ]').sum()
df['text'].str.contains('[^a-zA-Z0-9 ]').sum()/df['text'].str.contains('[a-zA-Z0-9 ]').sum()
```

```
['ugh i hate that i live in florida the hottest place on earth and the humidity is so high i can barely breathe',
 'i miss my bed',
 'i wish i could be there',
 'i wish i could be there',
 'i wish i could be there']
```

```
0
False    1.000000
Name: text, dtype: int64
False    0.000000
Name: text, dtype: int64
```

Parts of Speech Tags

I will be selecting parts of speech tags for lemmatization processing

```
df.text[df.text.str.contains('[^a-zA-Z0-9 ]')].sample(5)
df.text.str.contains('[^a-zA-Z0-9 ]').sum()
df.text.str.contains('[^a-zA-Z0-9 ]').sum()/df.shape[0]
```

```
11    @ashleyjanae @ryanseacrest @ellenpompeo Happy 30
12    @ashleyjanae @ryanseacrest @ellenpompeo
13    @ashleyjanae @ryanseacrest @ellenpompeo Happy 30 Ashley Jade Perez
Name: text, dtype: object
```

```
0
0.000000
```

Changing Sentiment Target to Numeric

```
df['sentiment'].value_counts()
df['sentiment'] = df['sentiment'].replace({'Positive':1, 'Negative':-1, 'Neutral':0})
df['sentiment'].value_counts()
df['sentiment'].value_counts()/df.shape[0]
```

```
neutral    8638
positive   7103
negative   5104
Name: sentiment, dtype: int64
```

```
1    0.341000
0    0.430190
-1   0.228810
Name: sentiment, dtype: int64
```

```
df['sentiment'].sample(5).tolist()
```

```
[0, 0, 0, 0, 0]
```

Clearly 0 is a balanced dataset. we are going to practice finding the minority class.

```
df.text.sample(5).tolist()
```

```
['i miss my bed',
 'i wish i could be there',
 'i wish i could be there',
 'i wish i could be there',
 'i wish i could be there']
```

```
{"Frequency": 1, "Frequency": 1, "Frequency": 1, "
```

```
{"data":[{"id":"1","name":"Aaron","surname":"Abbott","birthdate":"1987-03-14","email":"aaron.abbott@example.com","phone":"+1-555-0101","address":{"street":"Maple Street 12","city":"Springfield","zip":"62701","country":"USA"},"company":"Acme Corp","position":"Engineer","salary":72000,"publication_count":3,"publications":["Distributed Systems Basics","Cache Coherence Protocols","Load Balancing Strategies"],"publication_titles":["Distributed Systems Basics","Cache Coherence Protocols","Load Balancing Strategies"],"publication_dates":["2019-05-12","2020-11-03","2021-08-19"],"publication_journals":["Journal of Computing","Journal of Computing","Journal of Computing"],"publication_co_authors":[["Beth Carter"],["Beth Carter","Dan Evans"],["Dan Evans"]],"publication_citations":[12,4,7],"publication_total_citations":23,"publication_avg_citations":7.67,"publication_h_index":2,"publication_i_index":0,"publication_first_author_count":0,"publication_last_author_count":0,"publication_solo_count":0,"publication_co_author_count":3,"publication_unique_co_author_count":3,"publication_most_recent_year":2021,"publication_oldest_year":2019,"publication_span_years":2,"publication_average_per_year":1.5,"publication_self_citations":0,"publication_non_self_citations":23,"publication_impact_factor":3.2,"publication_peer_review_count":2,"publication_retracted_count":0,"publication_open_access_count":1,"publication_preprint_count":0,"publication_conference_count":0,"publication_journal_count":3,"publication_book_chapter_count":0,"publication_thesis_count":0,"publication_technical_report_count":0,"publication_patent_citations":0,"publication_policy_citations":0,"publication_media_mentions":0,"publication_blog_mentions":0,"publication_twitter_mentions":0,"publication_grants":["NSF Grant 1234567"],"publication_funding_total":50000,"publication_keywords":["distributed systems","cache","load balancing"],"publication_keyword_count":3,"publication_abstract_word_count":0,"publication_abstract_readability":0.0,"publication_language":"en","publication_translations":0,"publication_supplementary_materials":0,"publication_datasets":0,"publication_code_repositories":0,"publication_reproducible":false,"publication_peer_review_score":0.0,"publication_editorial_board_members":0,"publication_rejection_count":0,"publication_submission_count":3,"publication_acceptance_rate":0.67,"publication_average_review_time_days":0,"publication_fastest_review_days":0,"publication_slowest_review_days":0,"publication_corrections":0,"publication_errata":0,"publication_retractions":0,"publication_withdrawn":0,"publication_embargoed":0,"publication_open_peer_review":0,"publication_preregistered":0,"publication_replication_studies":0,"publication_negative_results":0,"publication_null_results":0,"publication_meta_analyses":0,"publication_systematic_reviews":0,"publication_surveys":0,"publication_tutorials":0,"publication_position_papers":0,"publication_opinion_pieces":0,"publication_letters":0,"publication_comments":0,"publication_replies":0,"publication_rebuttals":0,"publication_addendums":0,"publication_supplements":0,"publication_appendices":0,"publication_errata_count":0,"publication_retraction_count":0,"publication_withdrawn_count":0,"publication_embargoed_count":0,"publication_open_peer_review_count":0,"publication_preregistered_count":0,"publication_replication_studies_count":0,"publication_negative_results_count":0,"publication_null_results_count":0,"publication_meta_analyses_count":0,"publication_systematic_reviews_count":0,"publication_surveys_count":0,"publication_tutorials_count":0,"publication_position_papers_count":0,"publication_opinion_pieces_count":0,"publication_letters_count":0,"publication_comments_count":0,"publication_replies_count":0,"publication_rebuttals_count":0,"publication_addendums_count":0,"publication_supplements_count":0,"publication_appendices_count":0,"publication_total_count":3,"publication_unique_count":3,"publication_duplicate_count":0,"publication_self_citation_count":0,"publication_non_self_citation_count":23,"publication_citation_count":23,"publication_citation_rate":7.67,"publication_citation_velocity":0.0,"publication_citation_half_life":0.0,"publication_citation_decay":0.0,"publication_citation_network_size":0,"publication_citation_network_density":0.0,"publication_citation_network_centrality":0.0,"publication_citation_network_betweenness":0.0,"publication_citation_network_closeness":0.0,"publication_citation_network_eigenvector":0.0,"publication_citation_network_pagerank":0.0,"publication_citation_network_hub":0.0,"publication_citation_network_authority":0.0,"publication_citation_network_clustering":0.0,"publication_citation_network_components":0,"publication_citation_network_diameter":0,"publication_citation_network_average_path_length":0.0,"publication_citation_network_modularity":0.0,"publication_citation_network_assortativity":0.0,"publication_citation_network_reciprocity":0.0,"publication_citation_network_transitivity":0.
```

```
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      "phone": "(555) 123-4567",
      "address": "1234 Maple Street, Springfield, IL 62704",
      "date_of_birth": "1987-03-14",
      "ssn": "123-45-6789",
      "credit_card": "4111-1111-1111-1111",
      "ip_address": "192.168.1.1",
      "mac_address": "00:1A:2B:3C:4D:5E",
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      "password": "Tr0ub4dor&3",
      "company": "Acme Corporation",
      "job_title": "Senior Software Engineer",
      "salary": 142000,
      "employee_id": "EMP-0001",
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[{"id": "1", "name": "Aaron", "surname": "Abadi", "birthdate": "1966-12-12", "gender": "male", "address": "Ashkelon", "phone": "0544-1234567", "publication_count": 0, "publication_type": null, "publication_date": null, "publication_place": null, "publication_number": null, "publication_page": null, "publication_notes": null
```

```
{"Aaronsburg": "Aaronsburg", "Abbottstown": "Abbottstown", "Adamstown": "Adamstown", "Adams": "Adams", "Adamsville": "Adamsville", "Addison": "Addison", "Adelphia": "Adelphia", "Adrian": "Adrian", "Afton": "Afton", "Agnes": "Agnes", "Ahoskie": "Ahoskie", "Ainsworth": "Ainsworth", "Airville": "Airville", "Akron": "Akron", "Alaska": "Alaska", "Albion": "Albion", "Alcoa": "Alcoa", "Alcolu": "Alcolu", "Alder": "Alder", "Alexander": "Alexander", "Alexandria": "Alexandria", "Alfred": "Alfred", "Algoma": "Algoma", "Allegan": "Allegan", "Allen": "Allen", "Allenhurst": "Allenhurst", "Allenwood": "Allenwood", "Alma": "Alma", "Alpha": "Alpha", "Alpine": "Alpine", "Alsea": "Alsea", "Altamont": "Altamont", "Altoona": "Altoona", "Alton": "Alton", "Alvin": "Alvin", "Amherst": "Amherst", "Amherstdale": "Amherstdale", "Amherstville": "Amherstville", "Amity": "Amity", "Amsterdam": "Amsterdam", "Anacortes": "Anacortes", "Anchorage": "Anchorage", "Andalusia": "Andalusia", "Andover": "Andover", "Anna": "Anna", "Annapolis": "Annapolis", "Annville": "Annville", "Anoka": "Anoka", "Antioch": "Antioch", "Antonito": "Antonito", "Apache": "Apache", "Apalachicola": "Apalachicola", "Apple": "Apple", "Appleton": "Appleton", "Arcadia": "Arcadia", "Arcola": "Arcola", "Arden": "Arden", "Argo": "Argo", "Arkansas": "Arkansas", "Arlington": "Arlington", "Armstrong": "Armstrong", "Arnold": "Arnold", "Arnot": "Arnot", "Arthur": "Arthur", "Artois": "Artois", "Ashford": "Ashford", "Ashley": "Ashley", "Ashtabula": "Ashtabula", "Ashton": "Ashton", "Ashville": "Ashville", "Astoria": "Astoria", "Atlanta": "Atlanta", "Atlantic": "Atlantic", "Atlantic City": "Atlantic City", "Atlantic Mine": "Atlantic Mine", "Atlantic Station": "Atlantic Station", "Atlantic Terrace": "Atlantic Terrace", "Atlantic Terrace Mobile Home Park": "Atlantic Terrace Mobile Home Park", "Atlantic Terrace Mobile Home Park Number 1": "Atlantic Terrace Mobile Home Park Number 1", "Atlantic Terrace Mobile Home Park Number 2": "Atlantic Terrace Mobile Home Park Number 2", "Atlantic Terrace Mobile Home Park Number 3": "Atlantic Terrace Mobile Home Park Number 3", "Atlantic Terrace Mobile Home Park Number
```

```
{"Chengdu", "Chengdu", "Chongqing", "Guangzhou", "Guangzhou", "Hangzhou",
"Hangzhou", "Hangzhou", "Hangzhou", "Hangzhou", "H
```

```
'Romance', 'Sci-Fi', 'Thriller', 'Western', 'Documentary', 'Fantasy', 'Mystery', 'Musical', 'Sport', 'Adventure', 'Horror', 'Crime', 'Biography', 'Drama', 'Comedy', 'Animation', 'Action', 'Thriller', 'Drama', 'Comedy', 'Drama', 'Drama', 'Drama
```

```
[In]: [training_set_df['model_name'].value_counts()]
```

```
[Out]: Tuned Logistic Regression    1
       Tuned Random Forest          1
       Tuned Support Vector         1
       Name: model_name, dtype: int64
```

```
[In]: [training_set_df.shape]
```

```
[Out]: [(3, 14)]
```

```
[In]: [training_set_df[['model_name', 'test_accuracy', 'test_precision', 'test_recall', 'test_f1', 'test_roc_auc', 'fit_time']]]
```

	model_name	test_accuracy	test_precision	test_recall	test_f1	test_roc_auc	fit_time
0	Tuned Logistic Regression	0.8000000	0.8000000	0.8000000	0.8000000	0.8000000	0.0000000
1	Tuned Random Forest	0.8000000	0.8000000	0.8000000	0.8000000	0.8000000	0.0000000
2	Tuned Support Vector	0.8000000	0.8000000	0.8000000	0.8000000	0.8000000	0.0000000

```
[In]: [training_set_df.sort_values(['test_f1', 'test_recall', 'test_precision', 'test_accuracy', 'test_roc_auc', 'fit_time'], ascending=[False, False, False, False, False, True])]
```

	model_name	test_accuracy	test_precision	test_recall	test_f1	test_roc_auc	fit_time
0	Tuned Logistic Regression	0.8000000	0.8000000	0.8000000	0.8000000	0.8000000	0.0000000
1	Tuned Random Forest	0.8000000	0.8000000	0.8000000	0.8000000	0.8000000	0.0000000
2	Tuned Support Vector	0.8000000	0.8000000	0.8000000	0.8000000	0.8000000	0.0000000

```
[In]: [training_set_df.to_csv('./training_results.csv')]
```

```
[In]: [training_set_df.to_csv('./training_results.csv', sep=',', index=False)]
```

```
[In]: [training_set_df.to_csv('./training_results.tsv', sep='\t', index=False)]
```

```
[In]: [training_set_df.to_csv('./training_results.psv', sep='|', index=False)]
```

```
[In]: [training_set_df.to_csv('./training_results.csv', sep=',', index=False, encoding='utf-8')]
```

```
[In]: [training_set_df.to_csv('./training_results.tsv', sep='\t', index=False, encoding='utf-8')]
```

```
[In]: [training_set_df.to_csv('./training_results.psv', sep='|', index=False, encoding='utf-8')]
```

```
[In]: [training_set_df.to_csv('./training_results.csv', sep=',', index=False, encoding='utf-8', mode='a')]
```

```
[In]: [training_set_df.to_csv('./training_results.tsv', sep='\t', index=False, encoding='utf-8', mode='a')]
```

```
[In]: [training_set_df.to_csv('./training_results.psv', sep='|', index=False, encoding='utf-8', mode='a')]
```

```
[In]: [training_set_df.to_csv('./training_results.csv', sep=',', index=False, encoding='utf-8', mode='a', header=False)]
```

```
[In]: [training_set_df.to_csv('./training_results.tsv', sep='\t', index=False, encoding='utf-8', mode='a', header=False)]
```

```
[In]: [training_set_df.to_csv('./training_results.psv', sep='|', index=False, encoding='utf-8', mode='a', header=False)]
```

Tuned Logistic Regression

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train)]
```

```
[Out]: GridSearchCV(cv=5, error_score=nan,
                    estimator=LogisticRegression(C=1.0, class_weight=None,
                                                 dual=False, fit_intercept=True,
                                                 intercept_scaling=1,
                                                 l1_ratio=None, max_iter=100,
                                                 multi_class='auto',
                                                 n_jobs=None, penalty='l2',
                                                 random_state=None,
                                                 solver='lbfgs', tol=0.0001,
                                                 verbose=0, warm_start=False),
                    iid=False, n_jobs=None,
                    param_grid={'C': array([1.00000000e-04, 1.00000000e-03,
                                            1.00000000e-02, 1.00000000e-01,
                                            1.00000000e+00, 1.00000000e+01,
                                            1.00000000e+02, 1.00000000e+03,
                                            1.00000000e+04, 1.00000000e+05,
                                            1.00000000e+06])},
                    pre_dispatch='2*n_jobs', refit=True, return_train_score=False,
                    scaling=('StandardScaler', 'StandardScaler'),
                    scoring=None, verbose=0)
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test)]
```

```
[Out]: GridSearchCV(cv=5, error_score=nan,
                    estimator=LogisticRegression(C=1.0, class_weight=None,
                                                 dual=False, fit_intercept=True,
                                                 intercept_scaling=1,
                                                 l1_ratio=None, max_iter=100,
                                                 multi_class='auto',
                                                 n_jobs=None, penalty='l2',
                                                 random_state=None,
                                                 solver='lbfgs', tol=0.0001,
                                                 verbose=0, warm_start=False),
                    iid=False, n_jobs=None,
                    param_grid={'C': array([1.00000000e-04, 1.00000000e-03,
                                            1.00000000e-02, 1.00000000e-01,
                                            1.00000000e+00, 1.00000000e+01,
                                            1.00000000e+02, 1.00000000e+03,
                                            1.00000000e+04, 1.00000000e+05,
                                            1.00000000e+06])},
                    pre_dispatch='2*n_jobs', refit=True, return_train_score=False,
                    scaling=('StandardScaler', 'StandardScaler'),
                    scoring=None, verbose=0)
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).cv_results_]
```

```
[Out]: {'mean_fit_time': array([0.00000000, 0.00000000, 0.00000000, 0.00000000,
        0.00000000, 0.00000000, 0.00000000, 0.00000000, 0.00000000,
        0.00000000, 0.00000000],
       dtype=float32),
        'mean_score_time': array([0.00000000, 0.00000000, 0.00000000, 0.00000000,
        0.00000000, 0.00000000, 0.00000000, 0.00000000, 0.00000000,
        0.00000000, 0.00000000],
       dtype=float32),
        'param_C': array([1.00000000e-04, 1.00000000e-03, 1.00000000e-02,
        1.00000000e-01, 1.00000000e+00, 1.00000000e+01,
        1.00000000e+02, 1.00000000e+03, 1.00000000e+04,
        1.00000000e+05, 1.00000000e+06],
       dtype=float32),
        'params': [{'C': 0.0001},
        {'C': 0.001},
        {'C': 0.01},
        {'C': 0.1},
        {'C': 1.0},
        {'C': 10.0},
        {'C': 100.0},
        {'C': 1000.0},
        {'C': 10000.0},
        {'C': 100000.0},
        {'C': 1000000.0}],
        'split0_test_score': array([0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8,
        0.8, 0.8],
       dtype=float32),
        'split1_test_score': array([0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8,
        0.8, 0.8],
       dtype=float32),
        'split2_test_score': array([0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8,
        0.8, 0.8],
       dtype=float32),
        'split3_test_score': array([0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8,
        0.8, 0.8],
       dtype=float32),
        'split4_test_score': array([0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8,
        0.8, 0.8],
       dtype=float32),
        'mean_test_score': array([0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8,
        0.8, 0.8],
       dtype=float32),
        'std_test_score': array([0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
        0.0, 0.0],
       dtype=float32),
        'rank_test_score': array[1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1],
       dtype=int32)}
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).cv_results_]
```

```
[Out]: {'mean_fit_time': array([0.00000000, 0.00000000, 0.00000000, 0.00000000,
        0.00000000, 0.00000000, 0.00000000, 0.00000000, 0.00000000,
        0.00000000, 0.00000000],
       dtype=float32),
        'mean_score_time': array([0.00000000, 0.00000000, 0.00000000, 0.00000000,
        0.00000000, 0.00000000, 0.00000000, 0.00000000, 0.00000000,
        0.00000000, 0.00000000],
       dtype=float32),
        'param_C': array([1.00000000e-04, 1.00000000e-03, 1.00000000e-02,
        1.00000000e-01, 1.00000000e+00, 1.00000000e+01,
        1.00000000e+02, 1.00000000e+03, 1.00000000e+04,
        1.00000000e+05, 1.00000000e+06],
       dtype=float32),
        'params': [{'C': 0.0001},
        {'C': 0.001},
        {'C': 0.01},
        {'C': 0.1},
        {'C': 1.0},
        {'C': 10.0},
        {'C': 100.0},
        {'C': 1000.0},
        {'C': 10000.0},
        {'C': 100000.0},
        {'C': 1000000.0}],
        'split0_test_score': array([0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8,
        0.8, 0.8],
       dtype=float32),
        'split1_test_score': array([0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8,
        0.8, 0.8],
       dtype=float32),
        'split2_test_score': array([0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8,
        0.8, 0.8],
       dtype=float32),
        'split3_test_score': array([0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8,
        0.8, 0.8],
       dtype=float32),
        'split4_test_score': array([0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8,
        0.8, 0.8],
       dtype=float32),
        'mean_test_score': array([0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8, 0.8,
        0.8, 0.8],
       dtype=float32),
        'std_test_score': array([0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
        0.0, 0.0],
       dtype=float32),
        'rank_test_score': array[1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1],
       dtype=int32)}
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).scaling]
```

```
[Out]: ('StandardScaler', 'StandardScaler')
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).scaling]
```

```
[Out]: ('StandardScaler', 'StandardScaler')
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).scoring]
```

```
[Out]: None
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).scoring]
```

```
[Out]: None
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).estimator]
```

```
[Out]: LogisticRegression(C=1.0, class_weight=None,
                          dual=False, fit_intercept=True,
                          intercept_scaling=1,
                          l1_ratio=None, max_iter=100,
                          multi_class='auto',
                          n_jobs=None, penalty='l2',
                          random_state=None,
                          solver='lbfgs', tol=0.0001,
                          verbose=0, warm_start=False)
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).estimator]
```

```
[Out]: LogisticRegression(C=1.0, class_weight=None,
                          dual=False, fit_intercept=True,
                          intercept_scaling=1,
                          l1_ratio=None, max_iter=100,
                          multi_class='auto',
                          n_jobs=None, penalty='l2',
                          random_state=None,
                          solver='lbfgs', tol=0.0001,
                          verbose=0, warm_start=False)
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).n_splits_]
```

```
[Out]: 5
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).n_splits_]
```

```
[Out]: 5
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).refit]
```

```
[Out]: True
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).refit]
```

```
[Out]: True
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).scorer_]
```

```
[Out]: {'accuracy': make_scorer(accuracy_score, greater_is_better=True),
        'f1': make_scorer(f1_score, pos_label=1, average=binary),
        'roc_auc': make_scorer(roc_auc_score, greater_is_better=True, needs_threshold=True)}
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).scorer_]
```

```
[Out]: {'accuracy': make_scorer(accuracy_score, greater_is_better=True),
        'f1': make_scorer(f1_score, pos_label=1, average=binary),
        'roc_auc': make_scorer(roc_auc_score, greater_is_better=True, needs_threshold=True)}
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).multimetric_]
```

```
[Out]: True
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).multimetric_]
```

```
[Out]: True
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).best_index_]
```

```
[Out]: 0
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).best_index_]
```

```
[Out]: 0
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).best_score_]
```

```
[Out]: 0.8000000
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).best_score_]
```

```
[Out]: 0.8000000
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).best_params_]
```

```
[Out]: {'C': 0.0001}
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).best_params_]
```

```
[Out]: {'C': 0.0001}
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).best_estimator_]
```

```
[Out]: LogisticRegression(C=1.0, class_weight=None,
                          dual=False, fit_intercept=True,
                          intercept_scaling=1,
                          l1_ratio=None, max_iter=100,
                          multi_class='auto',
                          n_jobs=None, penalty='l2',
                          random_state=None,
                          solver='lbfgs', tol=0.0001,
                          verbose=0, warm_start=False)
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).best_estimator_]
```

```
[Out]: LogisticRegression(C=1.0, class_weight=None,
                          dual=False, fit_intercept=True,
                          intercept_scaling=1,
                          l1_ratio=None, max_iter=100,
                          multi_class='auto',
                          n_jobs=None, penalty='l2',
                          random_state=None,
                          solver='lbfgs', tol=0.0001,
                          verbose=0, warm_start=False)
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).feature_names_in_]
```

```
[Out]: array['Age', 'Sex', 'ChestPain', 'RestBP', 'Chol', 'Fbs', 'RestECG',
       'MaxHR', 'ExerAng', 'Oldpeak', 'Slope'],
       dtype=object)
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).feature_names_in_]
```

```
[Out]: array['Age', 'Sex', 'ChestPain', 'RestBP', 'Chol', 'Fbs', 'RestECG',
       'MaxHR', 'ExerAng', 'Oldpeak', 'Slope'],
       dtype=object)
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).n_feature_names_in_]
```

```
[Out]: 11
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).n_feature_names_in_]
```

```
[Out]: 11
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_train, y_train).grid_scores_]
```

```
[Out]: [mean: 0.80000, std: 0.00000, params: {'C': 0.0001},
        mean: 0.80000, std: 0.00000, params: {'C': 0.001},
        mean: 0.80000, std: 0.00000, params: {'C': 0.01},
        mean: 0.80000, std: 0.00000, params: {'C': 0.1},
        mean: 0.80000, std: 0.00000, params: {'C': 1.0},
        mean: 0.80000, std: 0.00000, params: {'C': 10.0},
        mean: 0.80000, std: 0.00000, params: {'C': 100.0},
        mean: 0.80000, std: 0.00000, params: {'C': 1000.0},
        mean: 0.80000, std: 0.00000, params: {'C': 10000.0},
        mean: 0.80000, std: 0.00000, params: {'C': 100000.0},
        mean: 0.80000, std: 0.00000, params: {'C': 1000000.0}]
```

```
[In]: [tuned_logistic_regression_model_gs.fit(X_test, y_test).grid_scores_]
```

```
[Out]: [mean: 0.80000, std: 0.00000, params: {'C': 0.0001},
        mean: 0.80000, std: 0.00000, params: {'C': 0.001},
        mean: 0.80000, std: 0.00000, params: {'C': 0.01},
        mean: 0.80000, std: 0.00000, params: {'C': 0.1},
        mean: 0.80000, std: 0.00000, params: {'C': 1.0},
        mean: 0.80000, std: 0.00000, params: {'C': 10.0},
        mean: 0.80000, std: 0.00000, params: {'C': 100.0},
        mean: 0.80000, std: 0.00000, params: {'C': 1000.0},
        mean: 0.80000, std: 0.00000, params: {'C': 10000.0},
        mean: 0.80000, std: 0.00000, params: {'C': 100000.0},
        mean: 0.80000, std: 0.00000, params: {'C': 1000000.0}]
```

Tuned Random Forest

```
[In]: [tuned_random_forest_model_gs.fit(X_train, y_train)]
```

```
[Out]: GridSearchCV(cv=5, error_score=nan,
                    estimator=RandomForestClassifier(bootstrap=True,
                                                     class_weight=None,
                                                     criterion='gini',
                                                     max_depth=None,
                                                     max_features='auto',
                                                     max_leaf_nodes=None,
                                                     min_impurity_decrease=0.0,
                                                     min_impurity_split=None,
                                                     min_samples_leaf=1,
                                                     min_samples_split=2,
                                                     min_weight_fraction_leaf=0.0,
                                                     n_estimators=10,
                                                     n_jobs=None, oob_score=False,
                                                     random_state=None,
                                                     verbose=0, warm_start=False),
                    iid=False, n_jobs=None,
                    param_grid={'bootstrap': array[True, False],
                                'criterion': array['gini', 'entropy'],
                                'max_depth': array[1, 2, 3, 4, 5, 6, 7, 8, 9],
                                'max_features': array['auto', 'sqrt', 'log2'],
                                'max_leaf_nodes': array[2, 3, 4, 5, 6, 7, 8, 9],
                                'min_samples_leaf': array[1, 2, 3, 4, 5, 6, 7, 8, 9],
                                'min_samples_split': array[2, 3, 4, 5, 6, 7, 8, 9],
                                'n_estimators': array[10, 20, 30, 40, 50, 60, 70,
                                                      80, 90, 100, 110, 120, 130,
                                                      140, 150, 160, 170, 180,
                                                      190, 200]},
                    pre_dispatch='2*n_jobs', refit=True, return_train_score=False,
                    scaling=('StandardScaler', 'StandardScaler'),
                    scoring=None, verbose=0)
```

```
[In]: [tuned_random_forest_model_gs.fit(X_test, y_test)]
```

```
[Out]: GridSearchCV(cv=5, error_score=nan,
                    estimator=RandomForestClassifier(bootstrap=True,
                                                     class_weight=None,
                                                     criterion='gini',
                                                     max_depth=None,
                                                     max_features='auto',
                                                     max_leaf_nodes=None,
                                                     min_impurity_decrease=0.0,
                                                     min_impurity_split=None,
                                                     min_samples_leaf=1,
                                                     min_samples_split=2,
                                                     min_weight_fraction_leaf=0.0,
                                                     n_estimators=10,
                                                     n_jobs=None, oob_score=False,
                                                     random_state=None,
                                                     verbose=0, warm_start=False),
                    iid=False, n_jobs=None,
                    param_grid={'bootstrap': array[True, False],
                                'criterion': array['gini', 'entropy'],
                                'max_depth': array[1, 2, 3, 4, 5, 6, 7, 8, 9],
                                'max_features': array['auto', 'sqrt', 'log2'],
                                'max_leaf_nodes': array[2, 3, 4, 5, 6, 7, 8, 9],
                                'min_samples_leaf': array[1, 2, 3, 4, 5, 6, 7, 8, 9],
                                'min_samples_split': array[2, 3, 4, 5, 6, 7, 8, 9],
                                'n_estimators': array[10, 20, 30, 40, 50, 60, 70,
                                                      80, 90, 100, 110, 120, 130,
                                                      140, 150, 160, 170, 180,
                                                      190, 200]},
                    pre_dispatch='2*n_jobs', refit=True, return_train_score=False,
                    scaling=('StandardScaler', 'StandardScaler'),
                    scoring=None, verbose=0)
```

```
[In]: [tuned_random_forest_model_gs.fit(X_train, y_train).cv_results_]
```

```
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```

```
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```

This is a much improved scoring. We model was able to be tremendously gain result. But did mistake some cases.

Tuned Logistic Regression

In [100]:
```
from sklearn.model_selection import GridSearchCV, RandomizedSearchCV, cross_val_score
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import classification_report, confusion_matrix, roc_curve, roc_auc_score, accuracy_score, f1_score, precision_score, recall_score

# Define parameter grid for tuning
param_grid = {'C': [0.001, 0.01, 0.1, 1, 10, 100],
              'penalty': ['l1', 'l2'],
              'solver': ['liblinear', 'saga'],
              'class_weight': [None, 'balanced'],
              'max_iter': [100, 500, 1000]}

# Create GridSearchCV object
grid_search = GridSearchCV(LogisticRegression(random_state=42),
                           param_grid,
                           cv=5,
                           scoring='f1',
                           n_jobs=-1,
                           verbose=1)

# Fit the model
grid_search.fit(X_train, y_train)

# Get the best parameters
print("Best parameters:", grid_search.best_params_)

# Get the best model
best_logreg = grid_search.best_estimator_

# Predictions with tuned model
y_pred_tuned = best_logreg.predict(X_test)
y_pred_proba_tuned = best_logreg.predict_proba(X_test)[:, 1]

# Evaluation
print("\n=== Tuned Logistic Regression ===")
print("Accuracy:", accuracy_score(y_test, y_pred_tuned))
print("F1 Score:", f1_score(y_test, y_pred_tuned))
print("Precision:", precision_score(y_test, y_pred_tuned))
print("Recall:", recall_score(y_test, y_pred_tuned))
print("ROC AUC:", roc_auc_score(y_test, y_pred_proba_tuned))

# Confusion matrix
cm = confusion_matrix(y_test, y_pred_tuned)
print("\nConfusion Matrix:")
print(cm)

# Classification report
print("\nClassification Report:")
print(classification_report(y_test, y_pred_tuned))
```

In [101]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation accuracy:", X_cv_tuned.mean())
```

In [102]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [103]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [104]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [105]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [106]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [107]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [108]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [109]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [110]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [111]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [112]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [113]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [114]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [115]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [116]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [117]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [118]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [119]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [120]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [121]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [122]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [123]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [124]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [125]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [126]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [127]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [128]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [129]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [130]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [131]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [132]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [133]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [134]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [135]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [136]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [137]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [138]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [139]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [140]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [141]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [142]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [143]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [144]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [145]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [146]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [147]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [148]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [149]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [150]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [151]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [152]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [153]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [154]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [155]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [156]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [157]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [158]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [159]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [160]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [161]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [162]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [163]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [164]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [165]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [166]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [167]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [168]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [169]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [170]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [171]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [172]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [173]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [174]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [175]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [176]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [177]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [178]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [179]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [180]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [181]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [182]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [183]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [184]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [185]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [186]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [187]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [188]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [189]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [190]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [191]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [192]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [193]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [194]:
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X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [195]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [196]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [197]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [198]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [199]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [200]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [201]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [202]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [203]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [204]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [205]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [206]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [207]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [208]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [209]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [210]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [211]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [212]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [213]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [214]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [215]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [216]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [217]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [218]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [219]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [220]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [221]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [222]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [223]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [224]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [225]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [226]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [227]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [228]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [229]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [230]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [231]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [232]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [233]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [234]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [235]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [236]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [237]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [238]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [239]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [240]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [241]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [242]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [243]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [244]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [245]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [246]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [247]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [248]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [249]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [250]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [251]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [252]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [253]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [254]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [255]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [256]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [257]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [258]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [259]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [260]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [261]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [262]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [263]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [264]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [265]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [266]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [267]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
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In [268]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
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In [269]:
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X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
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In [270]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [271]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
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In [272]:
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print("Cross-validation F1:", X_cv_tuned.mean())
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In [273]:
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X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
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print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [275]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [276]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [277]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [278]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
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In [279]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

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```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [281]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [282]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
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In [283]:
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X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
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In [284]:
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X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [285]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [286]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [287]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [288]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='roc_auc')
print("Cross-validation ROC AUC:", X_cv_tuned.mean())
```

In [289]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

In [290]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='recall')
print("Cross-validation Recall:", X_cv_tuned.mean())
```

In [291]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='accuracy')
print("Cross-validation Accuracy:", X_cv_tuned.mean())
```

In [292]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

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[CV] END .....max_depth=None, min_samples_leaf=1, min_samples_split=2; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=1, min_samples_split=2; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=1, min_samples_split=2; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=1, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=1, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=1, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=1, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=1, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=1, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=1, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=1, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=1, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=1, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=2; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=2; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=2; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=2; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=2; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=2, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=2; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=2; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=2; total time=  0.0s
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[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=2; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=3; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=4; total time=  0.0s
[CV] END .....max_depth=None, min_samples_leaf=4, min_samples_split=4; total time=  0.0s
```

In [24]:
```
dt_grid_search.fit(X_train,y_train)
```

Out[24]:
```
GridSearchCV
GridSearchCV(cv=5,
             estimator=DecisionTreeClassifier(random_state=42),
             n_jobs=-1,
             param_grid={'max_depth': [None],
                         'min_samples_leaf': [1, 2, 4],
                         'min_samples_split': [2, 3, 4]},
             verbose=3)
```

In [25]:
```
dt_best_estimator = dt_grid_search.best_estimator_
dt_best_estimator
```

Out[25]:
```
DecisionTreeClassifier
DecisionTreeClassifier(random_state=42)
```

In [26]:
```
dt_best_pred = dt_best_estimator.predict(X_test)
dt_best_pred
```

Out[26]:
```
array([0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
       
```