```
import numpy as np
import pandas as pd
import tqdm, gc, os
from ast import literal_eval
from collections import Counter
from joblib import Parallel, delayed
from scipy.stats import pearsonr, ttest_ind, ttest_rel, kurtosis, skew, kstest, gaussian_kde, kstest, ks_2samp,mannwhitneyu
from sklearn.metrics import roc_auc_score, f1_score, recall_score, precision_score
from sklearn.preprocessing import LabelEncoder
import lightgbm as lgb, xgboost as xgb, catboost as cat

from gensim.models.keyedvectors import KeyedVectors, Word2VecKeyedVectors, FastTextKeyedVectors

from nltk import WordNetLemmatizer
from nltk.stem.porter import PorterStemmer, LancasterStemmer
from nltk.stem.snowball import SnowballStemmer, RussianStemmer, FinnishStemmer
from nltk.stem.wordnet import WordNetLemmatizer
from nltk.stem.lancaster import LancasterStemmer
from nltk.stem.regexp import RegexpStemmer
from nltk.stem.porter import PorterStemmer
from nltk.stem.snowball import SnowballStemmer
from nltk.stem.lancaster import LancasterStemmer
from nltk.stem.wordnet import WordNetLemmatizer
from nltk.stem.porter import PorterStemmer
from nltk.stem.snowball import SnowballStemmer
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from nltk.stem.wordnet import WordNetLemmatizer
from nltk.stem.porter import PorterStemmer
from nltk.stem.snowball import SnowballStemmer
from nltk.stem.lancaster import LancasterStemmer
from nltk.stem.wordnet import WordNetLemmatizer

import matplotlib as mpl
import matplotlib.pyplot as plt
from matplotlib import MatplotLib

%matplotlib inline
from IPython.display import display, display_markdown, clear_output, HTML, Markdown
from IPython.display import display_markdown
from IPython.display import display, clear_output
from tqdm import tqdm, tqdm_notebook, tqdm_pandas
from os.path import join, isfile, isdir
from os import listdir, mkdir, rmdir
```

## Processing Text

This section is an ode to various conventional tricks-and-tricks. These tricks will be compared to deeper neural network tricks. I will search the data itself and see that for test, too.

```
df = pd.read_csv('../input/train.csv', nrows=100)
df = df.sample(frac=1.0).reset_index(drop=True)
df['comment_text'] = df['comment_text'].apply(lambda x: str(x))
df['target'] = (df['target'] >= 0.5).astype(int)
df['gender'] = (df[['male', 'female', 'transgender', 'other_gender', 'heterosexual', 'homosexual_gay_or_lesbian', 'other_sexual_orientation']].sum(axis=1) > 0).astype(int)
df['religion'] = (df[['christian', 'jewish', 'muslim', 'hindu', 'buddhist', 'atheist', 'other_religion']].sum(axis=1) > 0).astype(int)
df['race'] = (df[['black', 'white', 'asian', 'latino', 'other_race_or_ethnicity']].sum(axis=1) > 0).astype(int)
df['mental_illness'] = (df[['mental_illness', 'intellectual_or_learning_disability']].sum(axis=1) > 0).astype(int)
df['disability'] = (df[['physical_disability', 'other_disability']].sum(axis=1) > 0).astype(int)
df['identity_any'] = (df[['gender', 'religion', 'race', 'mental_illness', 'disability']].sum(axis=1) > 0).astype(int)
df['severe_toxicity'] = (df['severe_toxicity'] >= 0.5).astype(int)
df['obscene'] = (df['obscene'] >= 0.5).astype(int)
df['threat'] = (df['threat'] >= 0.5).astype(int)
df['insult'] = (df['insult'] >= 0.5).astype(int)
df['identity_attack'] = (df['identity_attack'] >= 0.5).astype(int)
df['sexual_explicit'] = (df['sexual_explicit'] >= 0.5).astype(int)
```

```
'''
    0    This is a test text. This is, test text.
    1    Test text, this is, is a test. Test.
    2    This is the test. Test text, this is test.
    3    Test text, this is, is a test. Test.
    4    This is the test. Test text, this is test.
    Name: comment_text, dtype: object
'''
df['comment_text'].head(5)
```

### Parts of Speech Tags

I will try adding parts of speech tags for lemmatization processing.

```
df.shape[0],df.shape[1]
df = df.sample(frac=1.0).reset_index(drop=True)
df['comment_text'] = df['comment_text'].apply(lambda x: str(x))
'''
    (100, 40)
    (100, 40)
    CPU times: user 2.04 ms, sys: 1.99 ms, total: 4.03 ms
    Wall time: 3.81 ms
    CPU times: user 2.04 ms, sys: 1.99 ms, total: 4.03 ms
    Wall time: 3.81 ms
'''
```

### Changing Sentiment Target to Numeric

```
df['target'].value_counts()
'''
    0    0.92
    1    0.08
    Name: target, dtype: float64
'''
```

Clearly, all of classical classifiers are going to prioritize finding the minority class.

```
df['target'].hist()
'''
    <matplotlib.axes._subplots.AxesSubplot at 0x7f8a1a0a0a90>
'''
```

```
{"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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    {
      "id": 1,
      "name": "Ashley Hernandez",
      "email": "ashley.hernandez@mail.com",
      "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",
      "username": "ashley_hernandez",
      "password": "Tr0ub4dor&3",
      "company": "Acme Corporation",
      "job_title": "Senior Software Engineer",
      "salary": 142000,
      "employee_id": "EMP-0001",
      "department": "Engineering",
      "manager": "Robert Chen",
      "publication_date": "2024-01-15",
      "publisher": "Springfield Publishing",
      "publication_number": "PUB-2024-0001",
      "publication_type": "Technical Report",
      "publication_status": "Published",
      "publication_language": "English",
      "publication_pages": 42,
      "publication_volume": "Vol. 12",
      "publication_issue": "Issue 3",
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      "publication_isbn": "978-3-16-148410-0",
      "publication_issn": "1234-5678",
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      "publication_keywords": "machine learning, neural networks, deep learning, artificial intelligence, data science",
      "publication_abstract": "This technical report presents a comprehensive analysis of machine learning algorithms applied to large-scale data processing. We evaluate the performance of various neural network architectures on benchmark datasets and propose a novel hybrid approach that combines convolutional and recurrent layers. Our results demonstrate significant improvements in accuracy and computational efficiency compared to state-of-the-art methods.",
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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]},
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```
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```

```
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                    scaling=('StandardScaler', 'StandardScaler'),
                    scoring=None, verbose=0)
```

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

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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]:
```
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())
```

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())
```

In [269]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
print("Cross-validation Precision:", X_cv_tuned.mean())
```

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())
```

In [272]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='f1')
print("Cross-validation F1:", X_cv_tuned.mean())
```

In [273]:
```
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 [274]:
```
X_cv_tuned = cross_val_score(best_logreg, X, y, cv=5, scoring='precision')
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]:
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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())
```

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

In [280]:
```
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())
```

In [283]:
```
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 [284]:
```
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,
       
```