In [1]:

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

from sklearn.linear_model import LogisticRegression
from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import train_test_split
from sklearn.metrics import classification_report

import warnings
warnings.filterwarnings('ignore')
```

In [2]:

```
path = "../CSV/diabetes.csv"
```

In [3]:

```
df = pd.read_csv(path)
```

In [4]:

```
df.head()
```

Out[4]:

| | Pregnancies | Glucose | BloodPressure | SkinThickness | Insulin | BMI | DiabetesPedigreeFunctio |
|---|---|---|---|---|---|---|---|
| 0 | 6 | 148 | 72 | 35 | 0 | 33.6 | 0.62 |
| 1 | 1 | 85 | 66 | 29 | 0 | 26.6 | 0.35 |
| 2 | 8 | 183 | 64 | 0 | 0 | 23.3 | 0.67 |
| 3 | 1 | 89 | 66 | 23 | 94 | 28.1 | 0.16 |
| 4 | 0 | 137 | 40 | 35 | 168 | 43.1 | 2.28 |

In [48]:

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 768 entries, 0 to 767
Data columns (total 9 columns):
Pregnancies                 768 non-null int64
Glucose                     768 non-null int64
BloodPressure               768 non-null int64
SkinThickness               768 non-null int64
Insulin                     768 non-null int64
BMI                         768 non-null float64
DiabetesPedigreeFunction    768 non-null float64
Age                         768 non-null int64
Outcome                     768 non-null int64
dtypes: float64(2), int64(7)
memory usage: 54.1 KB
```

In [49]:

```
df.isnull().sum()
```

Out[49]:

```
Pregnancies                 0
Glucose                     0
BloodPressure               0
SkinThickness               0
Insulin                     0
BMI                         0
DiabetesPedigreeFunction    0
Age                         0
Outcome                     0
dtype: int64
```

In [5]:

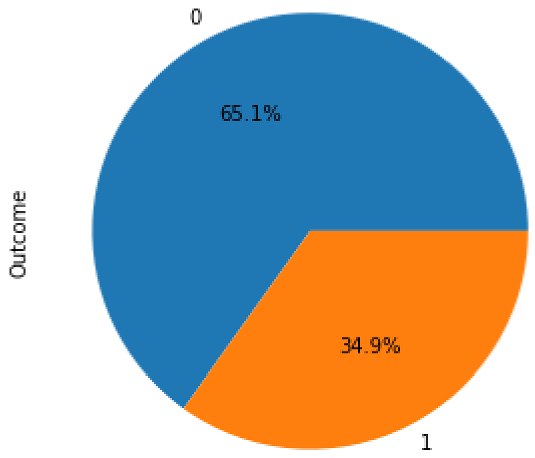
```
pd.set_option('display.float_format', '{:.2f}'.format)
df.describe()
```

Out[5]:

| | Pregnancies | Glucose | BloodPressure | SkinThickness | Insulin | BMI | DiabetesPedigreeF |
|---|---|---|---|---|---|---|---|
| count | 768.00 | 768.00 | 768.00 | 768.00 | 768.00 | 768.00 | |
| mean | 3.85 | 120.89 | 69.11 | 20.54 | 79.80 | 31.99 | |
| std | 3.37 | 31.97 | 19.36 | 15.95 | 115.24 | 7.88 | |
| min | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| 25% | 1.00 | 99.00 | 62.00 | 0.00 | 0.00 | 27.30 | |
| 50% | 3.00 | 117.00 | 72.00 | 23.00 | 30.50 | 32.00 | |
| 75% | 6.00 | 140.25 | 80.00 | 32.00 | 127.25 | 36.60 | |
| max | 17.00 | 199.00 | 122.00 | 99.00 | 846.00 | 67.10 | |

In [8]:

```
plt.figure(figsize=(5,5))
df["Outcome"].value_counts().plot(kind="pie",autopct="%1.1f%%")
plt.show()
```



In [6]:

```
X = df.iloc[:,:-1]
y = df.iloc[:,-1]
```

In [7]:

```
X_train,X_test,y_train,y_test = train_test_split(X,y,test_size=0.3,random_state=1)
```

In [8]:

```
def create_model(model):
    model.fit(X_train,y_train)
    y_pred = model.predict(X_test)
    print(classification_report(y_test,y_pred))
    return model
```

## Naive Aggregation

In [12]:

```
lr = LogisticRegression()
dt1 = DecisionTreeClassifier()
dt2 = DecisionTreeClassifier(criterion="entropy")
```

In [13]:

```
model_list = [('lr',lr),('dt1',dt1),('dt2',dt2)]
```

In [14]:

```
from sklearn.ensemble import VotingClassifier
```

### *1) Hard voting*

### 1) Hard voting

In [17]:

```
vc_hard =  VotingClassifier(estimators=model_list)
```

In [19]:

```
create_model(vc_hard)
```

```
              precision    recall  f1-score   support

           0       0.78      0.86      0.82       146
           1       0.71      0.59      0.65        85

    accuracy                           0.76       231
   macro avg       0.75      0.73      0.73       231
weighted avg       0.76      0.76      0.76       231
```

Out[19]:

```
VotingClassifier(estimators=[('lr',
                              LogisticRegression(C=1.0, class_weight=None,
                                                 dual=False, fit_intercept=T
rue,
                                                 intercept_scaling=1,
                                                 l1_ratio=None, max_iter=10
0,
                                                 multi_class='warn',
                                                 n_jobs=None, penalty='l2',
                                                 random_state=None,
                                                 solver='warn', tol=0.0001,
                                                 verbose=0, warm_start=Fals
e)),
                             ('dt1',
                              DecisionTreeClassifier(class_weight=None,
                                                     criterion='gini',
                                                     max_depth=None...
                             ('dt2',
                              DecisionTreeClassifier(class_weight=None,
                                                     criterion='entropy',
                                                     max_depth=None,
                                                     max_features=None,
                                                     max_leaf_nodes=None,
                                                     min_impurity_decrease=
0.0,
                                                     min_impurity_split=Non
e,
                                                     min_samples_leaf=1,
                                                     min_samples_split=2,
                                                     min_weight_fraction_lea
f=0.0,
                                                     presort=False,
                                                     random_state=None,
                                                     splitter='best'))],
                 flatten_transform=True, n_jobs=None, voting='hard',
                 weights=None)
```

### *2) Soft voting*

In [21]:

```
vc_soft = VotingClassifier(estimators=model_list,voting='soft')
```

In [22]:

```
create_model(vc_soft)
```

```
              precision    recall  f1-score   support

           0       0.77      0.86      0.81       146
           1       0.69      0.55      0.61        85

    accuracy                           0.74       231
   macro avg       0.73      0.70      0.71       231
weighted avg       0.74      0.74      0.74       231
```

Out[22]:

```
VotingClassifier(estimators=[('lr',
                              LogisticRegression(C=1.0, class_weight=None,
                                                 dual=False, fit_intercept=T
rue,
                                                 intercept_scaling=1,
                                                 l1_ratio=None, max_iter=10
0,
                                                 multi_class='warn',
                                                 n_jobs=None, penalty='l2',
                                                 random_state=None,
                                                 solver='warn', tol=0.0001,
                                                 verbose=0, warm_start=Fals
e)),
                             ('dt1',
                              DecisionTreeClassifier(class_weight=None,
                                                     criterion='gini',
                                                     max_depth=None...
                             ('dt2',
                              DecisionTreeClassifier(class_weight=None,
                                                     criterion='entropy',
                                                     max_depth=None,
                                                     max_features=None,
                                                     max_leaf_nodes=None,
                                                     min_impurity_decrease=
0.0,
                                                     min_impurity_split=Non
e,
                                                     min_samples_leaf=1,
                                                     min_samples_split=2,
                                                     min_weight_fraction_lea
f=0.0,
                                                     presort=False,
                                                     random_state=None,
                                                     splitter='best'))],
                 flatten_transform=True, n_jobs=None, voting='soft',
                 weights=None)
```

## Bootstrap Aggregation

In [12]:

```
from sklearn.ensemble import BaggingClassifier
```

***1) Bagging***

In [16]:

```
# use odd number of n_estimators for better output
bg1 = BaggingClassifier(LogisticRegression(),n_estimators=11,random_state=1)
```

In [17]:

```
create_model(bg1)
```

```
              precision    recall  f1-score   support

           0       0.78      0.90      0.83       146
           1       0.76      0.55      0.64        85

    accuracy                           0.77       231
   macro avg       0.77      0.73      0.74       231
weighted avg       0.77      0.77      0.76       231
```

Out[17]:

```
BaggingClassifier(base_estimator=LogisticRegression(C=1.0, class_weight=Non
e,
                                                    dual=False,
                                                    fit_intercept=True,
                                                    intercept_scaling=1,
                                                    l1_ratio=None, max_iter=
100,
                                                    multi_class='warn',
                                                    n_jobs=None, penalty='l
2',
                                                    random_state=None,
                                                    solver='warn', tol=0.000
1,
                                                    verbose=0,
                                                    warm_start=False),
                  bootstrap=True, bootstrap_features=False, max_features=1.
0,
                  max_samples=1.0, n_estimators=11, n_jobs=None,
                  oob_score=False, random_state=1, verbose=0, warm_start=Fal
se)
```

In [34]:

```
bg2 = BaggingClassifier(DecisionTreeClassifier(),n_estimators=900,random_state=1)
```

In [35]:

```
create_model(bg2)
```

```
              precision    recall  f1-score   support

           0       0.81      0.88      0.84       146
           1       0.75      0.64      0.69        85

    accuracy                           0.79       231
   macro avg       0.78      0.76      0.76       231
weighted avg       0.78      0.79      0.78       231

```

Out[35]:

```
BaggingClassifier(base_estimator=DecisionTreeClassifier(class_weight=None,
                                                        criterion='gini',
                                                        max_depth=None,
                                                        max_features=None,
                                                        max_leaf_nodes=None,
                                                        min_impurity_decreas
e=0.0,
                                                        min_impurity_split=N
one,
                                                        min_samples_leaf=1,
                                                        min_samples_split=2,
                                                        min_weight_fraction_
leaf=0.0,
                                                        presort=False,
                                                        random_state=None,
                                                        splitter='best'),
                  bootstrap=True, bootstrap_features=False, max_features=1.
0,
                  max_samples=1.0, n_estimators=900, n_jobs=None,
                  oob_score=False, random_state=1, verbose=0, warm_start=Fal
se)
```

***2) Pasting***

In [35]:

```
bg3 = BaggingClassifier(LogisticRegression(),n_estimators=7,random_state=1,bootstrap=False)
```

In [36]:

```
create_model(bg3)
```

```
              precision    recall  f1-score   support

           0       0.78      0.90      0.84       146
           1       0.77      0.55      0.64        85

    accuracy                           0.77       231
   macro avg       0.77      0.73      0.74       231
weighted avg       0.77      0.77      0.76       231
```

Out[36]:

```
BaggingClassifier(base_estimator=LogisticRegression(C=1.0, class_weight=Non
e,
                                                    dual=False,
                                                    fit_intercept=True,
                                                    intercept_scaling=1,
                                                    l1_ratio=None, max_iter=
100,
                                                    multi_class='warn',
                                                    n_jobs=None, penalty='l
2',
                                                    random_state=None,
                                                    solver='warn', tol=0.000
1,
                                                    verbose=0,
                                                    warm_start=False),
                  bootstrap=False, bootstrap_features=False, max_features=1.
0,
                  max_samples=1.0, n_estimators=7, n_jobs=None, oob_score=Fa
lse,
                  random_state=1, verbose=0, warm_start=False)
```

## Random Forest

In [37]:

```
from sklearn.ensemble import RandomForestClassifier
```

In [44]:

```
rf1 = RandomForestClassifier(n_estimators=13)
```

In [45]:

```
create_model(rf1)
```

```
              precision    recall  f1-score   support

           0       0.79      0.87      0.83       146
           1       0.73      0.60      0.66        85

    accuracy                           0.77       231
   macro avg       0.76      0.73      0.74       231
weighted avg       0.77      0.77      0.77       231
```

Out[45]:

```
RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
                       max_depth=None, max_features='auto', max_leaf_nodes=N
one,
                       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=13,
                       n_jobs=None, oob_score=False, random_state=None,
                       verbose=0, warm_start=False)
```

In [150]:

```
rf2 = RandomForestClassifier(n_estimators=13,max_features=5,random_state=1)
```

In [151]:

```
create_model(rf2)
```

```
              precision    recall  f1-score   support

           0       0.81      0.84      0.83       146
           1       0.71      0.66      0.68        85

    accuracy                           0.77       231
   macro avg       0.76      0.75      0.75       231
weighted avg       0.77      0.77      0.77       231
```

Out[151]:

```
RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
                       max_depth=None, max_features=5, 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=13,
                       n_jobs=None, oob_score=False, random_state=1, verbose
=0,
                       warm_start=False)
```

In [180]:

```
rf3 = RandomForestClassifier(n_estimators=13,max_depth=15,random_state=1)
```

In [181]:

```
create_model(rf3)
```

```
              precision    recall  f1-score   support

           0       0.84      0.87      0.85       146
           1       0.76      0.71      0.73        85

    accuracy                           0.81       231
   macro avg       0.80      0.79      0.79       231
weighted avg       0.81      0.81      0.81       231
```

Out[181]:

```
RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
                       max_depth=15, max_features='auto', max_leaf_nodes=Non
e,
                       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=13,
                       n_jobs=None, oob_score=False, random_state=1, verbose
=0,
                       warm_start=False)
```

## Stacking

In [182]:

```
from mlxtend.classifier import StackingClassifier
```

In [183]:

```
lr = LogisticRegression()
dt1 = DecisionTreeClassifier()
dt2 = DecisionTreeClassifier(criterion="entropy")
model_list = [lr,dt1,dt2]
```

In [184]:

```
# meta classifier model --> Logistic Reg
meta_lr = LogisticRegression()
```

In [185]:

```
stack1 =  StackingClassifier(classifiers=model_list,meta_classifier=meta_lr)
```

In [186]:

```
create_model(stack1)
```

```
              precision    recall  f1-score   support

           0       0.78      0.86      0.82       146
           1       0.70      0.59      0.64        85

    accuracy                           0.76       231
   macro avg       0.74      0.72      0.73       231
weighted avg       0.75      0.76      0.75       231
```

Out[186]:

```
StackingClassifier(average_probas=False,
                   classifiers=[LogisticRegression(C=1.0, class_weight=None,
                                                   dual=False,
                                                   fit_intercept=True,
                                                   intercept_scaling=1,
                                                   l1_ratio=None, max_iter=1
00,
                                                   multi_class='warn',
                                                   n_jobs=None, penalty='l
2',
                                                   random_state=None,
                                                   solver='warn', tol=0.000
1,
                                                   verbose=0,
                                                   warm_start=False),
                                DecisionTreeClassifier(class_weight=None,
                                                       criterion='gini',
                                                       max_...
                   meta_classifier=LogisticRegression(C=1.0, class_weight=No
ne,
                                                      dual=False,
                                                      fit_intercept=True,
                                                      intercept_scaling=1,
                                                      l1_ratio=None,
                                                      max_iter=100,
                                                      multi_class='warn',
                                                      n_jobs=None, penalty
='l2',
                                                      random_state=None,
                                                      solver='warn', tol=0.0
001,
                                                      verbose=0,
                                                      warm_start=False),
                   store_train_meta_features=False, use_clones=True,
                   use_features_in_secondary=False, use_probas=False,
                   verbose=0)
```

In [188]:

```
stack1.meta_clf_.coef_
```

Out[188]:

```
array([[0.46143284, 3.75889513, 3.75889513]])
```

In [189]:

```
# meta classifier model --> Decision Tree
meta_dt = DecisionTreeClassifier()
```

In [190]:

```
stack2 =  StackingClassifier(classifiers=model_list,meta_classifier=meta_dt)
```

In [191]:

```
create_model(stack2)
```

```
              precision    recall  f1-score   support

           0       0.73      0.77      0.75       146
           1       0.57      0.52      0.54        85

    accuracy                           0.68       231
   macro avg       0.65      0.65      0.65       231
weighted avg       0.67      0.68      0.68       231
```

Out[191]:

```
StackingClassifier(average_probas=False,
                   classifiers=[LogisticRegression(C=1.0, class_weight=Non
e,
                                                   dual=False,
                                                   fit_intercept=True,
                                                   intercept_scaling=1,
                                                   l1_ratio=None, max_iter
=100,
                                                   multi_class='warn',
                                                   n_jobs=None, penalty='l
2',
                                                   random_state=None,
                                                   solver='warn', tol=0.00
01,
                                                   verbose=0,
                                                   warm_start=False),
                                DecisionTreeClassifier(class_weight=None,
                                                       criterion='gini',
                                                       max_...
                   meta_classifier=DecisionTreeClassifier(class_weight=Non
e,
                                                          criterion='gin
i',
                                                          max_depth=None,
                                                          max_features=Non
e,
                                                          max_leaf_nodes=N
one,
                                                          min_impurity_dec
rease=0.0,
                                                          min_impurity_spl
it=None,
                                                          min_samples_leaf
=1,
                                                          min_samples_spli
t=2,
                                                          min_weight_fract
ion_leaf=0.0,
                                                          presort=False,
                                                          random_state=Non
e,
                                                          splitter='bes
t'),
                   store_train_meta_features=False, use_clones=True,
use_features_in_secondary=False, use_probas=False
```

In [193]:

```
stack2.meta_clf_.feature_importances_
```

Out[193]:

```
array([0., 1., 0.])
```

# BOOSTING

## ADA Boosting / Adaptive Boosting

In [9]:

```
from sklearn.ensemble import AdaBoostClassifier
```

In [16]:

```
ada = AdaBoostClassifier(n_estimators=200)
create_model(ada)
```

```
              precision    recall  f1-score   support

           0       0.82      0.88      0.85       146
           1       0.77      0.67      0.72        85

    accuracy                           0.81       231
   macro avg       0.80      0.78      0.78       231
weighted avg       0.80      0.81      0.80       231
```

Out[16]:

```
AdaBoostClassifier(n_estimators=200)
```

## Gradient Boosting

In [18]:

```
from sklearn.ensemble import GradientBoostingClassifier
```

In [42]:

```
gb1 = GradientBoostingClassifier(n_estimators=100)
create_model(gb1)
```

```
              precision    recall  f1-score   support

           0       0.81      0.88      0.85       146
           1       0.76      0.65      0.70        85

    accuracy                           0.80       231
   macro avg       0.79      0.77      0.77       231
weighted avg       0.79      0.80      0.79       231
```

Out[42]:

```
GradientBoostingClassifier()
```

In [45]:

```
gb2 = GradientBoostingClassifier(n_estimators=100,min_samples_leaf=6)
create_model(gb2)
```

```
              precision    recall  f1-score   support

           0       0.81      0.89      0.85       146
           1       0.77      0.64      0.70        85

    accuracy                           0.80       231
   macro avg       0.79      0.76      0.77       231
weighted avg       0.79      0.80      0.79       231
```

Out[45]:

```
GradientBoostingClassifier(min_samples_leaf=6)
```

In [50]:

```
gb3 = GradientBoostingClassifier(n_estimators=100,max_depth=3)
create_model(gb3)
```

```
              precision    recall  f1-score   support

           0       0.81      0.88      0.85       146
           1       0.76      0.65      0.70        85

    accuracy                           0.80       231
   macro avg       0.79      0.77      0.77       231
weighted avg       0.79      0.80      0.79       231
```

Out[50]:

```
GradientBoostingClassifier()
```

In [57]:

```
gb4 = GradientBoostingClassifier(n_estimators=100,max_features=3)
create_model(gb4)
```

```
              precision    recall  f1-score   support

           0       0.82      0.90      0.86       146
           1       0.79      0.66      0.72        85

    accuracy                           0.81       231
   macro avg       0.80      0.78      0.79       231
weighted avg       0.81      0.81      0.81       231
```

Out[57]:

```
GradientBoostingClassifier(max_features=3)
```

## Xtreme Gradient Boosting

In [23]:

```
from xgboost import XGBClassifier
```

In [40]:

```
xgb1 = XGBClassifier(n_estimators=100,reg_alpha=1)
create_model(xgb1)
```

```
              precision    recall  f1-score   support

           0       0.81      0.88      0.84       146
           1       0.75      0.64      0.69        85

    accuracy                           0.79       231
   macro avg       0.78      0.76      0.76       231
weighted avg       0.78      0.79      0.78       231
```

Out[40]:

```
XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
              colsample_bynode=1, colsample_bytree=1, gamma=0, gpu_id=-1,
              importance_type='gain', interaction_constraints='',
              learning_rate=0.300000012, max_delta_step=0, max_depth=6,
              min_child_weight=1, missing=nan, monotone_constraints='()',
              n_estimators=100, n_jobs=0, num_parallel_tree=1, random_state=
0,
              reg_alpha=1, reg_lambda=1, scale_pos_weight=1, subsample=1,
              tree_method='exact', validate_parameters=1, verbosity=None)
```

In [41]:

```
xgb2 = XGBClassifier(n_estimators=100,reg_lambda=2)
create_model(xgb2)
```

```
              precision    recall  f1-score   support

           0       0.81      0.84      0.82       146
           1       0.70      0.66      0.68        85

    accuracy                           0.77       231
   macro avg       0.75      0.75      0.75       231
weighted avg       0.77      0.77      0.77       231
```

Out[41]:

```
XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
              colsample_bynode=1, colsample_bytree=1, gamma=0, gpu_id=-1,
              importance_type='gain', interaction_constraints='',
              learning_rate=0.300000012, max_delta_step=0, max_depth=6,
              min_child_weight=1, missing=nan, monotone_constraints='()',
              n_estimators=100, n_jobs=0, num_parallel_tree=1, random_state=
0,
              reg_alpha=0, reg_lambda=2, scale_pos_weight=1, subsample=1,
              tree_method='exact', validate_parameters=1, verbosity=None)
```