657Aass2CM5

July 18, 2021

1 [CM5] Gradient Tree Boosting

Importing all necessary libraries.

[52]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.ensemble import GradientBoostingClassifier
from sklearn.model_selection import cross_val_score
```

[53]:
```
df_train = pd.read_csv('cleaned_normalized_coviddata.csv')
```

[54]:
```
df_train.head()
```

[54]:
```
   Day  State ID       Lat     Long_    Active  Incident_Rate  \
0    2         1 -1.178243  0.304476 -0.200641       0.143976
1    2         2  3.607611 -3.031933 -0.448967      -0.290209
2    2         3 -0.945708 -0.944926  0.389043       0.088511
3    2         4 -0.741458  0.025816 -0.482359       0.202178
4    2         5 -0.552594 -1.365168  4.275448      -0.502417

   Total_Test_Results  Case_Fatality_Ratio  Testing_Rate  \
0           -0.483393            -0.475230     -1.301745
1           -0.569371            -1.797949      2.071154
2           -0.007491             0.075713     -1.268952
3           -0.456457            -0.029941     -0.559153
4            4.022089            -0.791062     -0.177543

   Resident Population 2020 Census  Population Density 2020 Census  \
0                        -0.128579                       -0.217013
1                        -0.754174                       -0.276752
2                         0.181561                       -0.239163
3                        -0.422031                       -0.242214
4                         4.903416                       -0.122735

   Density Rank 2020 Census  SexRatio  Confirmed  Deaths  Recovered
0                  0.118745 -1.168255       True   False      False
```

```
1                       1.614369  3.491260       True     True       False
2                       0.508908  0.384916       True     True        True
3                       0.573935 -0.546987       True     True        True
4                      -0.921689  0.384916       True     True       False
```

```
[55]: df_covid = df_train.iloc[:,:-3]
      #Target 1 is Recovered
      df_target1 = df_train.iloc[:,-1:]
      #Target 2 is Deaths
      df_target2 = df_train.iloc[:,-2:-1]
      #Target 3 is Confirmed
      df_target3 = df_train.iloc[:,-3:-2]
```

2 Part1: Gradient Boosting results using original features

2.1 1. Gradient Boosting implementation on Target 1: Recovered

2.1.1 number of estimators: {5, 10, 50, 150, 200} for target 1: Recovered

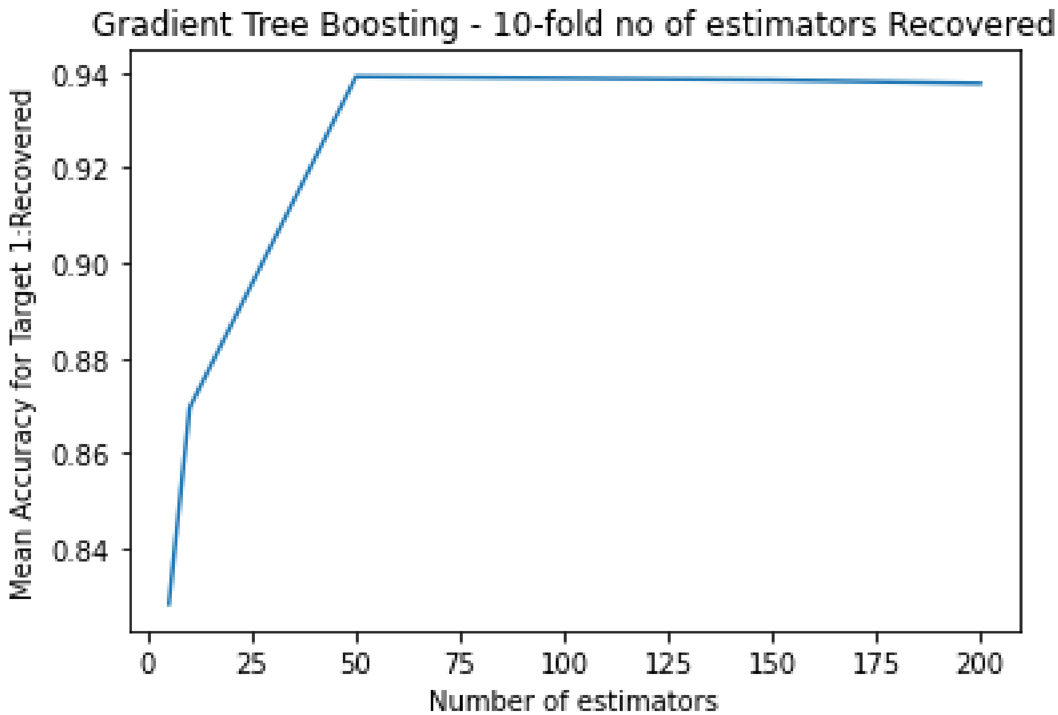
```
[56]: n_estimators_list1 = [5,10,50,150,200]
```

```
[57]: #Gradient Boosting: Checking for best value for no of estimators for target 1:␣
       ↪Recovered
      accuracies_recovered = []
      for n_estimators in n_estimators_list1:
          classifier_GradientBoosting = GradientBoostingClassifier(n_estimators =␣
       ↪n_estimators)
          scores = cross_val_score(classifier_GradientBoosting, df_covid, np.
       ↪ravel(df_target1), cv=10)
          accuracies_recovered.append(scores.mean())
      accuracies_recovered
```

```
[57]: [0.8282608695652174,
       0.8695652173913043,
       0.9391304347826088,
       0.9384057971014492,
       0.9376811594202898]
```

```
[58]: #Plotting the mean accuracy versus the number of estimators for Recovered
      plt.title("Gradient Tree Boosting - 10-fold no of estimators Recovered")
      plt.plot(n_estimators_list1, accuracies_recovered)
      plt.xlabel('Number of estimators')
      plt.ylabel('Mean Accuracy for Target 1:Recovered')
```

```
[58]: Text(0, 0.5, 'Mean Accuracy for Target 1:Recovered')
```



The accuracy almost remains constant after number of estimators = 50. Thus any value above this could result in overfitting. The best value of estimator is calculated by iterating over 5-50

2.1.2 Taking number of estimators: np.arange(5,50) for target 1: Recovered

[59]:
```
#Gradient Boosting: Further checking for best value for no of estimators for␣
↪target 1: Recovered from n _estimators 5 to 50
n_estimators_list1 = np.arange(5,50)
accuracies_recovered = []
for n_estimators in n_estimators_list1:
    classifier_GradientBoosting = GradientBoostingClassifier(n_estimators =␣
↪n_estimators)
    scores = cross_val_score(classifier_GradientBoosting, df_covid, np.
↪ravel(df_target1), cv=10)
    accuracies_recovered.append(scores.mean())
```

[60]:
```
# checking max accuracy for recovered and its estimator value
temp = np.where(accuracies_recovered == np.amax(accuracies_recovered))
print("The maximum value of accuracy is:",accuracies_recovered[temp[0][0]]*100)
print("The maximum value occurs when estimator value = ",temp[0][0])
```

```
The maximum value of accuracy is: 94.05797101449276
The maximum value occurs when estimator value =  29
```

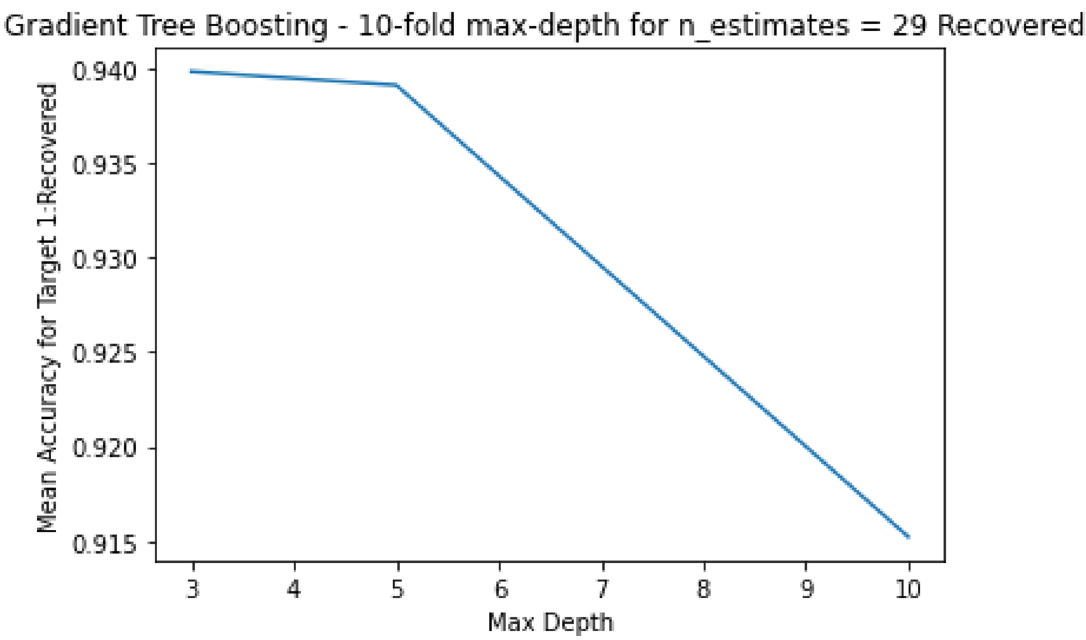
2.1.3 Performance peaks at n__estimators = 29 and hence we will choose that for the number of trees hyperparameter value for target 1: Recovered.

[61]:
```
#Gradient Boosting: Checking for best value for max depth for target 1:␣
↪Recovered ,by keeping n_estimates = 29
max_depth_list = [3,5,10,None]
accuracies_maxdepth1 = []
for max_depth in max_depth_list:
    classifier_GradientBoosting = GradientBoostingClassifier(n_estimators = 29,␣
↪max_depth = max_depth)
    scores = cross_val_score(classifier_GradientBoosting, df_covid, np.
↪ravel(df_target1), cv=10)
    accuracies_maxdepth1.append(scores.mean())
accuracies_maxdepth1
```

[61]:
```
[0.9398550724637682,
 0.9391304347826088,
 0.9152173913043479,
 0.9166666666666666]
```

[62]:
```
#Plotting the mean accuracy versus the max depth for n_estimates = 29 for␣
↪Recovered
plt.title("Gradient Tree Boosting - 10-fold max-depth for n_estimates = 29␣
↪Recovered ")
plt.plot(max_depth_list, accuracies_maxdepth1)
plt.xlabel('Max Depth')
plt.ylabel('Mean Accuracy for Target 1:Recovered')
```

[62]:
```
Text(0, 0.5, 'Mean Accuracy for Target 1:Recovered')
```



2.1.4 Accuracy is best for Max Depth 3 when we kept the n_estimators as 29 for target 1: Recovered.

2.2 2. Gradient Boosting implementation on Target 2: Deaths

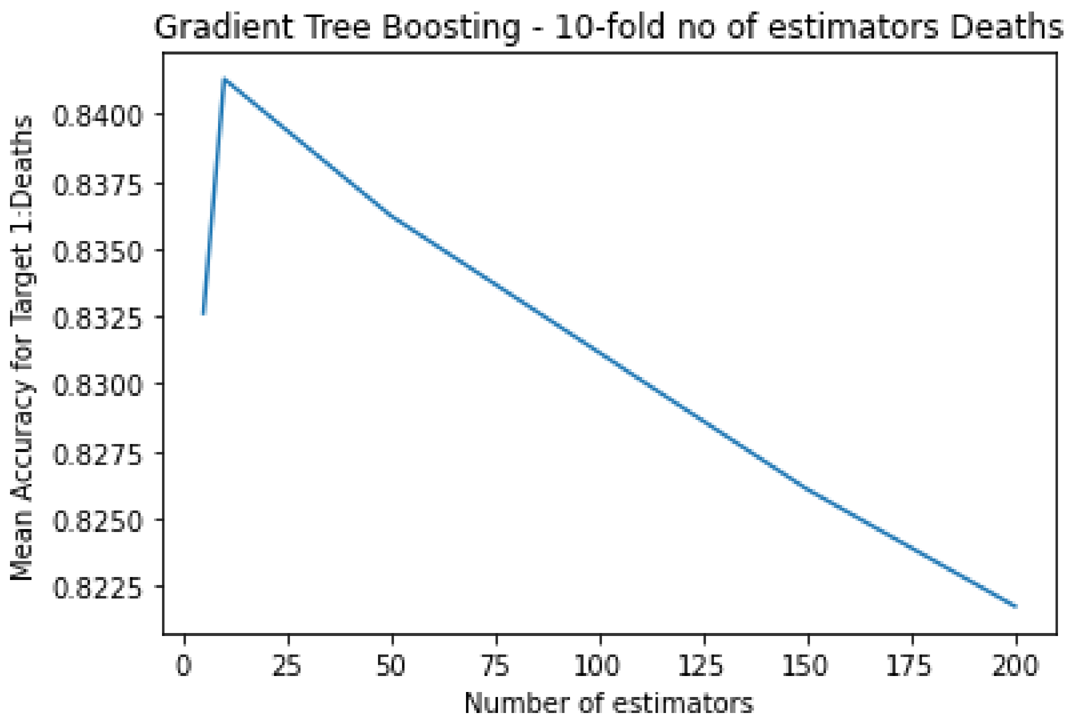
2.2.1 Taking number of estimators: [5, 10, 50, 150, 200] for target 2: Deaths

[63]:
```
#Gradient Boosting: Checking for best value for no of estimators for target 2:␣
↪Deaths
n_estimators_list2 = [5,10,50,150,200]
accuracies_deaths = []
for n_estimators in n_estimators_list2:
    classifier_GradientBoosting = GradientBoostingClassifier(n_estimators =␣
↪n_estimators)
    scores = cross_val_score(classifier_GradientBoosting, df_covid, np.
↪ravel(df_target2), cv=10)
    accuracies_deaths.append(scores.mean())
accuracies_deaths
```

[63]:
```
[0.832608695652174,
 0.8413043478260869,
 0.8362318840579709,
 0.826086956521739,
 0.8217391304347826]
```

[64]:
```
#Plotting the mean accuracy versus the number of estimators for Deaths
plt.title("Gradient Tree Boosting - 10-fold no of estimators Deaths")
plt.plot(n_estimators_list2, accuracies_deaths)
plt.xlabel('Number of estimators')
plt.ylabel('Mean Accuracy for Target 1:Deaths')
```

[64]:
```
Text(0, 0.5, 'Mean Accuracy for Target 1:Deaths')
```



Here we can see in the above graph that performance peaks between 5 to 25 no of estimators so we will further check on which particular value it peaks.

2.2.2 Taking number of estimators: np.arange(5,25) for target 2: Deaths

[65]:
```
#Gradient Boosting: Further checking for best value for no of estimators for␣
↪target 2: Deaths from n _estimators 5 to 50
n_estimators_list1 = np.arange(5,25)
accuracies_deaths = []
for n_estimators in n_estimators_list1:
    classifier_GradientBoosting = GradientBoostingClassifier(n_estimators =␣
↪n_estimators)
    scores = cross_val_score(classifier_GradientBoosting, df_covid, np.
↪ravel(df_target2), cv=10)
    accuracies_deaths.append(scores.mean())
```

```
[66]: # checking max accuracy for deaths and its estimator value
temp = temp = np.where(accuracies_deaths == np.amax(accuracies_deaths))
print("The maximum value of accuracy is:",accuracies_deaths[temp[0][0]]*100)
print("The maximum value occurs when estimator value = ",4+temp[0][0])
```

```
The maximum value of accuracy is: 84.42028985507247
The maximum value occurs when estimator value =  8
```

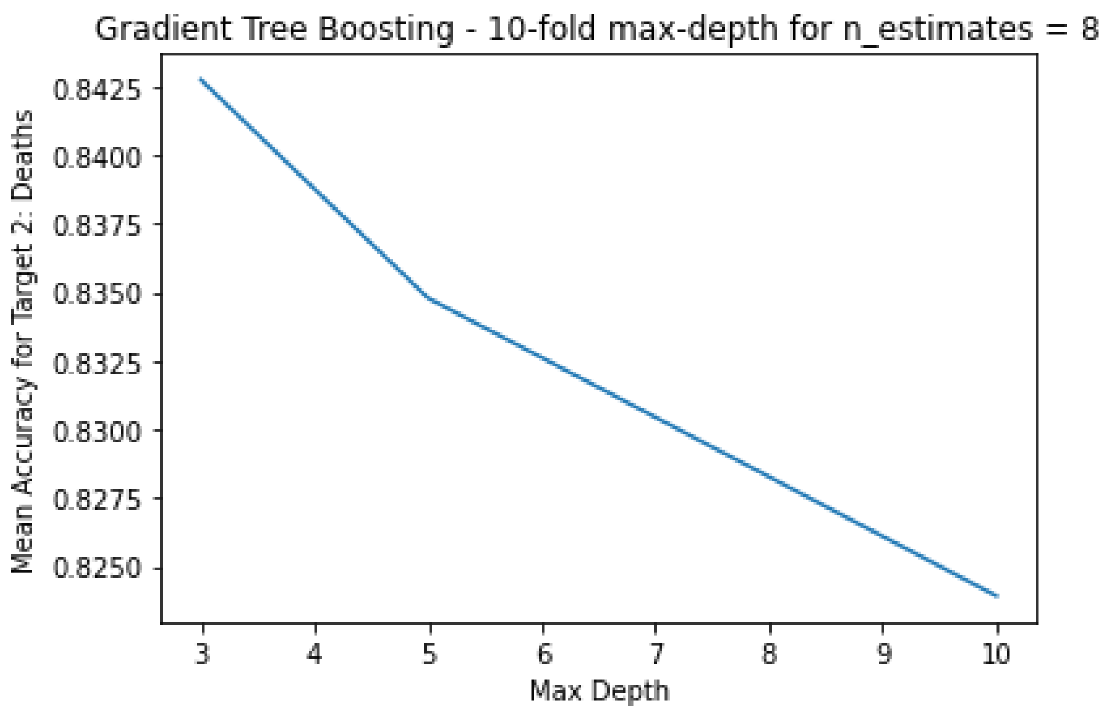
2.2.3 Performance peaks at n_estimators 8 and hence we will choose that for the number of trees hyperparameter value for target 2: Deaths.

```
[67]: #Checking for best value for max depth for target 2: Deaths by keeping␣
 ↪n_estimates = 8
max_depth_list = [3,5,10,None]
accuracies_maxdepth2 = []
for max_depth in max_depth_list:
    classifier_GradientBoosting = GradientBoostingClassifier(n_estimators = 8,␣
 ↪max_depth = max_depth)
    scores = cross_val_score(classifier_GradientBoosting, df_covid, np.
 ↪ravel(df_target2), cv=10)
    accuracies_maxdepth2.append(scores.mean())
accuracies_maxdepth2
```

```
[67]: [0.8427536231884056,
 0.8347826086956521,
 0.8239130434782608,
 0.8166666666666667]
```

```
[68]: #Plotting the mean accuracy versus the max depth for n_estimates = 8 for Deaths
plt.title("Gradient Tree Boosting - 10-fold max-depth for n_estimates = 8")
plt.plot(max_depth_list, accuracies_maxdepth2)
plt.xlabel('Max Depth')
plt.ylabel('Mean Accuracy for Target 2: Deaths')
```

```
[68]: Text(0, 0.5, 'Mean Accuracy for Target 2: Deaths')
```



2.2.4 Accuracy is best for Max Depth 3 when we kept the n_estimators as 8 for target 2: Deaths.

2.3 3. Gradient Boosting implementation on Target 3: Confirmed

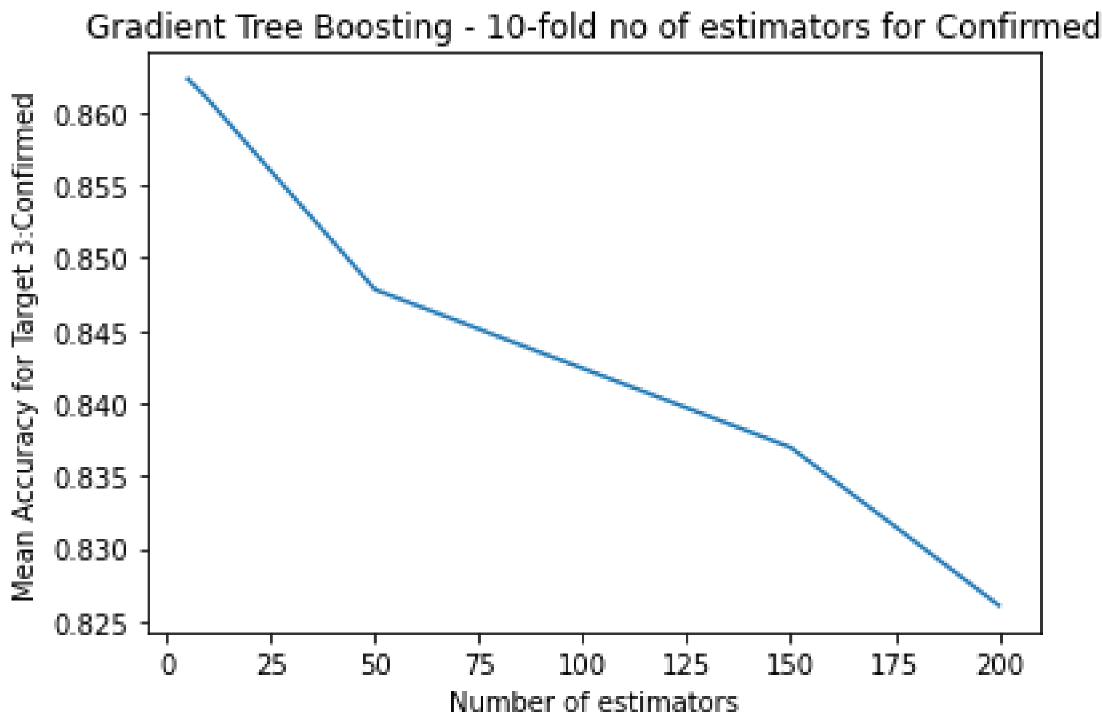
2.3.1 Taking number of estimators: [5, 10, 50, 150, 200] for target 3: Confirmed

[69]:
```
#Checking for best value for no of estimators for target 3: Confirmed
n_estimators_list3 = [5,10,50,150,200]
accuracies_confirmed = []
for n_estimators in n_estimators_list3:
    classifier_GradientBoosting = GradientBoostingClassifier(n_estimators =␣
↪n_estimators)
    scores = cross_val_score(classifier_GradientBoosting, df_covid, np.
↪ravel(df_target3), cv=10)
    accuracies_confirmed.append(scores.mean())
accuracies_confirmed
```

[69]:
```
[0.8623188405797102,
 0.8608695652173912,
 0.8478260869565218,
 0.8369565217391305,
 0.8260869565217392]
```

[70]:
```
#Plotting the mean accuracy versus the number of estimators for Confirmed
plt.title("Gradient Tree Boosting - 10-fold no of estimators for Confirmed")
plt.plot(n_estimators_list3, accuracies_confirmed)
plt.xlabel('Number of estimators')
plt.ylabel('Mean Accuracy for Target 3:Confirmed')
```

[70]: Text(0, 0.5, 'Mean Accuracy for Target 3:Confirmed')



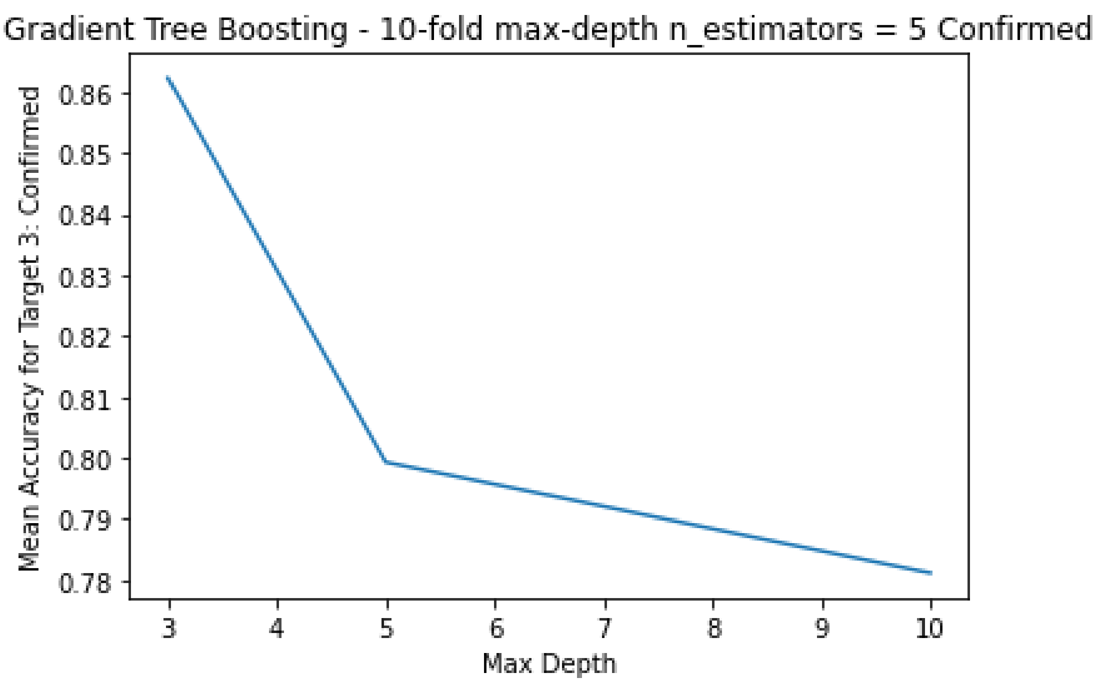
2.3.2 Performance peaks at 5 number of estimators and hence we will choose that for the number of trees hyperparameter value for target 3: Confirmed.

[71]:
```
#Checking for best value for max depth for target 3: Confirmed by keeping␣
↪n_estimates = 5
max_depth_list = [3,5,10,None]
accuracies_maxdepth3 = []
for max_depth in max_depth_list:
    classifier_GradientBoosting = GradientBoostingClassifier(n_estimators = 5,␣
↪max_depth = max_depth)
    scores = cross_val_score(classifier_GradientBoosting, df_covid, np.
↪ravel(df_target3), cv=10)
    accuracies_maxdepth3.append(scores.mean())
accuracies_maxdepth3
```

[71]: [0.8623188405797102,
 0.7992753623188407,
 0.7811594202898551,
 0.7797101449275363]

[72]:
```
#Plotting the mean accuracy versus the max depth for n_estimators = 5 for␣
↪Confirmed
plt.title("Gradient Tree Boosting - 10-fold max-depth n_estimators = 5␣
↪Confirmed")
plt.plot(max_depth_list, accuracies_maxdepth3)
plt.xlabel('Max Depth')
plt.ylabel('Mean Accuracy for Target 3: Confirmed')
```

[72]: Text(0, 0.5, 'Mean Accuracy for Target 3: Confirmed')



2.3.3 Accuracy is best for Max Depth 3 when we kept the n_estimators as 5 for target 3: Confirmed.

3 Part 2: Gradient Boosting results using PCA features

[73]:
```
#extracting pca features from CM2
%store -r pca_features
```

[74]:
```
pca_features.shape
```

[74]: (1380, 11)

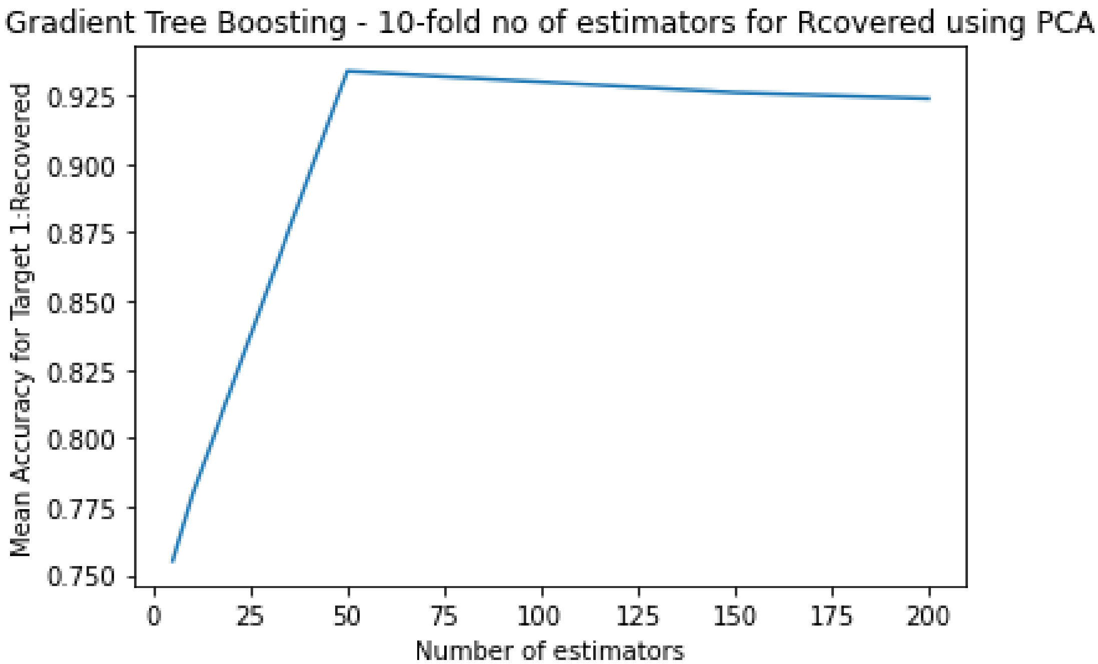
3.1 1. Gradient Boosting implementation on Target 1:Recovered using PCA

[75]:
```
#Checking for best value for no of estimators for target 1: Recovered using PCA
accuracies_recovered_pca = []
n_estimators_list1 = [5,10,50,150,200]
for n_estimators in n_estimators_list1:
    classifier_GradientBoosting = GradientBoostingClassifier(n_estimators =␣
↪n_estimators)
    scores = cross_val_score(classifier_GradientBoosting,pca_features[:,:3], np.
↪ravel(df_target1), cv=10)
    accuracies_recovered_pca.append(scores.mean())
accuracies_recovered_pca
```

[75]:
```
[0.7550724637681159,
 0.7789855072463767,
 0.9340579710144927,
 0.9260869565217391,
 0.9239130434782608]
```

[76]:
```
#Plotting the mean accuracy versus the number of estimators for Recovered using␣
↪PCA
plt.title("Gradient Tree Boosting - 10-fold no of estimators for Rcovered using␣
↪PCA")
plt.plot(n_estimators_list1, accuracies_recovered_pca)
plt.xlabel('Number of estimators')
plt.ylabel('Mean Accuracy for Target 1:Recovered')
```

[76]:
```
Text(0, 0.5, 'Mean Accuracy for Target 1:Recovered')
```



3.1.1 The Maximum accuracy occurs when n_estimators = 50 and hence we will choose that for the number of trees hyperparameter value for target 1: Recovered.

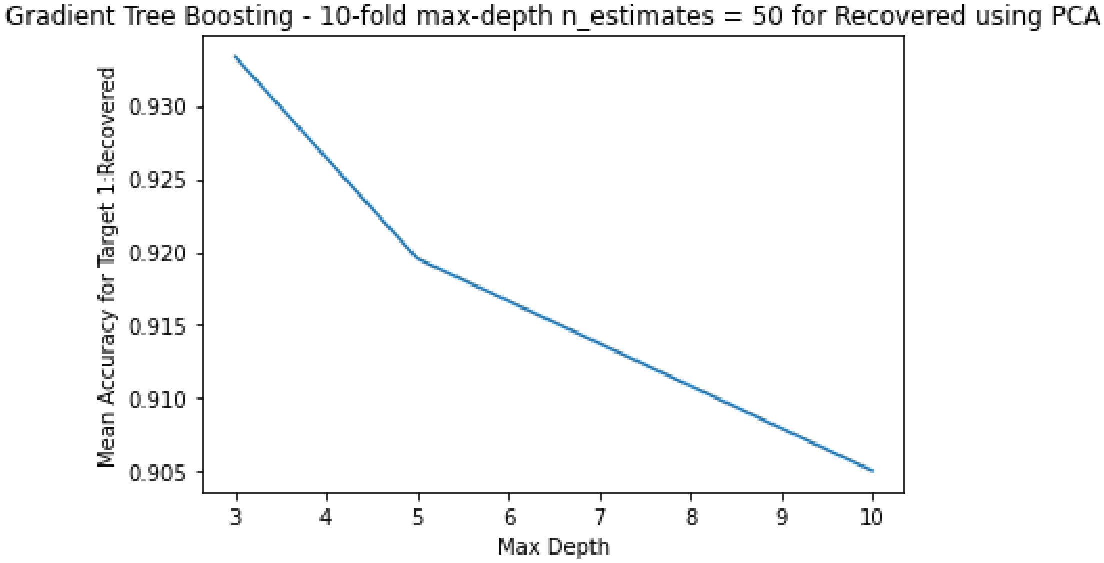
[77]:
```
#Checking for best value for max depth for target 1: Recovered ,by keeping␣
↪n_estimates = 50 using PCA
max_depth_list = [3,5,10,None]
accuracies_maxdepth1_pca = []
for max_depth in max_depth_list:
    classifier_GradientBoosting = GradientBoostingClassifier(n_estimators = 50,␣
↪max_depth = max_depth)
    scores = cross_val_score(classifier_GradientBoosting, pca_features[:,:3],␣
↪np.ravel(df_target1), cv=10)
    accuracies_maxdepth1_pca.append(scores.mean())
accuracies_maxdepth1_pca
```

[77]: [0.9333333333333333, 0.9195652173913043, 0.905072463768116, 0.8971014492753623]

[78]:
```
#Plotting the mean accuracy versus the max depth for n_estimates = 50 for␣
↪Recovered using PCA
plt.title("Gradient Tree Boosting - 10-fold max-depth n_estimates = 50 for␣
↪Recovered using PCA")
plt.plot(max_depth_list, accuracies_maxdepth1_pca)
plt.xlabel('Max Depth')
```

```
plt.ylabel('Mean Accuracy for Target 1:Recovered')
```

[78]:
```
Text(0, 0.5, 'Mean Accuracy for Target 1:Recovered')
```



3.1.2 Accuracy is best for Max Depth 3 when we kept the n_estimators as 50 for target 1: Recovered.

3.2 2. Gradient Boosting implementation on Target 2: Deaths using PCA

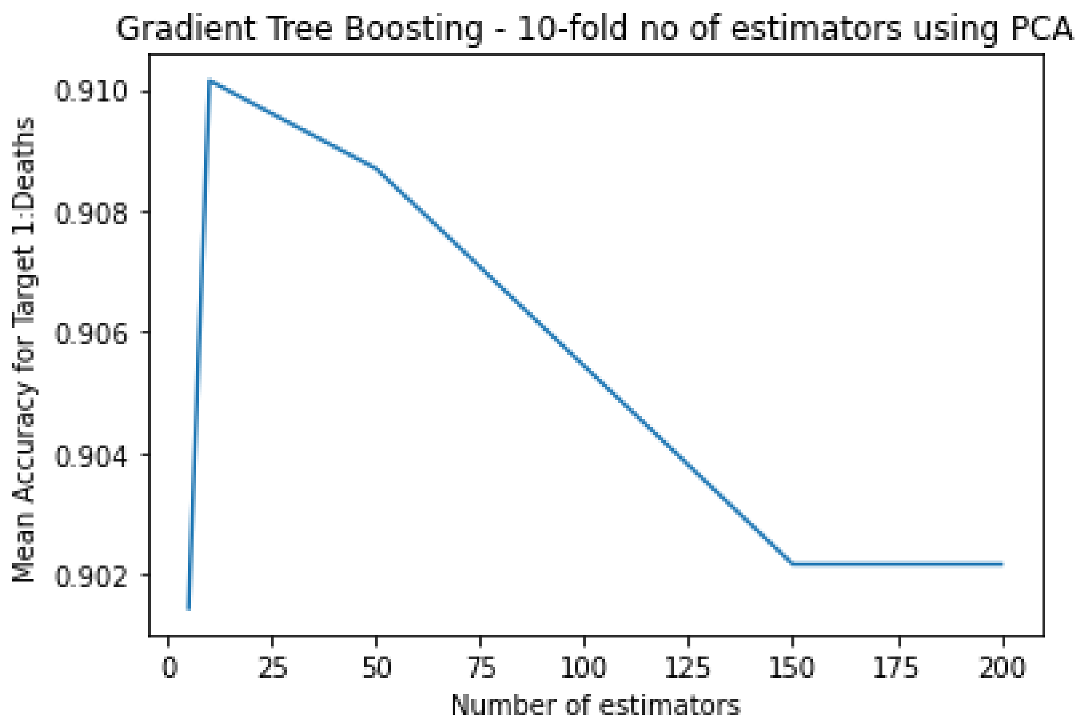
[79]:
```
#Checking for best value for no of estimators for target 2: Deaths using PCA
n_estimators_list2 = [5,10,50,150,200]
accuracies_deaths_pca = []
for n_estimators in n_estimators_list2:
    classifier_GradientBoosting = GradientBoostingClassifier(n_estimators =␣
 ↪n_estimators)
    scores = cross_val_score(classifier_GradientBoosting,pca_features[:,:3], np.
 ↪ravel(df_target2), cv=10)
    accuracies_deaths_pca.append(scores.mean())
accuracies_deaths_pca
```

[79]:
```
[0.9014492753623189,
 0.9101449275362319,
 0.9086956521739131,
 0.9021739130434783,
 0.9021739130434783]
```

[80]:
```
#Plotting the mean accuracy versus the number of estimators using PCA
plt.title("Gradient Tree Boosting - 10-fold no of estimators using PCA")
```

```
plt.plot(n_estimators_list2, accuracies_deaths_pca)
plt.xlabel('Number of estimators')
plt.ylabel('Mean Accuracy for Target 1:Deaths')
```

[80]: Text(0, 0.5, 'Mean Accuracy for Target 1:Deaths')



3.2.1 The maximum accuracy occurs when n_estimators = 10 and hence we will choose that for the number of trees hyperparameter value for target 2: Deaths.

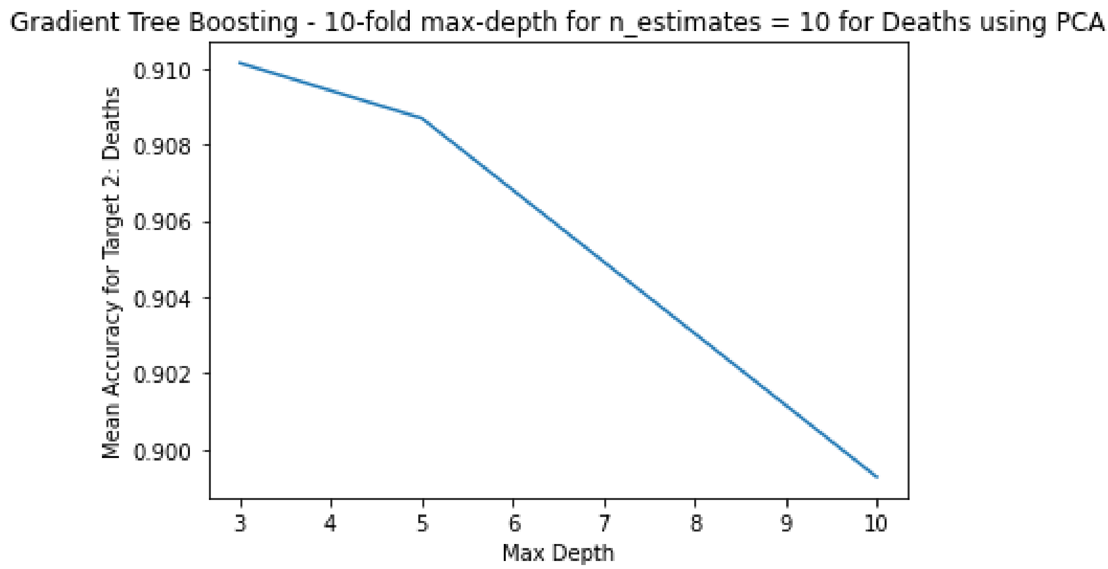
[81]:
```
#Checking for best value for max depth for target 2: Deaths by keeping␣
↪n_estimates = 10 using PCA
max_depth_list = [3,5,10,None]
accuracies_maxdepth2_pca = []
for max_depth in max_depth_list:
    classifier_GradientBoosting = GradientBoostingClassifier(n_estimators = 10,␣
↪max_depth = max_depth)
    scores = cross_val_score(classifier_GradientBoosting, pca_features[:,:3],␣
↪np.ravel(df_target2), cv=10)
    accuracies_maxdepth2_pca.append(scores.mean())
accuracies_maxdepth2_pca
```

[81]: [0.9101449275362319,
 0.9086956521739131,

0.8992753623188404,
 0.8942028985507247]

[82]:
```
#Plotting the mean accuracy versus the max depth for n_estimates = 10 for␣
↪Deaths using PCA
plt.title("Gradient Tree Boosting - 10-fold max-depth for n_estimates = 10 for␣
↪Deaths using PCA")
plt.plot(max_depth_list, accuracies_maxdepth2_pca)
plt.xlabel('Max Depth')
plt.ylabel('Mean Accuracy for Target 2: Deaths')
```

[82]:
```
Text(0, 0.5, 'Mean Accuracy for Target 2: Deaths')
```



3.2.2 Accuracy is best for Max Depth 3 when we kept the n_estimators as 10 for target 2: Deaths.

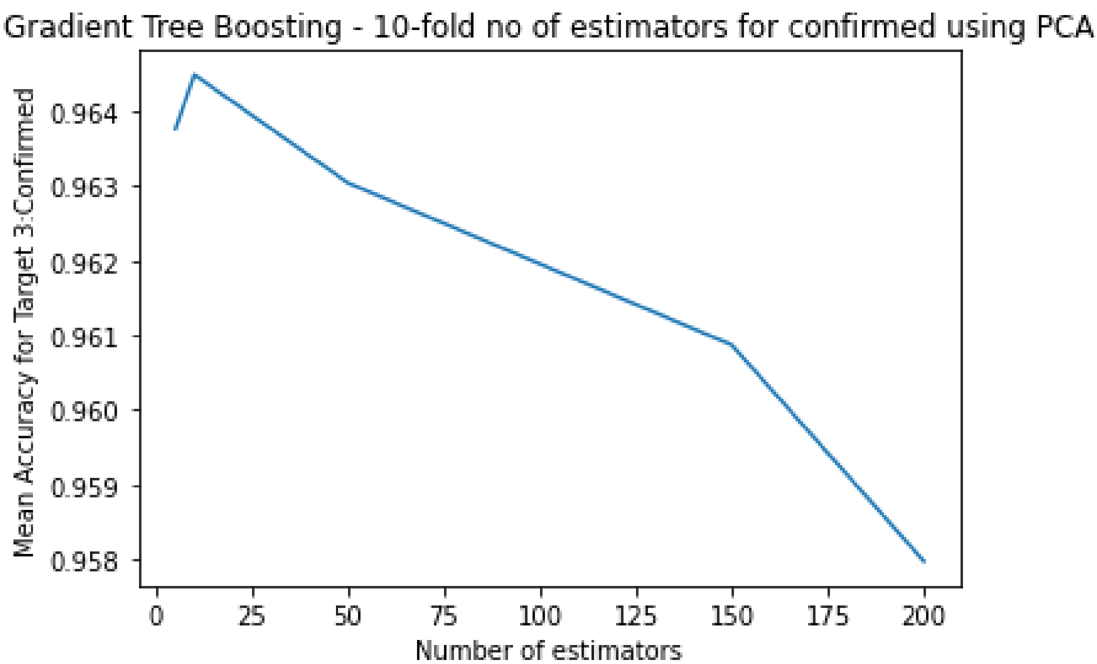
3.3 3. Gradient Boosting implementation on Target 3: Confirmed using PCA

[83]:
```
#Checking for best value for no of estimators for target 3: Confirmed using PCA
n_estimators_list3 = [5,10,50,150,200]
accuracies_confirmed_pca = []
for n_estimators in n_estimators_list3:
    classifier_GradientBoosting = GradientBoostingClassifier(n_estimators =␣
↪n_estimators)
    scores = cross_val_score(classifier_GradientBoosting, pca_features[:,:3],␣
↪np.ravel(df_target3), cv=10)
    accuracies_confirmed_pca.append(scores.mean())
accuracies_confirmed_pca
```

[83]: [0.963768115942029,
 0.9644927536231884,
 0.9630434782608696,
 0.9608695652173912,
 0.9579710144927536]

[84]:
```
#Plotting the mean accuracy versus the number of estimators for Confirmed using␣
↪PCA
plt.title("Gradient Tree Boosting - 10-fold no of estimators for confirmed␣
↪using PCA")
plt.plot(n_estimators_list3, accuracies_confirmed_pca)
plt.xlabel('Number of estimators')
plt.ylabel('Mean Accuracy for Target 3:Confirmed')
```

[84]: Text(0, 0.5, 'Mean Accuracy for Target 3:Confirmed')



3.3.1 The maximum accuracy occurs when n_estimators = 10 and hence we will choose that for the number of trees hyperparameter value for target 3: Confirmed.

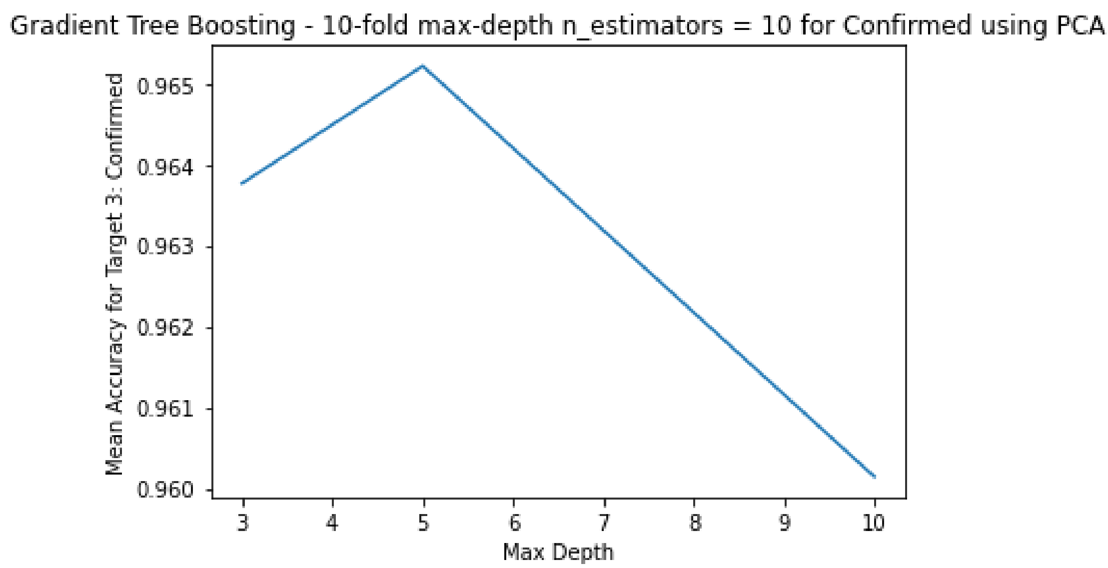
[85]:
```
#Checking for best value for max depth for target 3: confirmed by keeping␣
↪n_estimates = 10 using PCA
max_depth_list = [3,5,10,None]
accuracies_maxdepth3_pca = []
for max_depth in max_depth_list:
```

```
    classifier_GradientBoosting = GradientBoostingClassifier(n_estimators = 10,␣
↪max_depth = max_depth)
    scores = cross_val_score(classifier_GradientBoosting, pca_features[:,:3],␣
↪np.ravel(df_target3), cv=10)
    accuracies_maxdepth3_pca.append(scores.mean())
accuracies_maxdepth3_pca
```

[85]: [0.963768115942029, 0.9652173913043478, 0.960144927536232, 0.960144927536232]

[87]:
```
#Plotting the mean accuracy versus the max depth for n_estimators = 10 for␣
↪confirmed using PCA
plt.title("Gradient Tree Boosting - 10-fold max-depth n_estimators = 10 for␣
↪Confirmed using PCA")
plt.plot(max_depth_list, accuracies_maxdepth3_pca)
plt.xlabel('Max Depth')
plt.ylabel('Mean Accuracy for Target 3: Confirmed')
```

[87]: Text(0, 0.5, 'Mean Accuracy for Target 3: Confirmed')



3.3.2 The maximum accuracy occurs when n_estimators = 5 nd max_depth = 5 for target 3: Confirmed